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Low Energy Neutron Reactions (LENRs) in Automotive Catalytic Converters

Are 'green' LENRs occurring in common devices?

Opportunities for experimentalists

Lewis Larsen, President and CEO

"There are two possible outcomes: if the result confirms the hypothesis, then you've made a measurement. If the result is contrary to the hypothesis, then you've made a discovery. "

Prof. Enrico Fermi

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Background of new W-L nuclear paradigm

Objective and topics in this presentation - 1

Our objective is to discuss some fascinating experimental data and introduce more ideas about applications of the new breakthrough W-L theory that we hope will intrigue curious readers and scientists (especially experimentalists). Herein, we will provide:

- ✓ **Citations, quotations from published papers, and discussion of experimental data from technical publications reporting identification of various elements/isotopic products found in exhaust emissions emanating from catalytic converters commonly installed in cars and trucks powered by gasoline or diesel internal combustion engines**
- ✓ **We believe this evidence indicates that LENRs may be occurring in catalytic converters**

Please be aware that the following discussion involves a radical (some might say heretical) paradigm-shift in thinking about the types of environments where nuclear reactions may occur. LENRs may well be relatively common --- hidden in plain sight

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Background of new W-L nuclear paradigm

Objective and topics in this presentation -2

- ✓ **Previous Technical Overviews - for more technical details, including key theoretical concepts underlying this presentation, please see: 78-slide Lattice SlideShare Technical Overview dated June 25, 2009; 65-slide Lattice SlideShare Technical Overview dated September 3, 2009, periodically updated Resource Guide for Readers that was initially published on SlideShare during September 2009; as well as a 61-slide SlideShare Technical Overview dated November 25, 2009**

- ✓ **Recapping - in the November 25, 2009, Technical Overview we discussed W-L theory as it may apply to LENRs involving relatively common organic molecules called polycyclic aromatic hydrocarbons (PAHs). This new physical regime, wherein ULM neutron-catalyzed LENRs can potentially be triggered on PAHS with a combination of pressure, temperature, and hydrogen isotopes in the presence of certain metals (e.g., Pd, Pt, etc.), was discovered by Tadahiko Mizuno of Hokkaido University (Japan) in the course of innovative LENR transmutation experiments involving Phenanthrene (a 3-ring PAH) that were first reported back in 2008**

- ✓ **Herein - using extensions of W-L theory to PAHs outlined in the November 25, 2009, SlideShare Technical Overview, we will present and discuss published isotopic data we believe suggests that LENRs may be occurring at low rates in car/truck catalytic converters; fruitful opportunities await experimentalists here!**

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Background of new W-L nuclear paradigm

LENRs can occur in a wide variety of different environments - 1

- ✓ **Since the 1930s, it has been widely held that nuclear transmutation reactions could only take place within certain special environments, e.g., in fission reactors, nuclear weapons, or stars. In all other cases, strictly chemical processes (which by definition cannot produce new chemical elements not previously present in a system and/or changes to ratios of stable isotopes) were assumed to be at work**

- ✓ **Pons & Fleischmann's 1989 discovery of what seemed to be nuclear processes operating inside otherwise prosaic D_2O electrolytic chemical cells challenged this long-established conceptual paradigm about nuclear phenomena. On top of their irreproducible results, P&F's speculation that radiation-free "excess heat" and He-4 observed in their experiments resulted from a D-D "cold fusion" process further fueled scientific controversy about LENRs that has continued to the present**

- ✓ **Beginning in May 2005, the Widom-Larsen theory of LENRs has shown, using known physics, how energetic nuclear processes can occur in ordinary chemical cells. Our theory posits that in condensed matter systems, many-body collective effects allow the otherwise disparate chemical and nuclear energy realms to interconnect in special, micron-scale regions on surfaces and on small particles**

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Background of new W-L nuclear paradigm

LENRs can occur in a wide variety of different environments - 2

In our numerous publications to date, we have shown theoretically how LENRs may potentially occur in a diverse range of different types of experimental systems and natural environments that presently include, among other things:

- ✓ **Aqueous electrolytic chemical cells, including 'glow-discharge' types (EPJC, 2006)**
- ✓ **Metallic hydride 'membranes' with gas-phase pressure gradients (e.g., Iwamura et al.)**
- ✓ **Exploding wires and related electric discharges (e.g., high-current vacuum diodes a la Proton-21, Z-pinches, and natural lightning) as noted in SlideShare of June 25, 2009**
- ✓ **Surfaces of hydrogenated fullerenes and graphene as well as carbon ring structures (e.g., benzene, polycyclic aromatic hydrocarbons - PAHs) in prosaic chemical reactors that combine heat, and/or pressure, and metallic catalysts (see the Lattice SlideShare presentations dated September 3, and November 25, 2009, cited earlier)**
- ✓ **Atmospheres of stars out through their coronas, as well as on surfaces of small particles embedded in hydrogen-rich dust clouds located in stellar 'nurseries' as well as highly organized magnetic structures associated with black hole accretion disks and other types compact massive objects. Please note that vast majority of astronomers/astrophysicists presently believe nucleosynthesis only occurs inside stellar cores and supernovae (see SlideShare presentation dated November 25, 2009)**

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Growing anomalies trigger paradigm shifts

"As a paradigm is stretched to its limits, anomalies accumulate"

"As a paradigm is stretched to its limits, anomalies - failures of the current paradigm to take into account observed phenomena – accumulate … Some anomalies may be dismissed as errors in observation, others as merely requiring small adjustments to the current paradigm that will be clarified in due course. Some anomalies resolve themselves spontaneously, having increased the available depth of insight along the way. But no matter how great or numerous the anomalies that persist, Kuhn observes, the practicing scientists will not lose faith in the established paradigm for as long as no credible alternative is available."

"What is arguably the most famous example of a revolution in scientific thought is the Copernican Revolution. In Ptolemy's school of thought, cycles and epicycles (with some additional concepts) were used for modeling the movements of the planets in a cosmos that had a stationary Earth at its center. As the accuracy of celestial observations increased, the complexity of the Ptolemaic cyclical and epicyclical mechanisms had to increase in step with the increased accuracy of the observations, in order to maintain the calculated planetary positions close to the observed positions … The Ptolemaic approach of using cycles and epicycles was becoming strained: there seemed to be no end to the mushrooming growth in complexity required to account for the observable phenomena … epicycles were not eliminated in Europe until the 17th century … Whether or not Copernicus' models were simpler than Ptolemy's is moot. Copernicus eliminated Ptolemy's … equant but at a cost of additional epicycles. Various 16th-century books based on Ptolemy and Copernicus use about equal numbers of epicycles. The idea that Copernicus used only 34 circles in his system comes from his own statement in a preliminary unpublished sketch … By the time he published De revolutionibus orbium coelestium, he had added more circles. Counting the total number is difficult, but estimates are that he created a system just as complicated, or even more so. The popular total of about 80 circles for the Ptolemaic system … may have been inspired by the non-Ptolemaic system of Girolamo Fracastoro, who used either 77 or 79 orbs in his system [to describe the apparent motions of the then eight known planets]."

"Johannes Kepler was the first person to abandon the tools of the Ptolemaic paradigm. Later, Newton showed that Kepler's three laws could all be derived from a single theory of motion and planetary motion. … Newtonian Mechanics eliminated the need for deferent/epicycle methods altogether and produced theories many times more powerful. "

Source: Wikipedia articles, "The Structure of Scientific Revolutions" and "Deferent and epicycle" as of December 23, 2009

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LENRs represent a new domain of energy

Prof. W. Brian Arthur's thoughts on technology - 1

"It will probably have struck the reader that the overall cycle I am describing resembles the cycle Thomas Kuhn proposed for the development of scientific theories. Kuhn's cycle starts when a new theoretical model working on a new principle (he calls this a paradigm) replaces an old one … [this happens because] … Over time, examples that do not fit the base paradigm - anomalies - build up. The paradigm is stretched to accommodate these, but becomes increasingly strained as further anomalies build up. It collapses when and only when a newer, more satisfactory set of explanations - a newer paradigm - arrives." pp. 141 - 142

"As the [older, widely accepted reigning dominant] theory develops it elaborates – it adds addenda, further definitions, codicils, and special [ad hoc] constructions – all to take into consideration different special cases. And if the special cases do not quite fit, the theory becomes stretched; it adds the equivalent of epicycles. Eventually when confronted with sufficient anomalies its 'performance' diminishes and a new principle or paradigm is sought. A novel structure comes into being when the preceding one is stretched and fails. Kuhn's cycle repeats." pp. 142

W. Brian Arthur, "The Nature of Technology – What it is and how it evolves," Free Press, 2009

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Prof. W. Brian Arthur's thoughts on technology - 2

"… eventually there comes a time when neither component replacement nor structural deepening [of the older, dominant paradigm] add much to performance. If further advancement is sought, a [new] novel principle is needed." pp. 138

"There is a … reason the old [dominant conceptual paradigm] … persists beyond its time, an economic one. Even if a novel principle *is* developed and does perform better than the old, adopting it may mean changing surrounding [economic, academic, and governmental] structures and organizations. This is expensive and for that reason may not happen … another reason is psychological. The old principle lives on because practitioners are not comfortable with the vision – and promise – of the new. Origination is not just a new way of doing things, but a new way of *seeing* things … And the new threatens … to make the old expertise obsolete. Often in fact, some version of the new principle [paradigm] has been already touted or already exists and has been dismissed by standard practitioners, not necessarily because lack of imagination. But because it creates a cognitive dissonance, an emotional mismatch, between the potential of the new and the security of the old." pp. 139 "This time is likely to be decades not years."**

W. Brian Arthur, "The Nature of Technology – What it is and how it evolves," Free Press, 2009

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LENRs represent a new domain of energy

Prof. W. Brian Arthur's thoughts on technology - 3

"Sometimes elements [of revolutionary technologies] cluster because they share a common theory … What delineates a cluster of technologies is always some form of commonality, some shared and natural ability of components to work together. I will call such clusters – such bodies of technology – domains. A domain will be any cluster of components drawn from in order to form devices or methods, along with its collection of practices and knowledge, its rules of combination, and … associated way of thinking." pp. 70 "All of this unfolding … and readjustment takes a great deal of time."

"A technology (individual, that is) does a job; it achieves a purpose – often a very particular purpose. A domain (technology-plural) does no job; it merely exists as a toolbox of useful components to be drawn from, a set of practices to be used. A technology defines a product or a process. A domain defines no [particular] product; it forms a constellation of technologies – a mutually supporting set – and when these are represented by the firms that produce them, it defines a [new] industry. A technology is invented; it is put together by someone. A domain – think of radio engineering as a whole – is not invented; it emerges piece by piece from its individual parts." pp. 71

W. Brian Arthur, "The Nature of Technology – What it is and how it evolves," Free Press, 2009

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Present chemical fractionation paradigm

Nuclear reactions in few places; chemistry explains everything else - 1

- ✓ Modern isotopic chemical analysis using mass spectrometry initially began in the early 1920s as scientists started designing and building progressively better, more sensitive types of instruments; the scientific community gradually began to systematically measure and publish abundances of stable and unstable isotopes found on earth as well as in meteoritic materials from outer space

- ✓ Extensive compilations of varied isotopic data eventually lead to the idea of the "natural abundances:" natural abundance (NA) refers to the isotopic composition of a given chemical element as it is naturally found on a particular planet, e.g., earth. For a given element composed of one or more isotopes, a weighted average of the naturally occurring composition of these isotopes (natural abundance) is the specific value for atomic weight that is listed for that element in the periodic table. Note that although the 'natural' isotopic composition of a given chemical element can vary from planet to planet, it should remain essentially constant over geological time (except in the case of elements having one or more radioactive isotopes). On a given planet, the characteristic isotopic composition of a given element, i.e., its natural abundance, should be essentially identical everywhere. For example, in the case of the element Copper on earth, it is comprised of two stable isotopes that typically occur in ~ the following proportions: 69% Cu-63 and 31% Cu-65. With many terrestrial elements, one out of several stable isotopes frequently predominates --- the others may be present only in minor traces --- e.g., in the case of natural Oxygen one would in principle measure ~ 99.759% O-16; 0.0374% O-17; and 0.2039% O-18.

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Present chemical fractionation paradigm

Nuclear reactions in few places; chemistry explains everything else - 2

- ✓ **Statistically significant deviations from natural abundances began to appear in some early isotopic data collected by scientists; such anomalies were observed in many different types of experimental chemical reaction systems and in the natural environment , as well as in meteoritic materials**

*One example of a classic paper on abundances is: White, J. R. and Cameron, A. E., "The Natural Abundance of Isotopes of Stable Elements," Physical Review **74** pp. 991-1000 (1948)*

- ✓ **Given that the observed isotopic anomalies in question obviously did not involve material freshly processed in stars, fission reactors, or nuclear explosions, it was readily assumed that significant deviations from natural isotopic abundances had to be the result of chemical processes**

Two widely cited early papers on chemical isotopic fractionation are as follows:

*Bigeleisen, J. and Mayer, M. J., "Calculation of equilibrium constant for isotope exchange reaction," Chem. Phys. **15** pp. 261-267 (1947)*

Urey, H.C., "The thermodynamic properties of isotopic substances," J. Chem. Soc. pp. 562-581 (1947)

- ✓ **In the 1940-50s, early theories of "chemical fractionation" were published in an effort to explain significant anomalies from natural abundances found in some experimental data. These early theories mainly involved equilibrium isotope effects in reversible chemical systems and kinetic effects of isotopes on reaction rates in irreversible chemical systems (details will explained shortly in subsequent slides)**

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Present chemical fractionation paradigm

Nuclear reactions in few places; chemistry explains everything else - 3

- ✓ **Since the 1950s, development of an increasing variety of progressively improved, much less expensive, and substantially more accurate mass spectroscopy techniques has enabled M-S to be utilized in many different fields. A vast quantity of reliable isotopic data has thus accumulated**
- ✓ **Since early theories of chemical isotopic fractionation were directly tied to mass differences between isotopes, their applicability was generally limited to lighter elements in the periodic table (from hydrogen out through roughly sulfur) where % differences in relative masses are large enough to have a plausibly significant impact on isotopic separation via some form of mass-sensitive physico-kinetic process**
- ✓ **Today's fractionation theories include equilibrium and kinetic effects and mass-independent: nuclear field shift, photochemical, and Q-M symmetry effects that attempt to extend such concepts to higher-mass elements/isotopes in the periodic table. Details follow in next 8 slides; readers uninterested in such technical information may skip them**

*The first reliable report of an of an isotopic anomaly that could not plausibly be explained by simple physical processes such as condensation or evaporation --- phase changes --- (i.e., it was mass-independent) was published by Clayton, R., Grossman, L., and Mayeda, T., "A component of primitive nuclear composition in carbonaceous meteorites," in Science **182** pp. 485-488 (1973)*

Mass-independent fractionation is now utilized to explain a growing body of anomalous, perhaps otherwise chemically inexplicable isotopic data. For Oxygen, see Michalski, G. and Bhattacharya, S., "Role of symmetry in the mass-independent isotope effect in ozone," PNAS 106 pp. S493-S496 (2009)

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Present chemical fractionation paradigm

Nuclear reactions in few places; chemistry explains everything else - 4

Isotope fractionation: "… is the physical phenomenon which causes changes in the relative abundance of isotopes due to their differences in mass. There are two categories of isotope effects: equilibrium and kinetic."

"An equilibrium isotope effect will cause one isotope to concentrate in one component of a reversible system that is in equilibrium. If it is the heavier isotope that concentrates in the component of interest, then that component is commonly referred to as enriched or heavy. If it is the light isotope that concentrates then the component is referred to as depleted or light. In most circumstances the heavy isotope concentrates in the component in which the element is bound more strongly and thus equilibrium isotope effects usually reflect relative differences in the bond strengths of the isotopes in the various components of the system. A kinetic isotope effect occurs when one isotope reacts more rapidly than the other in an irreversible system or a system in which the products are swept away from the reactants before they have an opportunity to come to equilibrium. Normally, the lighter isotope will react more rapidly than the heavy isotope and thus the product will be lighter than the reactant."

"It should be noted that isotope fractionation will only occur in systems in which there is both an isotope effect and a reaction that does not proceed to completion. Thus, even in the presence of an isotope effect, there will be no isotope fractionation if all the reactant goes to a single product because all the atoms have reacted and thus the ratio of the heavy to light isotope must be the same in the product as it was in the reactant. The magnitude of an isotope effect is expressed as a fractionation factor. This is defined as the ratio of the heavy to light isotope in the product divided by the ratio of the heavy to light isotope in the reactant. Stated mathematically:"

$$f = \frac{(heavy / light)\text{product}}{(heavy / light)\text{reactant}}$$

"When f is greater than 1, the product is heavy or enriched. When it is less than 1, the product is light or depleted. Most fractionation factors lie between 0.9 and 1.1, but deuterium isotope effects can result in much smaller or larger fractionation factors. A fractionation factor of 1.050 is often referred to as a 5% isotope effect."

Source of Definition: D. Schoeller and A. Coward at http://www.unu.unupress/food2/uid05e/uid05e0e.htm

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Present chemical fractionation paradigm

Nuclear reactions in few places; chemistry explains everything else - 5

"**Mass-independent (isotope) fractionation: refers to any chemical or physical process that acts to separate isotopes, where the amount of separation does not scale in proportion with the difference in the masses of the isotopes.** Most isotope fractionations (including typical kinetic fractionations and equilibrium fractionations) are caused by the effects of the mass of an isotope on atomic or molecular velocities, diffusivities, or bond strengths. Mass-independent fractionation processes are less common, occurring mainly in photochemical and spin-forbidden reactions. Observation of mass-independently fractionated materials can therefore be used to trace these types of reactions in nature and in laboratory experiments."

"**Mass-independent fractionation in nature: the most notable examples of mass-independent fractionation in nature are found in the isotopes of oxygen and sulfur.** The first example was discovered by Robert N. Clayton, Toshiko Mayeda, and Lawrence Grossman in 1973, in the oxygen isotopic composition of refractory calcium-aluminum-rich inclusions in the Allende meteorite. The inclusions, thought to be among the oldest solid materials in the Solar System, show a pattern of low $^{18}O/^{16}O$ and $^{17}O/^{16}O$ relative to samples from the Earth and Moon. Both ratios vary by the same amount in the inclusions, although the mass difference between ^{18}O and ^{16}O is almost twice as large as the difference between ^{17}O and ^{16}O. Originally this was interpreted as evidence of incomplete mixing of ^{16}O-rich material (created and distributed by a large star in a supernova) into the Solar nebula. However, recent measurement of the oxygen-isotope composition of the Solar wind, using samples collected by the Genesis spacecraft, shows that the most ^{16}O-rich inclusions are close to the bulk composition of the solar system. This implies that Earth, the Moon, Mars and asteroids all formed from ^{18}O- and ^{17}O-enriched material. Photochemical dissociation of carbon monoxide in the Solar nebula has been proposed to explain this isotope fractionation. Another important mass-independent fractionation is found in ozone in the stratosphere. 1:1 variation of $^{18}O/^{16}O$ and $^{17}O/^{16}O$ in ozone was discovered in laboratory synthesis experiments by John Heidenreich and Mark Thiemens in 1983, and later found in stratospheric air samples measured by Konrad Mauersberger. Theoretical calculations by Rudolph Marcus and others suggest that ^{18}O- and ^{17}O enrichment in ozone is caused by the effects of ^{17}O and ^{18}O on molecular symmetry, and on the lifetimes of intermediate, excited states in the synthesis reaction."

"**Mass-independent fractionation: has also recently been discovered in sulfur from ancient geological samples, particularly those formed more than 2,450 million years ago**, by James Farquhar, Huiming Bao, and Mark Thiemens. Although the details of the fractionation process are not yet known, it appears most likely to be caused by photochemical reactions involving sulfur-bearing molecules in the early atmosphere. The creation and transfer of the mass-independent signature into minerals would be unlikely in an atmosphere containing abundant oxygen, indicating that the atmosphere was anoxic during the Archaean eon, before 2,450 million years ago."

Source: quoted from Wikipedia as of June 3, 2010, at URL = http://en.wikipedia.org/wiki/Mass-independent_fractionation

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Present chemical fractionation paradigm

Nuclear reactions in few places; chemistry explains everything else - 6

Nuclear field shift effect in mass independent isotope fractionation: "The classic theory of stable isotope fractionation in chemical exchange reactions has been established by Bigeleisen, Mayer, and Urey in 1947. The theory was based on the difference of molecular vibrational energies of isotopomers that are proportional to the respective masses, and hence, results in mass-dependent isotope effect only. In 1996, this conventional mass-dependent theory has been expanded by Bigeleisen to include a mass-independent term named the nuclear field shift effect. The nuclear field shift is an isotope shift in orbital electrons, which results from the isotopic difference in nuclear size and shape. The new equation defined by Bigeleisen (at a constant temperature) can be simply expressed as, $\ln \alpha = \delta\langle r^2\rangle A + (\delta m/mm') B$, where α is the isotope separation factor, $\delta\langle r^2\rangle$ isotopic difference in mean-square nuclear charge radius, δm difference between isotopic masses m and m'. A and B are scaling factors of the nuclear field shift effect and the conventional mass effect, respectively. Since this new theory was presented, the mass-independent isotope fractionation of various elements, e.g., Ti, Cr, Ni, Zn, Sr, Zr, Mo, Ru, Cd, Te, Ba, Nd, Sm, Gd, Yb, and U, found in chemical exchange systems has been successfully explained as the nuclear field shift effect. In our most recent studies, the nuclear field shift effect of Cr, Mo, Ru, Cd, and Te isotopes has been found in laboratory scale experiments. The isotopes of these elements were fractionated by using a liquid-liquid extraction system (a ligand exchange system) at room temperature. The isotopic analysis was performed by the multiple-collector inductively coupled plasma mass spectrometry (MC-ICP-MS) with a typical precision of <100 ppm (at ENS Lyon or UC Davis). Isotope enrichment factors did not show mass-dependent trend, but possessed a similar variation of their nuclear charge radii. For Cr, we tested a different chemical exchange system (a redox system): at high temperature (723-1023 K), an eutectic melt was contacted with a liquid metal. In this system, the nuclear field shift effect of Cr was also found. All these experimental results suggest that the nuclear field shift effect may occur in every chemical exchange reaction at various temperatures to various degrees … isotopic anomalies found in a natural system might be partly or largely affected by the nuclear field shift effect via chemical reactions occurred in the nature. In order to clarify the degree and significance of its contribution, we may need to pay more attention to the nuclear field shift effect created chemically."

Source: "Nuclear field shift effect in chemical exchange reactions," Fujii, T; Moynier, F; Yin, Q.; and Albarède, F. Meeting abstract for presentation: American Geophysical Union, San Francisco, California: December 10-14, 2007 at https://www.geology.ucdavis.edu/faculty/pubs/agu07/yin07_3.html

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Present chemical fractionation paradigm

Nuclear reactions in few places; chemistry explains everything else - 7

Stable isotope ratios are commonly expressed in δ-notation:

$$\delta = \left(\frac{R_{sample} - R_{standard}}{R_{standard}} \right) x1000$$

Wherein by convention: $R = ratio = \left(\frac{X_{heavy\ isotope}}{X_{light\ isotope}} \right)$

e.g., $$\delta^{18}O = \left[\frac{(^{18}O/^{16}O)_{sam} - (^{18}O/^{16}O)_{SMOW}}{(^{18}O/^{16}O)_{SMOW}} \right] \times 10^3$$

Source: Prof. Paul Asimow, Caltech, slide from a Geology lecture in 2006

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Overview XVI - Present chemical fractionation paradigm

Nuclear reactions in few places; chemistry explains everything else - 8

The x1000 in the previous slide implies that the units on δ are parts per thousand, per mil, or ‰

Table 9.1. Isotope Ratios of Stable Isotopes

Element	Notation	Ratio	Standard	Absolute Ratio
Hydrogen	δD	$D/H\ (^2H/^1H)$	SMOW	1.557×10^{-4}
Lithium	δ^6Li	$^6li/^7Li$	NBS L-SVEC	0.08306
Boron	$\delta^{11}B$	$^{11}B/^{10}B$	NBS 951	4.044
Carbon	$\delta^{13}C$	$^{13}C/^{12}C$	PDB	1.122×10^{-2}
Nitrogen	$\delta^{15}N$	$^{15}N/^{14}N$	atmosphere	3.613×10^{-3}
Oxygen	$\delta^{18}O$	$^{18}O/^{16}O$	SMOW, PDB	2.0052×10^{-3}
	$\delta^{17}O$	$^{17}O/^{16}O$	SMOW	3.76×10^{-4}
Sulfur	$\delta^{34}S$	$^{34}S/^{32}S$	CDT	4.43×10^{-2}

Source: Prof. Paul Asimow, Caltech, slide from a Geology lecture in 2006

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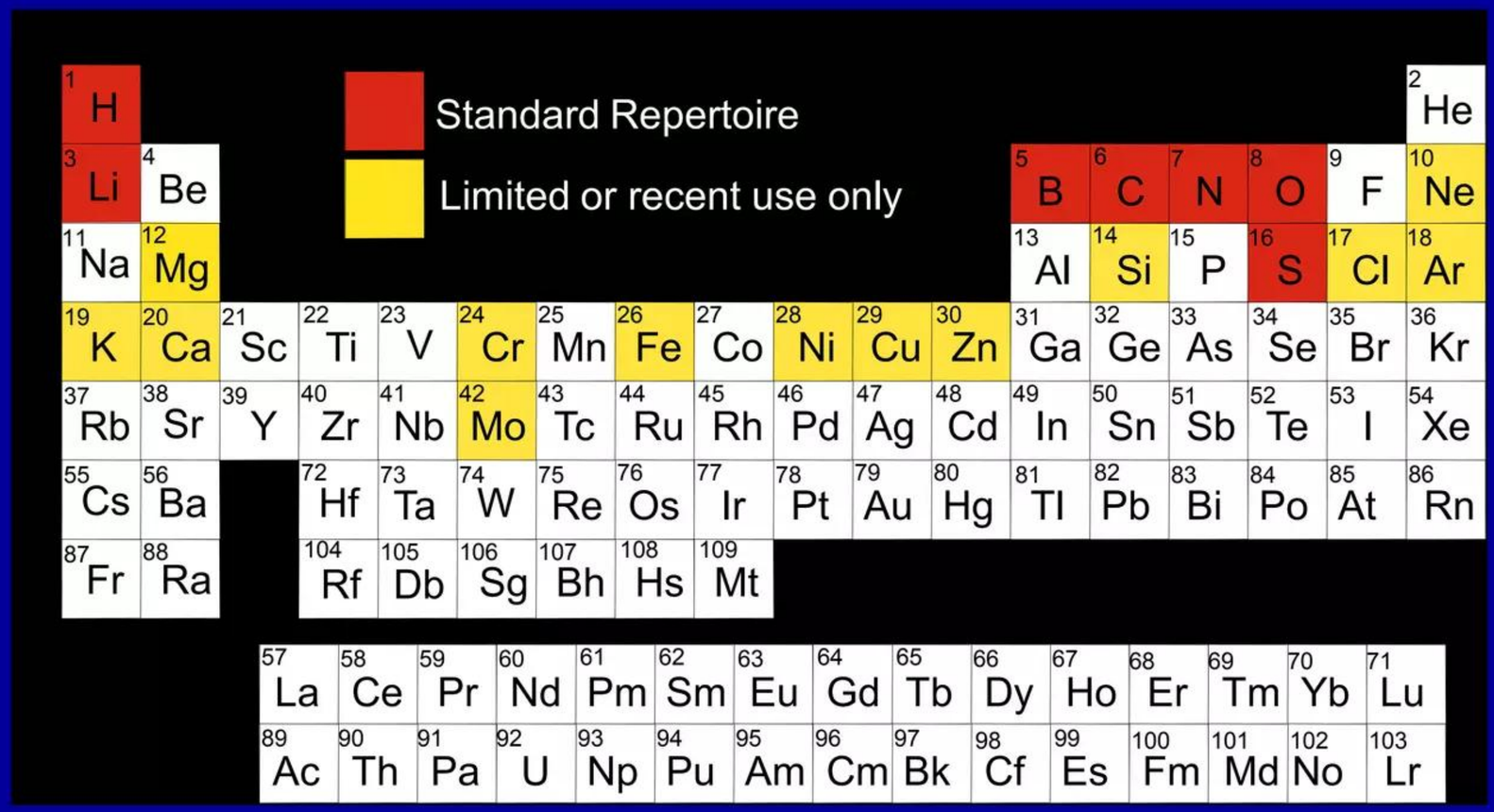
Present chemical fractionation paradigm

Nuclear reactions in few places; chemistry explains everything else - 9

Below is Prof. Asimow's 'map' showing the elements in the periodic table for which mass-dependent or mass-independent chemical fractionation processes are deemed applicable:



Source: Adapted from Prof. Paul Asimow, Caltech, slide from a Geology lecture in 2006

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Present chemical fractionation paradigm

Nuclear reactions in few places; chemistry explains everything else - 10

Mass-independent fractionation effects:

- "Looking at three isotopes of the same element, all mass-dependent fractionation (whether equilibrium or kinetic) should displace samples along the same line (e.g., slope 1/2 in $\delta^{17}O$ - $\delta^{18}O$ space)"
- "Clayton and Mayeda (1974) demonstrated that different classes of meteorites define *different* such lines, but that all objects from a given parent body (e.g., earth-moon system) share a common line"
- "But chondrites show a BIG depletion in ^{16}O along a line with slope one, originally interpreted as a nucleosynthetic effect, i.e. imperfect mixing into solar system of some pure ^{16}O material from a separate stellar source"
- "But Thiemens and coworkers discovered in the 1980's that certain reactions involving ozone (O_3) can fractionate isotopes independent of mass due to a quantum mechanical symmetry effect (there are more distinct states for $^{18}O^{16}O^{16}O$ or $^{17}O^{16}O^{16}O$ than for $^{16}O^{16}O^{16}O$; explained in detail by Gao and Marcus (2001) in a prize-winning Caltech thesis)"
- "No real mechanism has been proposed, but the possibility of mass-independent chemical effects casts doubt on the need for nucleosynthetic explanation of the three O-isotope heterogeneity of the solar system"
- "The symmetry mechanism also works for SO_2 and has been invoked to explain anomalies in $\Delta^{33}S \sim \delta^{33}S – \delta^{34}S$ in Archaean rocks, when presumably atmosphere was more reducing and H_2SO_4 less dominant"

Source: Prof. Paul Asimow, Caltech, slide from a Geology lecture in 2006

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Present chemical fractionation paradigm

Nuclear reactions in few places; chemistry explains everything else - 11

Example: explanation of $_{13}C$ abundance variations according to the chemical paradigm:

"The ratio of Carbon-12 to Carbon-13 is constant in earth's atmosphere. There are always 100 $_{12}C$ atoms to one $_{13}C$ atom. During the process of photosynthesis, plants absorb the carbon atoms in earth's atmosphere, water, and soil, and store them in the cells of their leaves, fruits, nuts, and roots. But as a result of the photosynthesis process, the ratio of the forms of carbon gets changed as it is being stored."

"The alteration of the chemical ratio is different for plants in different parts of the world. For example, plants that live in regions with lots of sun and little water have relatively fewer $_{12}C$ atoms in their cells (compared to$_{13}C$) than do plants that live in forests or wetlands. This ratio is hardwired into the plant's cells, and—here's the best part—as the cells get passed up the food chain (i.e., the roots, leaves, and fruit are eaten by animals and humans), the ratio of $_{12}C$ to $_{13}C$) remains virtually unchanged as it is in turned stored in bones, teeth and hair of the animals and humans."

"In other words, if you can determine the ratio of $_{12}C$ to $_{13}C$ in an animal's bones, you can figure out what kind of climate the plants it ate during its lifetime came from. The measuring takes mass spectrometer analysis; but that's another story, too."

Source: http://archaeology.about.com/od/stableisotopes/qt/dummies.htm

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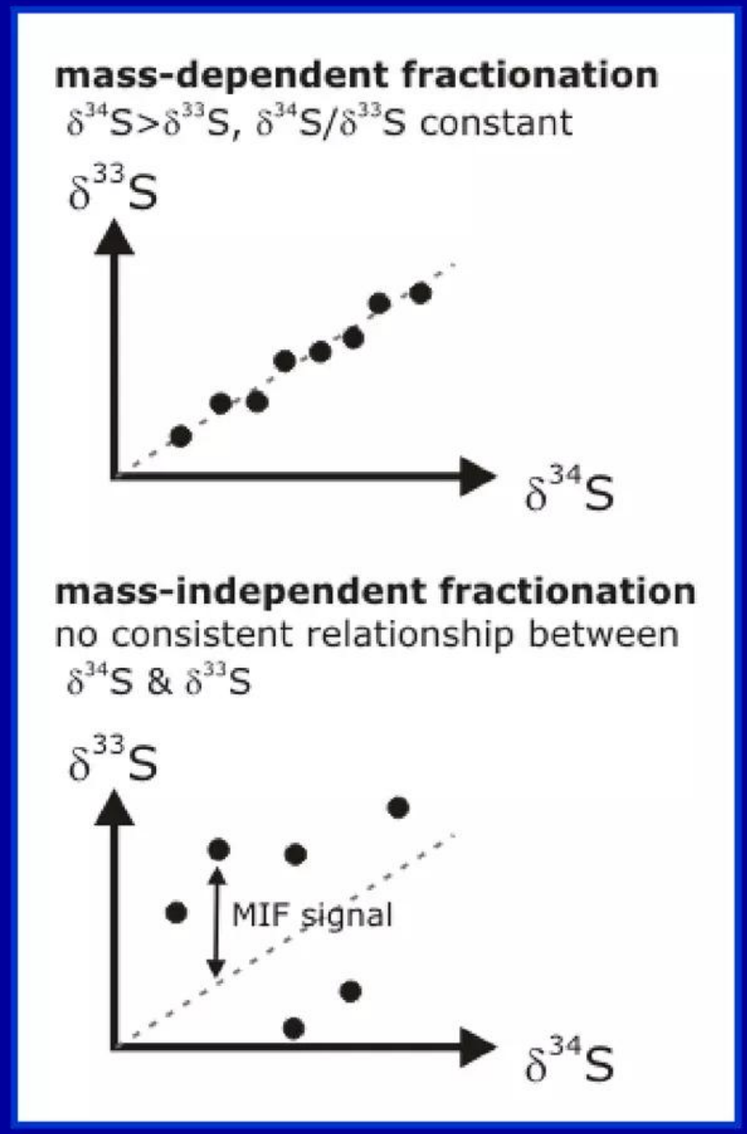
Chemical vs. Nuclear Paradigms

W-L theory and LENRs vs. chemical fractionation explanations - 1

- ✓ **For ~ 60 years, a body of theory has been developed and articulated to explain progressively increasing numbers of stable isotope anomalies observed in a vast array of mass spectroscopic data obtained from many different types of natural and experimental, abiological and biological, systems. Central ideas in chemical "fractionation" theory embody equilibrium and irreversible, mass-dependent and mass-independent, chemical processes that are claimed to separate isotopes, thus explaining the reported anomalies**

- ✓ **Although not explicitly acknowledged by fractionation theorists, an intrinsic *fundamental* assumption underlying all of this theory and interpretation of data is that no nucleosynthetic processes are occurring anywhere in any of these systems, at any time, that are capable of altering isotope ratios and/or producing new mixtures of different elements over time; ergo, chemistry explains everything**

- ✓ **However, if the Widom-Larsen theory is correct, for some of this data the above fundamental assumption may be wrong**



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Chemical and Nuclear Paradigms

W-L theory and LENRs vs. chemical fractionation explanations - 2

Before proceeding further, let it be crystal clear to readers exactly what we are and are *not* saying here:

- ✓ **We are not asserting that the existing chemical fractionation paradigm fails to adequately explain most reported isotope anomalies with respect to statistically significant deviations from natural abundances --- indeed, it may well effectively and accurately explain the vast majority of them!**
- ✓ **We are saying that the presently available published literature does contain a significant subset comprising many cases in which the chemical fractionation paradigm must be pushed very hard (which includes use of various ad hoc constructs) to explain certain isotope anomalies, i.e. it is being overly stretched to be able to comfortably accommodate some data**
- ✓ **We are suggesting that in those particular instances, it may be fruitful for researchers to reexamine such data through the conceptual lens of the LENR paradigm to determine whether the new W-L approach can help lead to a deeper, easier understanding of reported experimental data. In some cases, it well may; in others it may not --- but we should look anyway**

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Assumptions about chemical systems

Chemistry assumptions can break down on small length scales - 1

- ✓ **As background, let us briefly review some underlying, implicit assumptions about chemical systems that have not been much questioned since 1912, when Bohr and Rutherford formulated modern ideas of atomic structure and 1927, when the Born-Oppenheimer approximation (which is a physically justifiable simplifying assumption) made quantum mechanical calculations mathematically tractable for less complicated atoms such as hydrogen and not-too-large molecules (e.g., benzene)**

- ✓ **After 1927, chemistry's recognized domain was narrowed to comprise phenomena involving electron clouds surrounding atomic nuclei and the dynamics of outer valence electrons that interact with Coulomb electric fields induced by positively charged protons in nuclei; particle energies in chemical systems are thus typically in the eV range. Chemistry typically involves atomic and molecular phenomena at temperatures of up to ~6,000° C and non-degenerate electron pressures; it customarily excludes subatomic particles and their very fast, vastly more energetic MeV-and-higher nuclear reactions, as well as matter found in extremely hot, highly ionized plasmas at temperatures of up to millions of degrees**

"Toto, I have the feeling we're not in Kansas anymore."

Dorothy in "The Wizard of Oz" (1939)

"There is nothing as deceptive as an obvious fact."

Sherlock Holmes, "The Boscombe Valley Mystery" (1891)

"These are very deep waters."

Sherlock Holmes, "The Adventure of the Speckled Band" (1892)

" " … when you have eliminated the impossible, whatever remains, however improbable, must be the truth."

Sherlock Holmes, "The Sign of the Four" (1890)

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Assumptions about chemical systems

Chemistry assumptions can break down on small length scales - 2

<u>According to W-L theory</u>: in condensed matter chemical systems (as opposed to large-length-scale, magnetically dominated regimes explained in our technical publications), LENRs are primarily surface phenomena that can, under exactly the right conditions, occur in scattered, discrete regions with dimensions that range from as little as ~0.28 nanometers (benzene ring) up to ~100 microns (10^5 nm) on metal hydrides. In such tiny, uniquely different regions the:

- ✓ **Born-Oppenheimer approximation breaks down; many-body electron-nucleon (p+, d+, t+) dynamics can locally become electromagnetically (E-M) coupled (think of these hydrogen atoms behaving as 'bare nuclei')**
- ✓ **Many-body, collectively oscillating, coherent (i.e., particles effectively Q-M 'entangled'), spatially contiguous collections of protons, deuterons, or tritons E-M couple to immediately adjacent: surface plasmon polariton electrons on metallic hydride surfaces; or, collectively oscillating π electrons located on the 'surfaces' of benzene rings, polycyclic aromatic hydrocarbons (PAHs), fullerenes, and graphane/graphene structures**
- ✓ **Local coupling of many-body, collective oscillations of protons/deuterons/tritons with electrons creates nuclear-strength local electric fields >10^{11} V/m that renormalize masses of coupled electrons (e*); this enables ultra low momentum neutron (ULMN) production via e*+p or e*+d weak interaction; ~all ULMNs captured locally**
- ✓ **Purely chemical reactions always 'conserve' and preserve elements found in both reactants and products; once ULM neutrons are introduced to a system, 'conservation of elements' assumption is not necessarily valid**

In systems with LENRs, some of chemistry's key fundamental assumptions break down and are violated on small length scales. Thus, while 'pure chemistry' may reign supreme on 98 - 99% of a given sample surface, there can be many tiny sub-regions comprising just a few % of the total surface area in which W-L weak interaction-dominated nuclear processes can also occur

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Assumptions about chemical systems

Technical side note about ULM neutron capture cross-sections

- ✓ **Unlike energetic neutrons produced in most nuclear reactions, collectively produced LENR neutrons are effectively 'standing still' at the moment of their creation in condensed matter. Since they are vastly below thermal energies (ultra low momentum), ULM neutrons have huge DeBroglie wavelengths (from nm to ~100 microns) and accordingly large capture cross-sections on nearby nuclei; most or all will be locally absorbed; few will be detectable as 'free' neutrons**

- ✓ **For the vast majority of stable and unstable isotopes, their neutron capture cross-section (relative to measurements of cross-sections at thermal energies where *v* = 2,200 *m/sec* and the DeBroglie wavelength is ~ 2 Angstroms) is proportional to ~1/*v*, where *v* is velocity of a neutron in *m/sec*. Since *v* is extraordinarily small for ULM neutrons, their capture cross-sections on atomic nuclei will therefore be correspondingly larger. After being collectively created, an enormous percentage of the ULMNs produced will be locally absorbed before scattering on nearby atoms can elevate them to thermal kinetic energies; per Prof. S. Lamoreaux (Yale) thermalization would require ~0.1 to 0.2 msec, i.e. 10^{-4} sec., a long time on typical 10^{-16} – 10^{-19} sec. time-scale of nuclear reactions**

***Please note*: ultra low momentum (ULM) neutrons have enormous absorption cross-sections on 1/v isotopes. For example, Lattice has estimated the ULMN fission capture cross-section on U-235 to be ~1 million barns (b) and on Pu-239 at 49,000b, vs. ~586 b and ~752b, respectively, for 'typical' neutrons at thermal energies**

A neutron capture expert recently estimated the ULMN capture cross-section on He-4 at ~20,000b vs. a value of <1 b for thermal neutrons; this is a huge increase

By comparison, the highest known thermal n capture cross section for any stable isotope is Gadolinium-157 at ~49,000b

The highest measured cross-section for any unstable isotope is Xenon-135 at ~2.7 million b

***Crucial point*: ULMNs have many-body scattering, NOT 2-3 body**

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Assumptions about chemical systems

Consequences of local breakdown in chemistry assumptions - 1

Please recall the basic equation for fractionation:

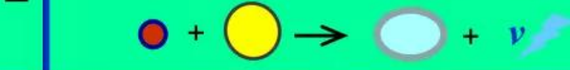
$$f = \frac{(heavy\ /\ light)\text{product}}{(heavy\ /\ light)\text{reactant}}$$

Now let us assume that in an idealized system:

- ✓ **Purely chemical reactions occur at specific types of surface sites that range in size from <1 nanometer (nm) up to say ~100 microns**
- ✓ **ULM neutron-catalyzed transmutation reactions also occur on small length scales at a much smaller number of widely scattered sites on the very same surfaces; dimensions of such LENR-active sites can also range from <1 nm up to perhaps ~100 microns**
- ✓ **Some percentage of chemical <u>product</u> atoms are transported by ordinary physico-kinetic diffusion processes to spatially separated LENR-active sites where they then capture one or more LENR ULM neutrons; assume that newly produced heavier isotopes are stable**

What has happened in this hypothetical example is that there has been an: (a) upward isotopic shift for some % of the <u>product</u> atoms; (b) increase in isotopic fractionation (i.e., larger value for the numerator)

<u>Key point</u>: transmutation processes can mimic chemical fractionation

Weak interaction	**W-L neutron production**	**LENR Nuclear Realm (MeVs) Occurs within micron-scale 'patches'** $\tilde{e}^- + p^+ \rightarrow n_{ulm} + \nu_e$ $\tilde{e}^- + d^+ \rightarrow 2n_{ulm} + \nu_e$ 
Strong interaction	**Neutron capture**	$n_{ulm} + (Z, A) \rightarrow (Z, A+1)$  **<u>Either a</u>: stable or unstable HEAVIER isotope**
Transmutations: isotope shifts occur; chemical elements disappear/appear	**Decays of unstable, very neutron-rich isotopes: beta and alpha (He-4)decays**	**<u>In the case of unstable isotopic products</u>: they subsequently undergo some type of nuclear decay process; e.g., beta, alpha, etc.** **In the case of a typical beta⁻ decay:**  $(Z, A) \rightarrow (Z+1, A) + e^- + \bar{\nu}_e$ **In the case of a typical alpha decay:**  $(Z,\ A) \rightarrow (Z-2, A-4) + {}^4_2\mathrm{He}$ **<u>Note</u>: extremely neutron-rich product isotopes may also deexcite via beta-delayed decays, which can also emit small fluxes of neutrons, protons, deuterons, tritons, etc.**

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Assumptions about chemical systems

Consequences of local breakdown in chemistry assumptions - 2

Now please recall the methodology for calculating δ:

$$\delta = \left(\frac{R_{sample} - R_{standard}}{R_{standard}} \right) x1000$$

In this methodology, the isotopic ratio R_{sample} measured in a sample is compared to an internationally agreed-upon reference standard; this approach is derived directly from the notion that there exists a time-invariant "natural isotopic abundance" for every stable element found on a given planet, e.g., earth. For example: in the case of hydrogen and oxygen isotopes, the commonly used standard is Standard Mean Ocean Water (SMOW), which represents an average 'global' value for the typical isotopic composition of ocean water. Results of such comparison-measurements are presented in what is called the delta (δ) notation (δ representing the measured difference between the isotopic composition of a given sample and a specific standard). A calculated δ value will be positive if a sample contains more of the specified heavy isotope than the standard; a δ value will be negative if a sample contains less of the heavy isotope than the standard. For many elements, δ values for isotopic composition are reported in per mille (‰), parts per thousands, rather than in percent (%)

Weak interaction	**W-L neutron production**	**LENR Nuclear Realm (MeVs) Occurs within micron-scale 'patches'** $\tilde{e}^- + p^+ \rightarrow n_{ulm} + \nu_e$ $\tilde{e}^- + d^+ \rightarrow 2n_{ulm} + \nu_e$ + → + ν
Strong interaction	**Neutron capture**	$n_{ulm} + (Z, A) \rightarrow (Z, A+1)$ + → or Either a: stable or unstable HEAVIER isotope
Transmutations: isotope shifts occur; chemical elements disappear/appear	**Decays of unstable, very neutron-rich isotopes: beta and alpha (He-4)decays**	**In the case of unstable isotopic products:** they subsequently undergo some type of nuclear decay process; e.g., beta, alpha, etc. **In the case of a typical beta⁻ decay:** → + + ν $(Z, A) \rightarrow (Z+1, A) + e^- + \bar{\nu}_e$
		In the case of a typical alpha decay: → + $(Z,\ A) \rightarrow (Z-2, A-4) + {}^4_2\mathrm{He}$
		Note: extremely neutron-rich product isotopes may also deexcite via beta-delayed decays, which can also emit small fluxes of neutrons, protons, deuterons, tritons, etc.

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Assumptions about chemical systems

Consequences of local breakdown in chemistry assumptions - 3

Now please recall the previous example for Oxygen:

$$\delta^{18}O = \left[\frac{(^{18}O/^{16}O)_{sam} - (^{18}O/^{16}O)_{SMOW}}{(^{18}O/^{16}O)_{SMOW}} \right] \times 10^3$$

Natural abundance: ^{16}O = 99.759%; ^{17}O = 0.0374%; ^{18}O = 0.2039%

If ^{16}O were somehow exposed to fluxes of ULM neutrons, one might expect that it would first be transmuted via LENRs to ^{17}O with the capture of one ULM neutron. Now ^{17}O has the highest neutron capture cross-section of the three stable Oxygen isotopes (^{17}O = 0.54 millibarns for neutrons at thermal energies which is 2.8x that of ^{16}O and 3.4x ^{18}O), so $^{17}O + n_{ulm} \rightarrow {}^{18}O$ would be favored. Also, Oxygen is an unusual lighter element in that ^{17}O just happens to have a significant cross-section for alpha decay upon capturing a neutron. Therefore, ^{17}O can be depleted in two ways by ULM neutron-catalyzed processes: (1.) neutron capture to ^{18}O; and (2.) alpha (^{4}He) decay to Carbon-14 (^{14}C). Those two competing processes are probably the reason why ^{17}O has a lower natural abundance than ^{16}O and ^{18}O

Thus, all other things being equal, repeated or protracted exposure of Oxygen atoms to ULM neutrons would likely tend to increase $\delta^{18}O$

Weak interaction	**W-L neutron production**	**LENR Nuclear Realm (MeVs) Occurs within micron-scale 'patches'** $\tilde{e}^- + p^+ \rightarrow n_{ulm} + \nu_e$ $\tilde{e}^- + d^+ \rightarrow 2n_{ulm} + \nu_e$
Strong interaction	**Neutron capture**	$n_{ulm} + (Z, A) \rightarrow (Z, A+1)$ **or** Either a: stable or unstable HEAVIER isotope
Transmutations: isotope shifts occur; chemical elements disappear/appear	**Decays of unstable, very neutron-rich isotopes: beta and alpha (He-4)decays**	In the case of unstable isotopic products: they subsequently undergo some type of nuclear decay process; e.g., beta, alpha, etc. In the case of a typical beta$^-$ decay: $(Z, A) \rightarrow (Z+1, A) + e^- + \bar{\nu}_e$
		In the case of a typical alpha decay: $(Z,\ A) \rightarrow (Z-2, A-4) + {}^4_2He$
		Note: extremely neutron-rich product isotopes may also deexcite via beta-delayed decays, which can also emit small fluxes of neutrons, protons, deuterons, tritons, etc.

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Assumptions about chemical systems

Consequences of local breakdown in chemistry assumptions - 4

Hydrogen natural abundance: ^{1}H = 99.985%; ^{2}H (D; deuterium) = 0.015%

^{1}H has substantial capture cross-section for neutrons, 0.332 barns at thermal energies; this is ~650x capture c-s for D and >50,000x that for tritium (^{3}H). In LENR systems, $^{1}H + n \rightarrow {}^{2}H + \gamma$ the ~2.2 MeV gamma photon produced by ULM neutron capture on ^{1}H is directly converted to infrared (IR) photons by coupled heavy electrons; thus, no gamma emissions would be detected; if present, this reaction could produce increases in δD; note - ^{1}H is 1/v isotope

Carbon natural abundance: ^{12}C = 98.93%; ^{13}C = 1.07%

At thermal energies, ^{12}C has a neutron capture cross-section of only ~3.5 millibarns; at ULMN energies it is probably >3,000 barns since ^{12}C is a 1/v isotope. Thus, in LENR systems the reaction $^{12}C + n \rightarrow {}^{13}C + \gamma$ could in theory occur at substantial rates; again, capture gammas would not be detected because of their conversion to IR by mass- renormalized heavy electrons; at relatively low ULMN fluxes this reaction would most likely tend to increase $\delta^{13}C$

Nitrogen natural abundance: ^{14}N = 99.632%; ^{15}N = 0.368%

At thermal energies, ^{14}N has a neutron capture cross-section of only 0.080 barns; at ULM energies it may be 10^5-10^6 larger because ^{14}N is 1/v isotope. Thus, in LENR systems the reaction $^{14}N + n \rightarrow {}^{15}N + \gamma$ can potentially occur at significant rates; again, capture gammas would not be detected because of conversion to IR by heavy electrons. ULMN capture on ^{15}N would produce ^{16}N which is unstable (half-life = 7.1 seconds) and beta decays into ^{16}O which is stable. Thermal neutron capture cross-section for ^{15}N is 2,000x less than ^{15}N; all other things being equal, at low ULM neutron fluxes ^{15}N should 'pile-up' faster than it can be transmuted via neutron capture into ^{16}N; altogether, these reactions would likely tend to produce increases in $\delta^{15}N$

Sulfur natural abundance: ^{32}S = 94.93%; ^{33}S = 0.76%; ^{34}S = 4.29%; ^{36}S = 0.02%

Beginning with ^{32}S, Sulfur's four stable isotopes have similar thermal neutron capture cross-sections of 0.55, 0.46, 0.30, and 0.23 barns, respectively; they are all 1/*v* isotopes. All other things being equal, at low ULM neutron fluxes, $\delta^{33}S$, $\delta^{34}S$, and $\delta^{36}S$ would all tend to increase; ^{35}S is unstable (h-l = 87 days) and beta decays to ^{35}Cl. Higher ULMN fluxes would produce ^{37}S which is unstable (h-l = 5.1 minutes) and β^- decays into Chlorine ^{37}Cl (stable but very reactive)

Weak interaction — **W-L neutron production**

LENR Nuclear Realm (MeVs)
Occurs within micron-scale 'patches'

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

$$\tilde{e}^- + d^+ \rightarrow 2n_{ulm} + \nu_e$$

Strong interaction — **Neutron capture**

$$n_{ulm} + (Z, A) \rightarrow (Z, A+1)$$

Either a: stable or unstable HEAVIER isotope

Transmutations: isotope shifts occur; chemical elements disappear/appear — **Decays of unstable, very neutron-rich isotopes: beta and alpha (He-4)decays**

In the case of unstable isotopic products: they subsequently undergo some type of nuclear decay process; e.g., beta, alpha, etc.

In the case of a typical beta$^-$ decay:

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

In the case of a typical alpha decay:

$$(Z,\ A) \rightarrow (Z-2, A-4) + {}^{4}_{2}\mathrm{He}$$

Note: extremely neutron-rich product isotopes may also deexcite via beta-delayed decays, which can also emit small fluxes of neutrons, protons, deuterons, tritons, etc.

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Assumptions about chemical systems

Consequences of local breakdown in chemistry assumptions - 5

In most chemical catalysis, reactants and products must be in intimate nanoscale contact with a surface (often a metal of some sort) in order for a catalytic acceleration of reaction rates to occur. Interestingly, the following three reactions are all well-known to be catalyzed by Palladium (Pd), Pt, and/or Rh and are important in truck and automobile catalytic converters:

$2NO_x \rightarrow xO_2 + N_2$ $\quad$ $2CO + O_2 \rightarrow 2CO_2$ $\quad$ $C_xH_{2x+2} + [(3x+1)/2]O_2 \rightarrow xCO_2 + (x+1)H_2O$

Hypothetically, what might occur if such reactions took place at tiny sites on a catalyst surface that also just happened to be located 'right on the edge' of a 30 micron 'patch' in which fluxes of LENR ULM neutrons were being produced? Well, according to the W-L theory all the atoms comprising any of the reactants (which are not necessarily 100% consumed) or products found in such locations would have an opportunity to 'compete' (with many thousands of other atoms located in and adjacent to the patch) to capture ULM neutrons. At low fluxes, typically only one ULM neutron might be captured by a given 'target' atom. That would tend to deplete lower-mass isotopes and enrich higher-mass isotopes; i.e., in above examples one could conjecture that $\delta^{15}N$, $\delta^{18}O$, $\delta^{13}C$ and δD would all tend to increase

All other things being equal, repeated or protracted exposure of molecular H, C, N, O, or S atoms to local fluxes of ULM neutrons would most likely tend to increase measured values for δD, $\delta^{13}C$, $\delta^{15}N$, $\delta^{17\text{-}18}O$, and $\delta^{34}S$; such LENR nuclear effects would be manifested as statistically significant variances from reference standards. At relatively low ULMN fluxes, LENRs might very well mimic mass-dependent chemical fractionation processes. At somewhat higher fluxes of captured neutrons, LENRs could potentially produce significantly larger stable isotope anomalies that would most likely exhibit no apparent relationship to mass; i.e., they would appear to be mass-independent

At high local ULM neutron fluxes, several neutrons might be captured by a particular atom, creating an unstable, neutron-rich 'heavy' isotope that beta decays, producing a different chemical element which would then be available to participate in other chemical reactions. Such newly produced stable elements, which may or not have been previously present, could mistakenly be regarded by researchers as 'outside contaminants' when they are really products of local LENR processes

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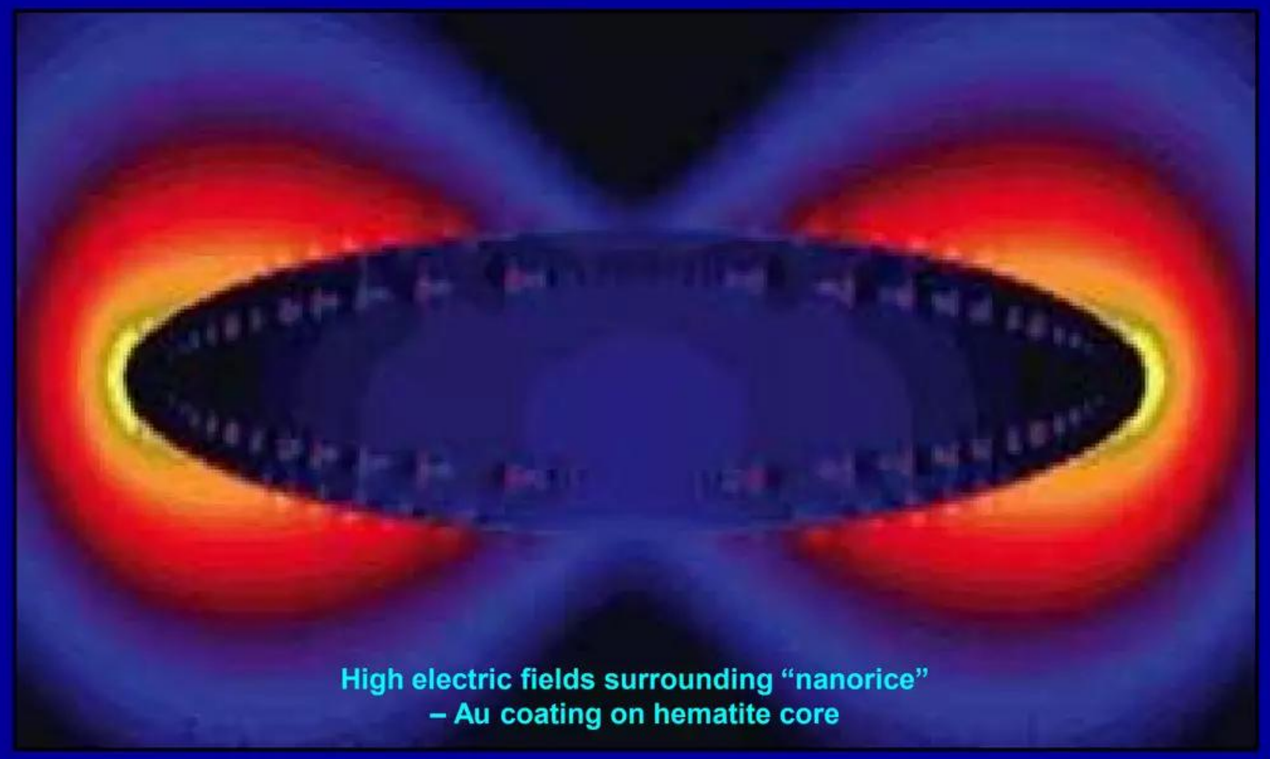
Recap of W-L theory in metallic hydride systems



High electric fields surrounding "nanorice"
– Au coating on hematite core

"Theories have four stages of acceptance:
i.) this is worthless nonsense;
ii.) this is an interesting, but perverse, point of view;
iii.) this is true, but quite unimportant;
and iv.) I always said so."

J.B.S. Haldane, 1963

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Recap of W-L theory in metallic hydride systems

Weak interaction processes are very important in LENRs

Nuclear and chemical processes can coexist on small length scales in condensed matter

1. **E-M radiation on metallic hydride surface increases mass of surface plasmon electrons**
2. **Heavy-mass surface plasmon polariton electrons react directly with surface protons (p^+) or deuterons (d^+) to produce ultra low momentum (ULM) neutrons (n_{ulm} or $2n_{ulm}$, respectively) and an electron neutrino (ν_e)**
3. **Ultra low momentum neutrons (n_{ulm}) are captured by nearby atomic nuclei (Z, A) representing some element with charge (Z) and atomic mass (A). ULM neutron absorption produces a heavier-mass isotope (Z, $A+1$) via transmutation. This new isotope (Z, $A+1$) may itself be a stable or unstable, which will perforce eventually decay**
4. **Many unstable isotopes β^- decay, producing: transmuted element with increased charge ($Z+1$), ~ same mass ($A+1$) as 'parent' nucleus; β^- particle (e^-); and an antineutrino**

→ **Note: colored shapes associated with diagram on next Slide**

No strong interaction fusion or heavy element fission occurring below, only weak interactions

1. (High E-M field) + ● → ●

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

Mass-renormalized surface plasmon polariton electron (e*)

2. ● + ● → ⬭ + ν

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

2. ● + ● → ⬭⬭ + ν

$$\tilde{e}^- + d^+ \rightarrow 2n_{ulm} + \nu_e$$

3. ⬭ + ● → ●

$$n_{ulm} + (Z, A) \rightarrow (Z, A+1)$$

Unstable or stable new isotope

4. ● → ● + ○ + ν

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

Unstable Isotope

Weak interaction β^- decays (shown above), direct gamma conversion to infrared (not shown), and α decays (not shown) produce most of the excess heat calorimetrically observed in LENR systems

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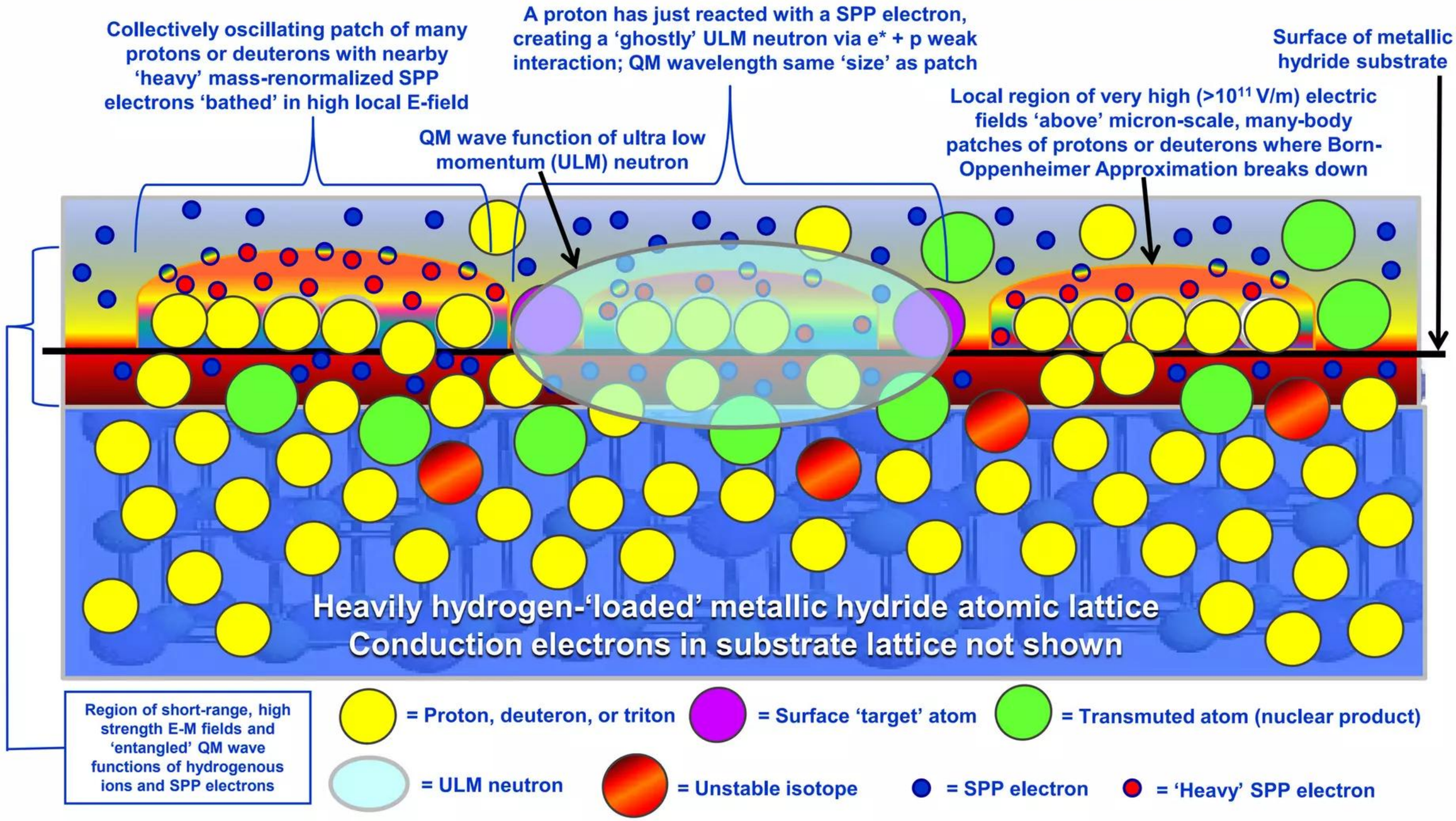
Recap of W-L theory in metallic hydride systems

Idealized nanoscale side view of LENRs on a hydride surface



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Recap of W-L theory in metallic hydride systems

Chemical and nuclear energy realms interconnect in small regions

LENR Nuclear Realm (MeVs)
Occurs within nm- to micron-scale 'patches'

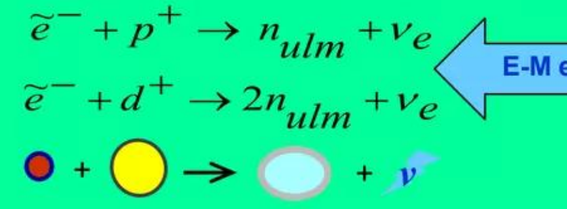
'Transducer' regions: many-body collective effects, ~eV energies are 'collected' and 'summed' to MeV energies in micron-scale, many-body surface 'patches' by 'film' of SPP electrons and p^+, d^+, t^+ ions in patches; all oscillate collectively

Chemical Energy Realm (eVs)
Everywhere else in LENR systems

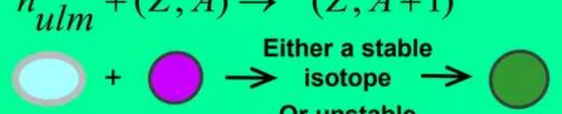
"Hot spots:"reach 3,000 - 6,000+ °C
'Craters' visible in post-experiment SEM images of LENR device surfaces

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

$$\tilde{e}^- + d^+ \rightarrow 2n_{ulm} + \nu_e$$



$$n_{ulm} + (Z, A) \rightarrow (Z, A+1)$$



Unstable isotope:

Which then subsequently undergoes some type of nuclear decay process

In the case of typical beta⁻ decay:

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

In the case of typical alpha decay:

$$(Z,\ A) \rightarrow (Z-2, A-4) + {}^{4}_{2}\mathrm{He}$$

Extremely neutron-rich product isotopes may also deexcite via beta-delayed decays, which also emit small fluxes of neutrons, protons, deuterons, tritons, etc.

E-M energy | **E-M energy** | **E-M energy** | **Input**

Many-body, collectively oscillating surface' patches' of **p^+, d^+, or t^+** ions

Mass-renormalized surface plasmon polariton (SPP) electrons (e^*) – also convert gammas to IR

Normal-mass surface plasmon polariton (SPP) or **π electrons** on surfaces of certain carbon structures

Gamma photons

IR

Micron-scale surface regions with very high local electromagnetic fields

Surface 'film' of SPP electrons inherently oscillates collectively

Energy must be inputted to create high surface E-M radiation fields that are needed to produce ULM neutrons. Required input energy can be provided from one or a combination of: electron 'beams' (electric currents); ion 'beams', i.e., fluxes of ions across the surface 'film' of SPP electrons (protons, deuterons, tritons, or other ions); and E-M photons, e.g., from lasers if nanoscale surface roughness coupling parameters are satisfied

Infrared (IR) photons

IR photons excite lattice phonons

ULM neutron captures on 'target fuel' elements and subsequent nuclear reactions all release nuclear binding energy – neutrons are the 'match' that lights the fuel 'on fire'

Heat

Energetic charged particles excite lattice phonons

Born-Oppenheimer Approximation breaks down in many-body 'patches' of p^+, d^+, or t^+ on 'loaded' hydride surfaces

Two-way, collective energy transfers occur back-and-forth via E-M fields coupling the chemical and nuclear realms

Output

LENR final products: primarily stable isotopes, energetic β^-, α (He-4) particles, other charged particles, IR photons (with small 'tail' in soft X-rays), and neutrinos

Output

Neutrinos (ν) fly off into space at velocity c

End with:  **ν and IR photons**

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Recap of W-L theory in metallic hydride systems

Can't boil tea, but LENRs boil metals on nanoscale

- ✓ **While LENR devices cannot "boil a cup of tea" yet, Cirillo and Iorio have reported results wherein post-experiment SEM images show unusual surface structures that appear to have resulted from flash boiling of Tungsten cathodes (MP = 3,410 C; BP = 5,666 C) in roughly circular 50 - 100 micron 'patches'**

- ✓ **With W's high boiling point, it is unlikely that such features were produced by oxidative chemical processes, since the hottest known chemical 'flames' are cyanogen-oxygen under pressure at 4,367° C; carbon subnitride burning in pure O^2 at 4,987° C**

- ✓ **One might argue that such heating was caused by local electrical discharges (prosaic arcing). Perhaps, but micron-scale arcing events result in somewhat different surface morphologies. More importantly, in the same experiments Rhenium (Re), Osmium (Os), and Gold (Au) were observed as nuclear transmutation products on the cathode surface**

- ✓ **According to W-L theory, ULM neutron production and successive ULM neutron captures interspersed with beta decays would be expected to produce W -> Re -> Os -> Au, which are in fact observed experimentally**

Please see:

D. Cirillo and V. Iorio, "Transmutation of metal at low energy in a confined plasma in water" on pp. 492-504 in "Condensed Matter Nuclear Science – Proceedings of the 11th International Conference on Cold Fusion," J-P. Biberian, ed., World Scientific 2006

Free copy of paper available at: *http://www.lenr-canr.org/acrobat/CirilloDtransmutat.pdf*

Note:

Unbeknownst to the experimenters, they may have had either Barium (Ba) titanate and/or Dysprosium (Dy) as component(s) in the composition of the dielectric ceramic sleeve that was partially covering the cathode immersed in the electrolyte; Ba and/or Dy are often present in such ceramics. Under the stated experimental conditions, Ba and Dy could easily 'leach-out' from the surface of the ceramic into the electrolyte, creating yet another 'target' element that could migrate onto the surface of their Tungsten cathode. Since none of the potential intermediate transmutation products such as Nd (Neodymium), Sm (Samarium), and Gd (Gadolinium) were observed/reported, it is possible that there may have been LENR ULM neutron captures starting with Dy -> Er (Erbium) -> Tm (Thulium) ->Yb (Ytterbium) which are transmutation products that were in fact observed in their experiments

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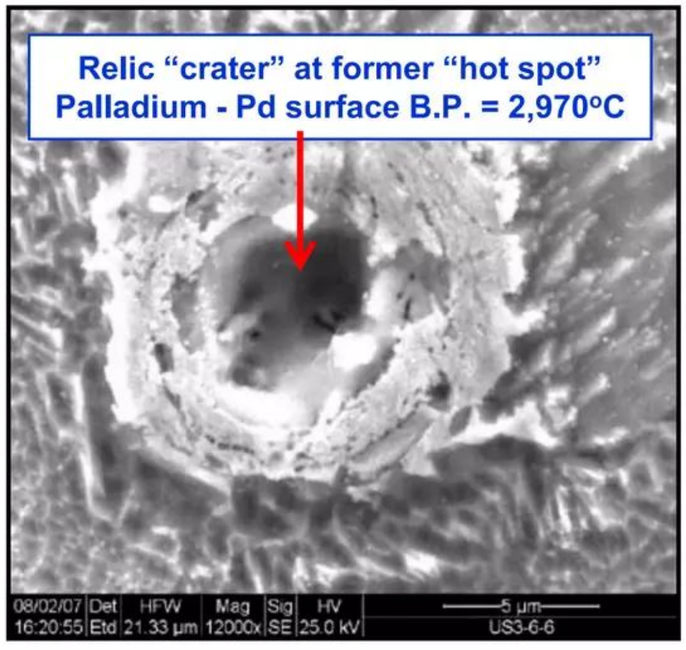
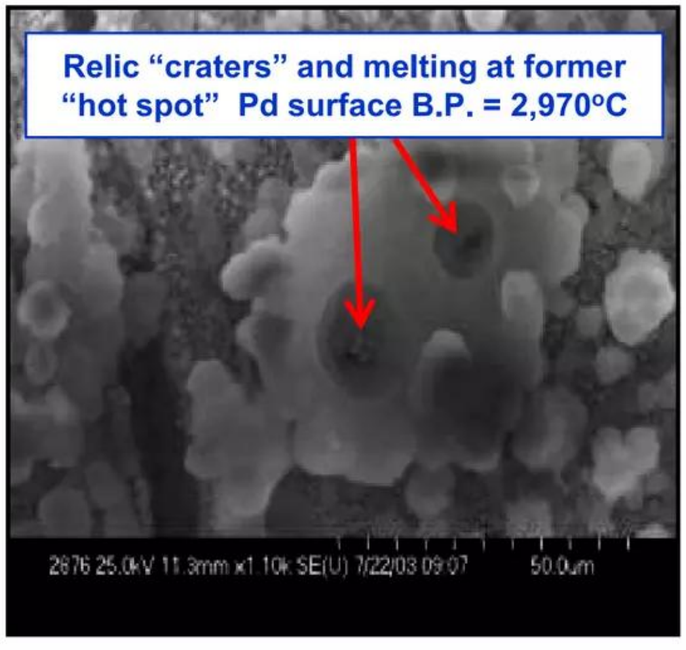
Recap of W-L theory in metallic hydride systems

SEM images show evidence of micron-scale heating by LENRs

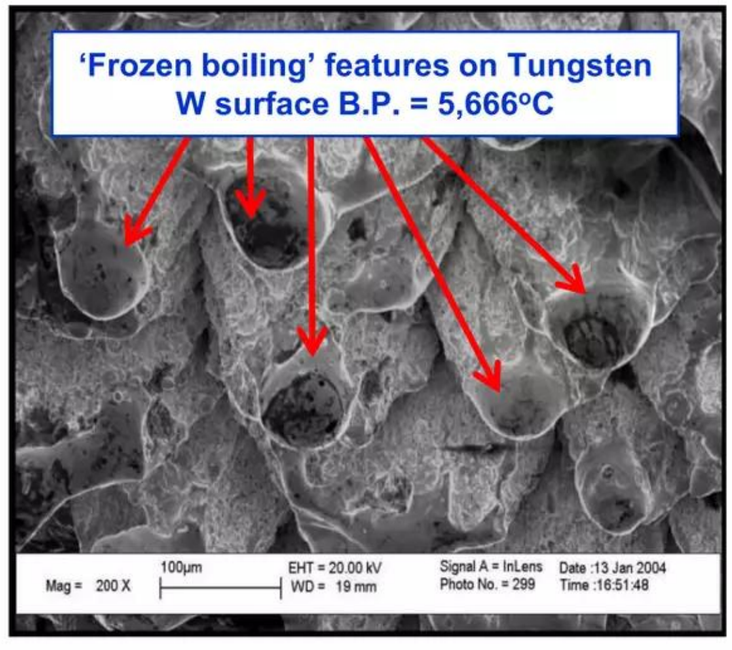
- ✓ **Interested readers are encouraged to examine reported SEM images of LENR surface features**
- ✓ **To find more such images, go to the free website:** http://www.lenr-canr.org **--- several hundred papers are downloadable from that site. However, caveat emptor! Most of the publications thereon have not been peer-reviewed and their quality varies immensely. Nevertheless, a significant number of them contain good experimental data and it is worth the time to separate such wheat from obvious chaff**
- ✓ **Below, more sample images from LENR researchers on Palladium (Pd) and Tungsten (W) surfaces:**



Pd surface: image source is Energetics Technologies, Omer, Israel



Pd surface: image source is US Navy SPAWAR (San Diego, CA)

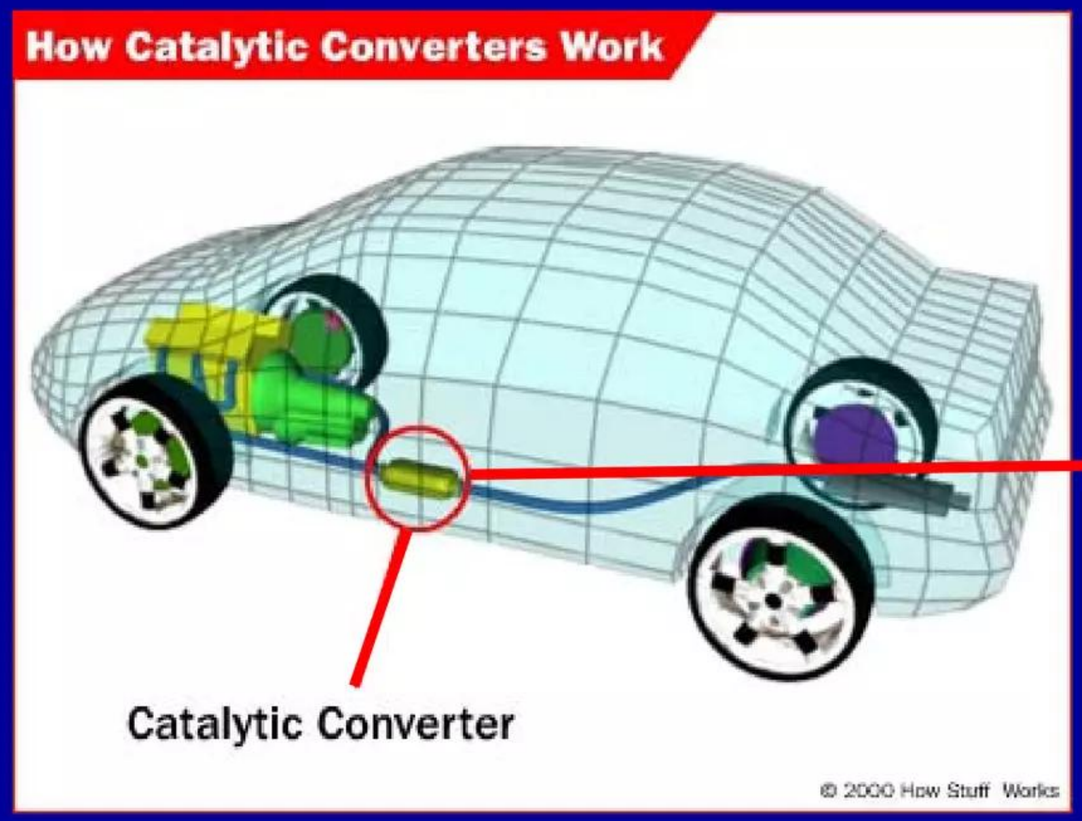


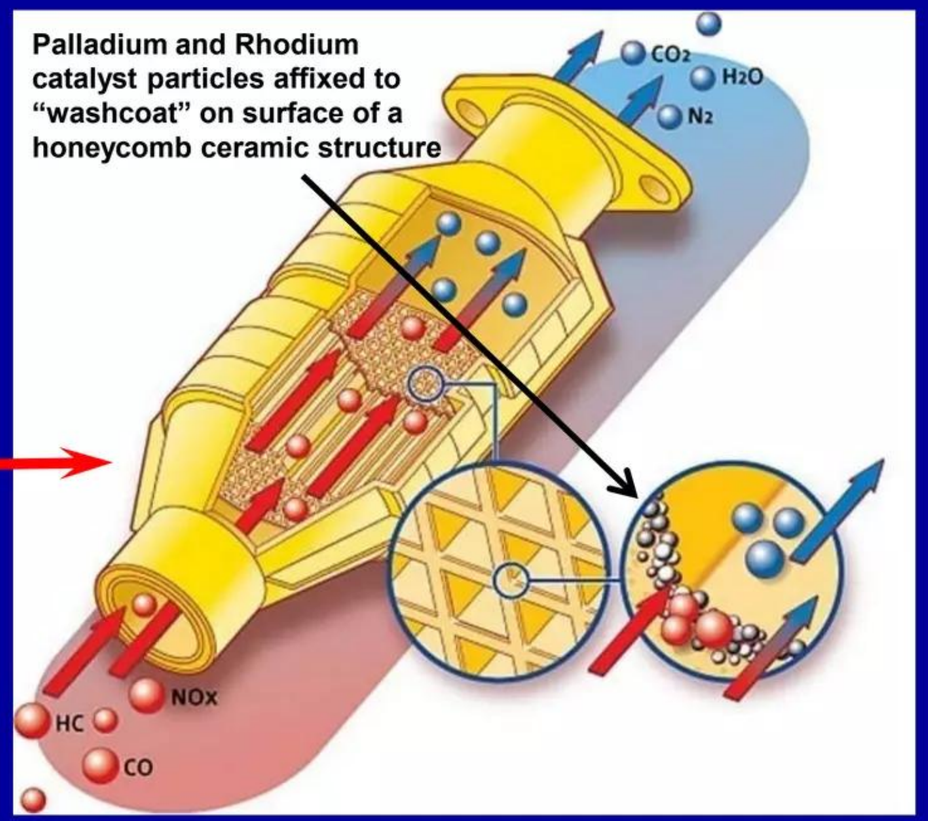
W surface: image source is D. Cirillo and V. Iorio, Laboratorio M. Ruta, 81100, Caserta, Italy

Lattice Energy LLC

Commercializing a Next-Generation Source of Safe Nuclear Energy

LENRs in catalytic converters of cars and trucks





"Led by a new paradigm, scientists adopt new instruments and look in new places … during revolutions scientists see new and different things when looking with familiar instruments in places they have looked before. It is rather as if [they] had been suddenly transported to another planet where familiar objects are seen in a different light and are joined by unfamiliar ones as well."

Thomas Kuhn, "The Structure of Scientific Revolutions ," 1962

Hot metal fragments from car's exhaust blamed in Freeway Complex Fire

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LENRs in catalytic converters of cars and trucks

Introductory remarks

- ✓ **We have investigated some intriguing published data that suggests physical processes beyond 'just chemistry' could potentially be at work inside three-way catalytic converters commonly found in modern cars and trucks**
- ✓ **Before embarking on a preliminary exploratory odyssey, we must first confess that we are not experts on isotopic literature, nor have we 'earned our stripes' by virtue of having spent long years collecting and studying such data**
- ✓ **What we do bring to the party is a deep understanding of the W-L theory, LENRs, and a new nuclear paradigm that has gradually emerged over our past five years of work**
- ✓ **We will examine some isotopic data in light of our new concepts to see whether: (a) it can also be explained by the new nuclear paradigm; (b) W-L theory of LENRs can provide helpful insights into processes underlying the data; and (c) important questions can be formulated that could potentially be answered by daring experimentalists**

Source URL =

http://www.pe.com/reports/wildfires/stories/PE_News_Local_S_complex17.44c773f.html

"Hot metal fragments from car's exhaust blamed in Freeway Complex fire"

Tuesday, June 16, 2009
By John Asbury, The Press-Enterprise

"A driver on Highway 91 in Corona probably had no idea that hot metal fragments were shooting from the vehicle's exhaust pipe last November, igniting a fire that burned 30,000 acres and damaged or destroyed more than 350 homes, fire investigators have ruled."

"Exhaust and debris from a faulty catalytic converter is likely the cause of the Freeway Complex Fire, Cal Fire/Riverside County Fire Department investigators said late Monday ... Herrera said investigators found small metal particles near the fire's origin, 15 to 30 feet off the freeway. The metal fragments, resembling BBs, are commonly found in faulty catalytic converters, he said. They can get lodged in a vehicle's exhaust system and shoot out onto the roadway. Fire officials believe multiple metal fragments at a temperature between 800 and 1,200 degrees shot out of the car and landed in the dry brush, Herrera said. Vehicles cause about 10 percent of the state's fires, said Cal Fire spokesman Daniel Berlant. Most vehicle-related fires in California are ignited by the hot metal from an exhaust pipe, Berlant said."

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LENRs in catalytic converters of cars and trucks

Catalytic converters in vehicles

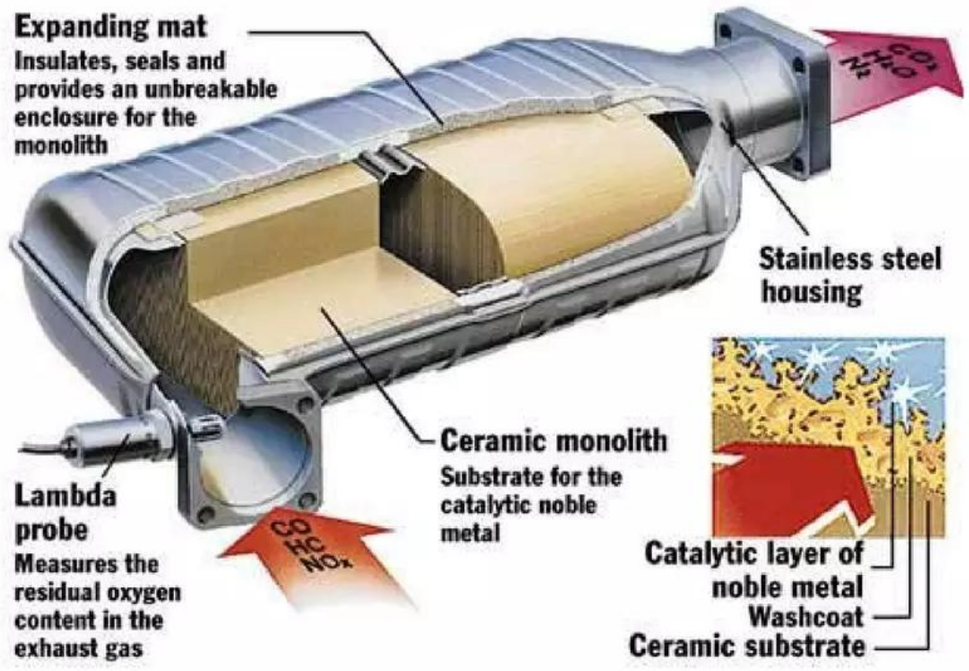
Catalytic converter: is a device used to reduce the toxicity of emissions from an internal combustion engine. First widely introduced on production automobiles in the U.S. market for the 1975 model year to comply with tightening EPA regulations on auto exhaust, [today, three-way] catalytic converters are ... most commonly used in motor vehicle exhaust systems [to remove NO, CO, and HC pollutants]. Consists of several components:

Core or substrate: is often a ceramic honeycomb in modern catalytic converters, but stainless steel foil honeycombs are used, too. The honeycomb surface increases the amount of surface area available to support the catalyst, and … is called a "catalyst support" [or also, "monolith"]

Washcoat: is used to make converters more efficient, often as a mixture of silica and alumina. The washcoat, when added to the core, forms a rough, irregular surface, which has a far greater surface area than the flat core surfaces do, which then gives the converter core a larger surface area, and therefore more places for active precious metal sites … catalyst is added to the washcoat (in suspension) before being applied to the core

Catalyst particles: most often a precious metal. Platinum is the most active catalyst and is widely used. It is not suitable for all applications, however, because of unwanted additional reactions and/or cost. Palladium and rhodium are two other precious metals used. Platinum and rhodium are used as a reduction catalyst, while platinum and palladium are used as an oxidation catalyst. Cerium, iron, manganese, and nickel ... also used

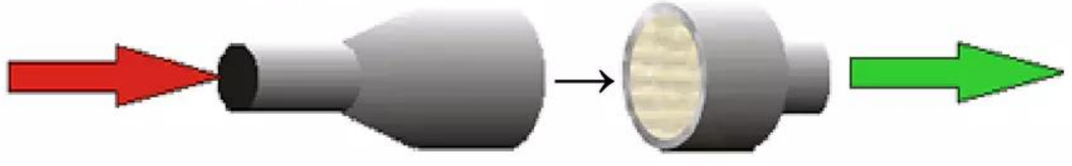
Source: Wikipedia, article titled "Catalytic Converter" as of June 12, 2010



$$2NO_x \rightarrow xO_2 + N_2$$

$$2CO + O_2 \rightarrow 2CO_2$$

$$C_xH_{2x+2} + [(3x+1)/2]O_2 \rightarrow xCO_2 + (x+1)H_2O$$



CO, HC and NO enter the catalyst → CO_2, H_2O and N_2 leave catalyst as fumes

Carbon Monoxide (CO) → Carbon Dioxide (CO_2) - gas

Hydrocarbons (HC - i.e. C_xH_{2x+2}) → Water (H_2O) + (CO_2) - vapor/gas

Nitrous Oxide (NO_x) → Nitrogen (N_2) - gas

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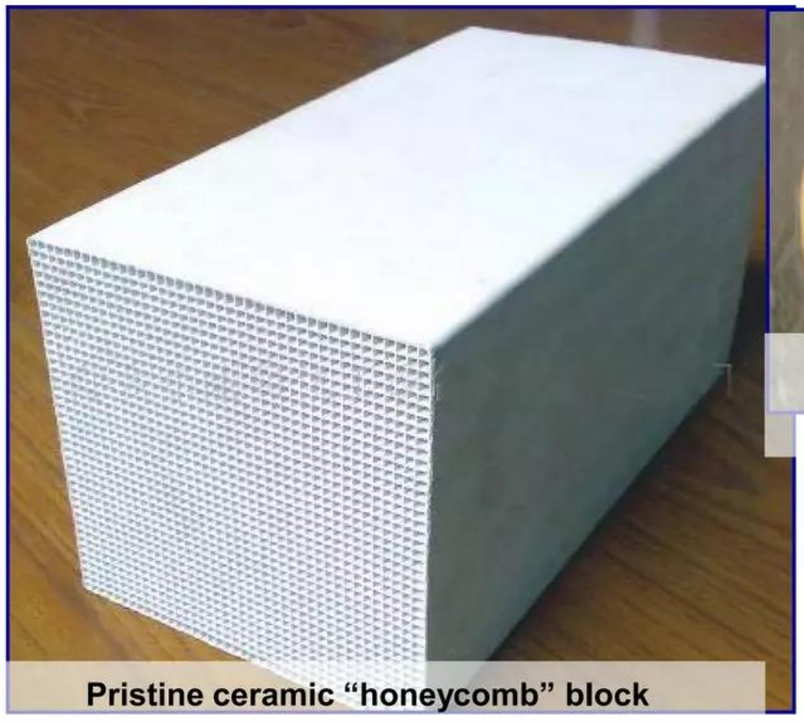
LENRs in catalytic converters of cars and trucks

Images of catalytic converters and components



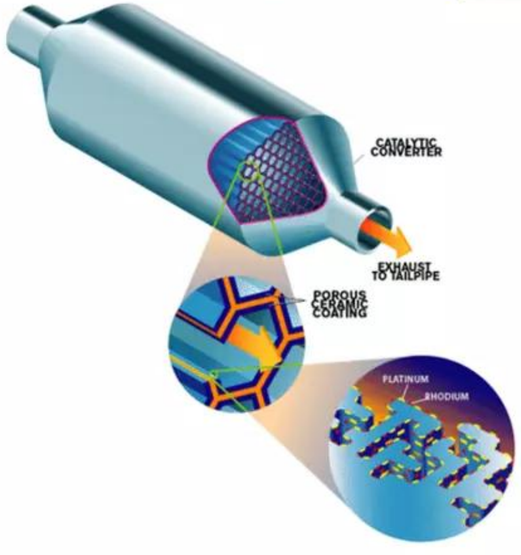
Pristine ceramic “honeycomb” block

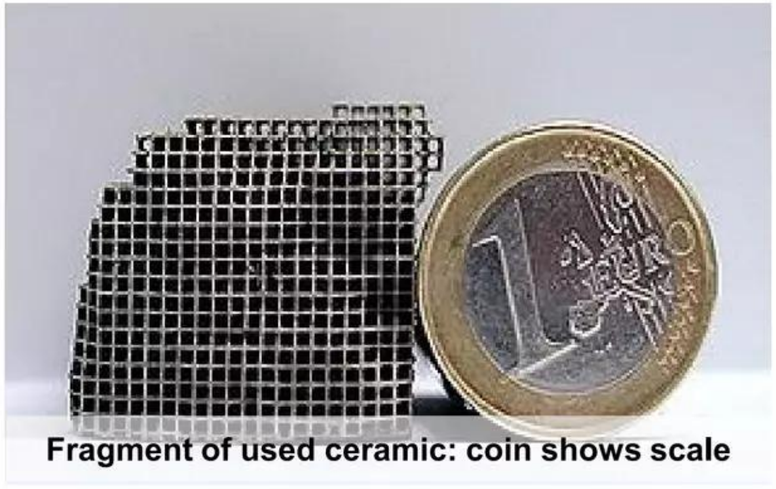
End view: metal honeycomb - BMW

Below: heated and operating

Catastrophic honeycomb melting: ceramic m.p. is ~1,400°C

Cutaway: unused “monoliths” in steel housing





Fragment of used ceramic: coin shows scale

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LENRs in catalytic converters of cars and trucks

Modern three-way catalytic converters - 1

Three-way catalytic converters:

Since 1981, three-way catalytic converters have been used in vehicle emission control systems in North America and many other countries on roadgoing vehicles. A modern catalytic converter has three simultaneous tasks:

- ✓ **Reduction of nitrogen oxides to nitrogen and oxygen:** $2NO_x \rightarrow xO_2 + N_2$
- ✓ **Oxidation of carbon monoxide to carbon dioxide:** $2CO + O_2 \rightarrow 2CO_2$
- ✓ **Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and water:** $C_xH_{2x+2} + [(3x+1)/2]O_2 \rightarrow xCO_2 + (x+1)H_2O$

These three reactions occur most efficiently when the catalytic converter receives exhaust from an engine running slightly above the stoichiometric point. This is between 14.6 and 14.8 parts air to 1 part fuel, by weight, for gasoline. The ratio for LPG, natural gas and ethanol fuels is slightly different, requiring modified fuel system settings when using those fuels. Generally, engines fitted with 3-way catalytic converters are equipped with a computerized closed-loop feedback fuel injection system employing one or more oxygen sensors, though early in the deployment of 3-way converters, carburetors equipped for feedback mixture control were used. While a 3-way catalyst can be used in an open-loop system, NO_x reduction efficiency is low. Within a narrow fuel/air ratio band surrounding stoichiometry, conversion of all three pollutants is nearly complete. However, outside of that band, conversion efficiency falls off very rapidly. When there is more oxygen than required, then the system is said to be running lean, and the system is in oxidizing condition. In that case, the converter's two oxidizing reactions (oxidation of CO and hydrocarbons) are favored, at the expense of the reducing reaction. When there is excessive fuel, then the engine is running rich. The reduction of NO_x is favored, at the expense of CO and HC oxidation

Source: Wikipedia, article titled "Catalytic Converter" as of June 12, 2010

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LENRs in catalytic converters of cars and trucks

Modern three-way catalytic converters - 2

Three-way catalytic converters (continued):

Our comments: using older technology, GM presently consumes roughly 4 grams of precious metals in every 3-way catalytic converter manufactured. Mazda recently developed a new converter design that purportedly uses 70-90% less platinum, rhodium and palladium, reducing its OEM manufacturing cost. Nissan also recently announced that they will also utilize nanotech in their converters, claiming a 50% reduction in precious metals needed. At the heart of this new development is using nano-sized ceramic particles with Pd, Pt, and/or Rh nanoparticles embedded in their surfaces; this advance simultaneously provides substantial cost-reduction as well as enabling even greater surface area for a given converter volume (which can increase efficiency and reduce exhaust-system backpressure that can rob horsepower)

Most catalytic converters do not begin to operate effectively until their internal temperatures reach ~250^{o}C - 300^{o}C; their recommended optimal operating temperatures typically range from ~650^{o}C - 870^{o}C --- most manufacturers do not recommend sustained operation at >900^{o}C, because converter ceramic structures will begin to weaken at ~1,000^{o}C - 1,100^{o}C and actually start melting at ~1,400^{o}C. Catalytic converters can melt down when too much unburned fuel is discharged from combustion chambers along with hot exhaust gases; such unburned fuel is ignited by the converter's high operating temperatures. Burning excessive amounts of raw gasoline or diesel fuel inside a converter can produce so much additional heat that ceramic supports, e.g., honeycombs, can fail and begin to melt. Catastrophic melting causes ceramic monoliths to collapse, which destroys the converter. Also, a melted ceramic converter may suddenly block exhaust flow, potentially causing irreparable engine damage

By comparison, peak temperatures at flame fronts in the center of a gasoline engine's combustion chambers can briefly reach ~1,880^{o}C - 3,034^{o}C; temperatures of hot, post-burn gases subsequently released from combustion chambers into engine exhaust manifolds typically range from ~700^{o}C - 900^{o}C. It is interesting to note that a catalytic converter is actually a *heat-producing* device; the multitude of very complex, mutually interacting precious-metal-catalyzed chemical reactions taking place inside it (some of which are specifically engineered to reduce certain atmospheric pollutants, e.g., NO_x) are net-net exothermic

Three way catalysts are capable, within a narrow range (+/- 0.05 from optimum) of exhaust stoichiometry, of simultaneously removing NO_x, HC, and CO with reasonably high efficiencies (e.g., CO>98%, HC>95%, NO_x>90%). However, input Oxygen sensors are required to maintain the very narrow range of stoichiometry that is optimal for eliminating atmospheric pollutants

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LENRs in catalytic converters of cars and trucks

What is required for LENRs to occur? - 1

In Lattice's view, key factors for initiation and operation of LENRs are as follows:

1. **Substantial quantities of Hydrogen isotopes must be brought into intimate contact with 'fully-loaded' metallic hydride-forming catalyst metals; e.g., Palladium, Platinum, Rhodium, Nickel, Titanium etc; please note that collectively oscillating, 2-D surface plasmon polariton (SPP) electrons are intrinsically present and cover the surfaces of such metals. At full loading, many-body, collectively oscillating 'patches' of protons (p^+), deuterons (d^+), or tritons (t^+) will form spontaneously at random locations scattered across such surfaces**

2. **Alternatively, delocalized collectively oscillating π electrons that comprise the outer 'covering surfaces' of fullerenes, graphene, benzene, and polycyclic aromatic hydrocarbon (PAH) molecules behave very similarly to SPPs; when such molecules are hydrogenated, they can create many-body, collectively oscillating, 'entangled' quantum systems that, within context of W-L theory, are functionally equivalent to loaded metallic hydrides**

3. **Born-Oppenheimer approximation breaks down in tiny surface 'patches' of contiguous collections of collectively oscillating p^+, d^+, and/or t^+ ions; enabling E-M coupling between nearby SPP or π electrons and hydrogen ions at these locations --- creates local nuclear-strength electric fields; effective masses of coupled electrons are then increased to some multiple of an electron at rest ($e \rightarrow e^*$) determined by required simultaneous energy input(s)**

4. **System must be subjected to external non-equilibrium fluxes of charged particles or E-M photons that are able to transfer input energy directly to many-body SPP or π electron 'surface films.' Examples of such external energy sources include (they may be used in combination): electric currents (electron 'beams'); E-M photons (e.g., emitted from lasers, walls of resonant cavities, etc.); pressure gradients of p^+, d^+, and/or t^+ ions imposed across 'surfaces'; currents of other ions crossing the 'electron surface' in either direction (ion 'beams'); etc. Such sources provide additional input energy that is required to surpass certain minimum H-isotope-specific electron-mass thresholds that allow production of ULM neutron fluxes via $e^* + p$, $e^* + d$, or $e^* + t$ weak interactions**

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LENRs in catalytic converters of cars and trucks

What is required for LENRs to occur? - 2

Table I – Key requirements for LENRs are met in catalytic converters

Key requirement for LENRs	Present somewhere inside vehicle catalytic converters? (Y/N)	Comments
Large quantities of Hydrogen isotopes	**Yes**	Hydrogen isotopes (e.g., protons, deuterons) exist in several forms; also present within many different types of organic molecules
Hydride-forming catalyst metals	**Yes**	By design, Palladium (Pd), Rhodium (Rh), and/or Platinum (Pt) are always present in the "washcoat" on interior surfaces; much LENR research on Pd
Fullerenes (CNTs), graphene, benzene, and/or PAHs (aromatics)	**Yes, virtually all of them in greater or lesser amounts**	Well established that all of these (except for graphene, which is speculative) are emitted from engine exhausts in gasoline-powered cars and diesel-powered trucks and buses (btw – nanoparticulate diesel 'soot' is well-known)
Breakdown of B-O approximation	**Yes**	Breakdown of the Born-Oppenheimer approximation is almost certain in time-varying numbers of nm-to-micron-scale 'patches' on catalyst surfaces
External energy source(s) that can transfer energy directly to surface plasmon or π electrons (so that: e $\rightarrow$ e*)	**Yes**	Hydrogen simply being present will spontaneously load aggressive hydride-forming metals such as Palladium; very modest pressure gradients inside converters (usually <<1 atm); at typical operating temperatures of 650 - 870^{o}C, interior walls of converter's metal/ceramic honeycomb 'tunnels' may function as approximately cylindrical resonant E-M cavities

<u>Note</u>: while basic requirements are met, this does not always guarantee that LENRs will occur in such systems; other important criteria must also be satisfied, such as maintaining very high local surface electric fields in nm-to-micron-scale 'spots,' as well as other sensitive details that are Lattice proprietary

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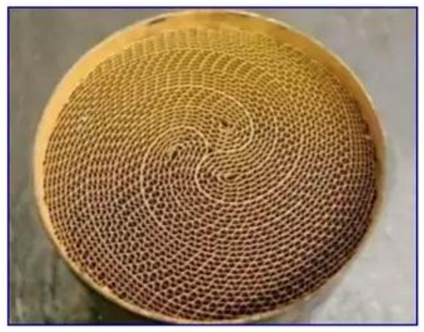
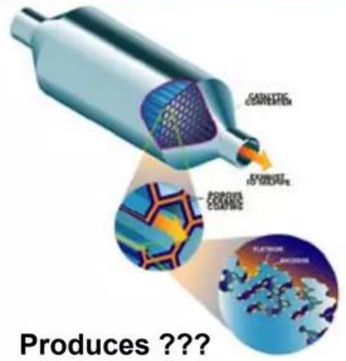
LENRs in catalytic converters of cars and trucks

Resonant electromagnetic (E-M) cavities in catalytic converters

BMW catalytic converter:



End view: metal honeycomb - BMW
Below: heated and operating



Produces ???

A common factor amongst these particular types of systems is that, on some length scale, resonant E-M cavities exist inside of all of them; they also contain hydrogen isotopes in some chemical form. That, coupled with metallic catalysts and/or aromatic rings working in concert w. thermal energy (temperature), and/or pressure, and time, can produce detectable LENR transmutation products, e.g., $\delta^{13}C$, $\delta^{15}N$ & 'new' elements, e.g., ^{4}He and ^{14}N

Photo of a 'battery' of modern coking ovens in Australia:

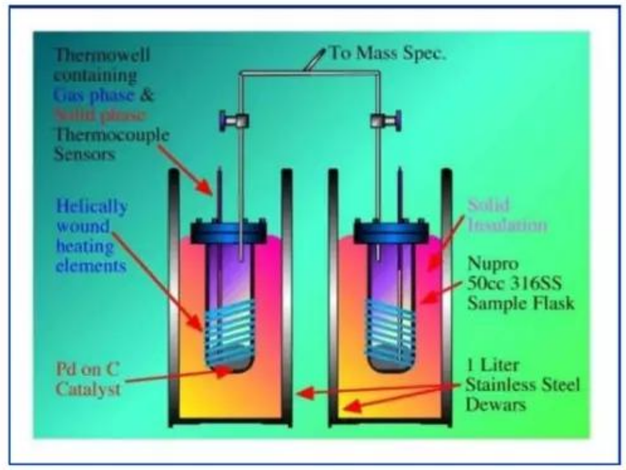
Hot coke inside an oven

2002 IAEA study: coking ovens at S. African steel plant produced >> $+\delta^{15}N$

Hokkaido U. 2008 - LENR reactor vessels:

Mizuno produced >>$+\delta\ ^{13}C$ & $^{14}N_2$ from $^{12\text{-}13}C_{14}{}^{1}H_{10}$ w. Pt

SRI 1999 - Repeated Case LENR Experiment w. D_2 gas:



McKubre produced ^{4}He from $^{2}H_2$ & $^{12\text{-}13}C$ w. Pd

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LENRs in catalytic converters of cars and trucks

What would be observed if LENRs were occurring therein?

If LENRs a la the W-L theory were occurring at non-negligible rates somewhere inside catalytic converters, one would expect to be able to observe:

- ✓ **Isotope shifts of stable isotopes comprising solids and/or gases:** ULM neutron captures on atoms would effectively deplete lower-mass isotopes and simultaneously enrich higher-mass isotopes of a given element; all other things being equal, LENRs would tend to increase $\delta^{15}N$, $\delta^{18}O$, $\delta^{13}C$, δD; and the …….
- ✓ **Appearance of 'new' stable elements in solids and/or gases that were not initially present anywhere in the system:** since LENRs commonly produce stable isotopes at '~normal' abundances, bona fide transmutation products could be peremptorily dismissed by most researchers as assumed 'contaminants' even when they are not. If thorough analyses of the composition of starting materials fails to support a strong argument for contamination, and if the appearance of such 'new elements' is highly correlated with simultaneous isotopic shifts in other elements present, then such 'new elements could potentially be LENR transmutation products. Unfortunately, most experiments and isotopic data are not decisive on this issue.

We will now review and discuss selected elemental and isotopic data covering:

- ✓ **Reactants and products involved in the three key pollutant conversion reactions**: Carbon (C), Hydrogen (H, D), Oxygen (O), and Nitrogen (N) isotopes
- ✓ **Metal hydride catalysts**: Palladium (Pd), Platinum (Pt), and Rhodium (Rh)
- ✓ **Other elements/isotopes of interest**: Osmium (Os)
- ✓ **Note**: in many cases, it may be quite difficult to distinguish between end-results of chemical fractionation processes versus LENR transmutations; we will address that important issue in our conclusions

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LENRs in catalytic converters of cars and trucks

Carbon (C) - two stable isotopes: ^{12}C, ^{13}C

- ✓ **Carbon and hydrogen are main elements found in gasoline (C/H ratio avg. 0.56 – Na et al., 2004) & diesel fuels; ^{13}C is heavy isotope**
- ✓ **In Nakagawa et al.'s (2005) abstract, regarding CH_4 they state that:**

> "**Both $\delta^{13}C$ and δD values of CH_4 in automobile exhaust increased in accordance with the model year of the engine**, probably as a result of isotope fractionation effects associated with oxidation over metal catalysts in the catalytic converter of modern vehicles. **Thus, CH_4 emissions from recent automobiles exhibit conspicuous ^{13}C and D enrichment compared to the flux from other major anthropogenic sources**, such as natural gas leakage, landfills and rice paddies. Using average $\delta^{13}C$ and δD CH_4 values estimated for local sources, automobile exhaust in Nagoya, Japan, was determined to contribute significant amounts (up to 30%) of CH_4 to the troposphere in the study area."
>
> On pp. 731 they remark,"… However**, the range of measured δD CH_4 values from exhaust gases is difficult to explain entirely by δD variation in gasoline.** It is also plausible to attribute some of the variation in δD CH_4 values to fractionation associated with removal of CH_4 from exhaust by catalytic converters. …. A strong inverse relationship between the log of CH_4 content and $\delta^{13}C$ and δD values of CH_4 in automobile exhaust (Figs. 4 and 5) **suggests that ^{13}C- and D-enrichment in CH_4 results from isotopic fractionation effects associated with a specific oxidation process, most probably catalytic oxidation over a metal surface.**

- ✓ **<u>Comments</u>: while not conclusive by any means, their data is consistent with LENR ULM neutron capture on Carbon-12 and Hydrogen atoms somewhere inside catalytic converters of two gasoline-powered cars in this study; air sampled in Nagoya, Japan**

<u>For example, please see the following, which is worth reading</u>:

*F. Nakagawa et al., "Automobile exhaust as a source of ^{13}C- and D-enriched atmospheric methane in urban areas," Organic Geochemistry **36** pp. 727 - 738 (2005)*

<u>Also see</u>:

*U. Tsunogai et al., "An updated estimation of the stable carbon and oxygen isotopic compositions of automobile CO emissions," Atmospheric Environment **37** pp. 4901 - 4910 (2003)*

<u>In this also interesting paper; they state,</u>

*"While the dependence on the automobile manufacturer is little, **each automobile equipped with a functional catalytic converter exhibits a large temporal $d^{13}C$ and $d^{18}O$ variation. They tend to show ^{13}C and ^{18}O enrichment in accordance with the reduction of CO in the exhaust**, suggesting that the functional catalytic converter in engines enhances the $d^{13}C$ and $d^{18}O$ values of CO from tail pipes through a **kinetic isotope effect during CO destruction."***

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LENRs in catalytic converters of cars and trucks

Hydrogen (H) - two stable isotopes: ^1H, ^2H = D = deuterium - 1

- ✓ **Hydrogen is one of the principal elements found in gasoline and diesel vehicle fuels; ^2H (Deuterium) is heavy isotope: nat. ab. ^1H = 99.985%; ^2H (D; deuterium) = 0.015%**
- ✓ **Preprint of a new paper by Vollmer et al. (2010) has recently become available; in contrast to post-catalytic converter increases in δD CH_4 and δD CO reported by Nakagawa (2005) and Tsunogai (2003), it actually reports decreases in δD H_2**
- ✓ **Vollmer et al.'s experiment involves a single automobile engine using gasoline or methane (CH_4) fuel in which they measure δD H_2 (molecular hydrogen) going into and coming out of a 3-way catalytic converter (TWC); note that Nakagawa and Tsunogai studies sampled larger numbers of vehicles**
- ✓ **They report significant decreases in δD H_2 in a TWC exhaust stream compared to δD H_2 in the corresponding input stream and propose a "H_2 - H_2O equilibration" to explain the results**
- ✓ **Please note that their TWC contained only Pd and Rh; no Pt was said to be present --- this differs from the other two studies in which all 3 catalysts were present in converters**

Important point:

Astronomers and astrophysicists believe that virtually all of the deuterium left in the Universe today is primordial; i.e., nucleosynthesis of D from H has been essentially negligible since the Big Bang. That being the case, chemists have in turn assumed ipso facto that ***all changes in dD, up or down, must be caused by chemical fractionation***

Re Deuterium's primordial nature see Wikipedia:

Article, "Big Bang nucleosynthesis – there are no known post-Big Bang processes which would produce significant amounts of deuterium … hard to come up with another process that would produce deuterium via nuclear fusion … Producing deuterium by fission is also difficult … problem here … is that deuterium is … subject to nuclear processes …that … result … in … absorption of … nuclei or … release of free neutrons or alpha particles."

Please see:

M. Vollmer et al., "Molecular hydrogen (H_2) emissions and their isotopic signatures (H/D) from a [single] motor vehicle: implications on atmospheric H_2", Atmospheric Chemistry and Physics Discussions ***10*** *pp. 3021 - 3051 (2010)*

Free 30-page preprint is available online at:

http://www.atmos-chem-phys-discuss.net/10/3021/2010/acpd-10-3021-2010-print.pdf

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LENRs in catalytic converters of cars and trucks

Hydrogen (H) - two stable isotopes: ^1H, ^2H = D = deuterium - 2

✓ **Vollmer et al. (2010) is complex and contains a great deal of data. It is worth examining because it breaks new ground in that they measure, "pre- and post-catalytic H_2 concentrations and - to our knowledge for the first time - H/D signatures under variable engine and fuel settings." From the abstract,**

"H_2 and CO concentrations were largely reduced downstream of the three-way catalytic converter (TWC) compared to levels upstream, and showed a strong dependence on the air-fuel ratio (expressed as lambda, λ). The **isotopic composition of H_2 ranged from δD=–140‰ to δD=–195‰ upstream of the TWC but these values decreased to –270‰ to –370‰ after passing through the TWC**. Post-TWC δD values for the fuel-rich range showed a strong dependence on TWC temperature with more negative δD for lower temperatures**. These effects are attributed to a rapid temperature-dependent H-D isotope equilibration between H_2 and water (H_2O).** In addition, post TWC δD in H_2 showed a strong dependence on the fraction of removed H_2, suggesting isotopic enrichment during catalytic removal of H_2 with enrichment factors (ε) ranging from –39.8‰ to –15.5‰ depending on the operating mode. **Our results imply that there may be considerable variability in real-world δD emissions from vehicle exhaust, which may mainly depend on TWC technology and exhaust temperature regime.** This variability is suggestive of a δD from traffic that varies over time, by season, and by geographical location. An earlier-derived integrated pure (end-member) δD from anthropogenic activities of –270‰ (Rahn et al., 2002) can be explained as a mixture of mainly vehicle emissions from cold starts and fully functional TWCs, but enhanced δD values by >50‰ are likely for regions where TWC technology is not fully implemented. **Our results also suggest that a full hydrogen isotope analysis on fuel and exhaust gas may greatly aid at understanding process-level reactions in the exhaust gas, in particular in the TWC**."

<u>On pp. 3024 they state that</u>:

"Automobile traffic is believed to dominate anthropogenic H_2 emissions."

<u>On pp. 3026 they state</u>:

"In addition to the chemical species discussed here, measurements in the exhaust were made of O_2, nitrogen oxides (NO_x, NO, NO_2), CH_4, short-chained hydrocarbons (C_2–C_4), some aromatics, total hydrocarbons (HC), water (H_2O), N_2O, and sulphur dioxide (SO_2)."

<u>But then on pp. 3030 they admit that they really DID NOT MEASURE δD in exhaust output water because H_2O was NOT collected; instead, they then went on to make an assumption</u>:

"*To bring the calculated equilibrium values and our results to the same scale, information on the D of the exhaust H_2O is necessary.* ***This can in principle be obtained by isotope analysis of the exhaust H_2O, but unfortunately H_2O was not collected.*** *Alternatively,* ***assuming that H_2O is the dominant hydrogen pool in exhaust, its D could be approximated by that of the gasoline,*** *which is estimated at –80‰ to –110‰ vs. VSMOW (Schimmelmann et al., 2006). We therefore convert the theoretical results (Bottinga, 1969) to the VSMOW scale by shifting them by these offsets (Fig. 2)****. Our measured D values of the fuel-rich post-TWC samples then agree well with the prediction at the corresponding temperatures****."*

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LENRs in catalytic converters of cars and trucks

Hydrogen (H) - two stable isotopes: ^1H, ^2H = D = deuterium - 3

- ✓ **While Vollmer et al. (2010) have collected very interesting data, their analysis of it raises questions. For example, to explain observed decreases δD H_2, on pp. 3033 they propose, "… the presence of two separate isotope effects, a H_2 - H_2O temperature-dependent isotope equilibration, and a kinetic isotope fractionation during H_2 removal."**

- ✓ **Unfortunately, they later admitted that H_2O (the other chemical species involved in their proposed "H_2 - H_2O isotope equilibration" process) was not collected and measured. That being the case, how can they conclude that their proposed fractionation process was the best explanation for such data when δD was not measured in both output chemical species that are supposed to be exchanging hydrogen isotopes: H_2 *and* H_2O? In not measuring D in both, they cannot say definitively where the 'missing' Deuterium 'went' in their experiment**

- ✓ **Comments: Vollmer et al. express some discomfort with parts of their analysis (see examples over to the right). Underneath, they may well realize that if δD is not measured in *every* chemical species present in the output exhaust, it could be that δD actually went up net-net across all chemical species. On the other hand, if input D went *down* and if it did not 'migrate' into other *unmeasured* chemical species (e.g., H_2O) and was not retained somewhere in the TWC, it would imply that some D had been destroyed; importantly, only nuclear reactions can do that**

On pp. 3033 they state that:

"This enhances the confidence that these samples may not have been altered significantly by any potential contamination."

On pp. 3033 they also state:

*"While our observations can be fully explained by these two mechanisms, **it is the simultaneous appearance of both effects in our samples that remains puzzling**. Since H_2 removal is largely bound to the TWC surface, this is the place where the **kinetic isotope fractionation is believed to occur during the 100 msec residence time in the TWC.** The H_2 - H_2O equilibration step must, however, also mainly occur in the TWC. This is obvious from the **strong isotopic depletion when comparing post-TWC with corresponding pre-TWC isotope results.** It is unlikely that the H_2 - H_2O isotope equilibration would occur downstream of the TWC, as this would remove the clear isotopic signatures related to fractionation during removal. It is more likely that the equilibrium fractionation sets the general D value at the TWC temperature, and subsequently **there is a kinetic process that removes H_2 with the stated kinetic isotope effect."***

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LENRs in catalytic converters of cars and trucks

Oxygen (O) - three stable isotopes: ^{16}O, ^{17}O, ^{18}O - 1

- ✓ **Oxygen is a principal reactant in the burning of gasoline and diesel fuels in combustion chambers of IC engines; two heavy isotopes: nat. ab. ^{16}O = 99.762%; ^{17}O = 0.038%; ^{18}O = 0.200%; air going into engine ~comprises 78.1% N_2; 20.1% O_2; 1.8% other**
- ✓ **Tsunogai et al. (2003 – cited) further stated in their paper that,**

"While the $\delta^{13}C$ and $\delta^{18}O$ values of recent gasoline automobiles coincide well with the isotopic compositions of source CO in present trunk road atmosphere estimated in this study, **those are +4–+6‰ ($\delta^{13}C$) and +1–+3‰ ($\delta^{18}O$) higher than those reported previously and also those emitted from old, non-catalyst automobiles** determined in this study. **Recent improvements in functional catalytic converters have enhanced and will enhance the $\delta^{13}C$ and $\delta^{18}O$ values of CO from automobiles**."

- ✓ **According to Affek & Eiler, CO_2 of mass 47 is mainly $^{13}C^{18}O^{16}O$; they were somewhat surprised by their results when on pp. 6,**

"**We expected CO_2 produced in car exhaust to have a Δ_{47} value close to zero** as was observed in one of two car exhaust samples measured by Eiler and Schauble (2004), because it is generated by combustion at temperatures of at least 900 ^{o}C**. Instead, the measured Δ_{47} value of 0.41 ± 0.03 ‰** is consistent with the equilibrium distribution of isotopologues at 195 ± 15 ^{o}C (Wang et al., 2004). **We suggest this reflects isotopic re-equilibration of CO_2 in the car exhaust stream, mediated by exchange with water**, as detailed in the following paragraph…"

"**Isotopic exchange among isotopologues of pure gaseous CO_2 is slow relative to the timescales of exhaust production and emission, even at temperatures of up to several hundred degree Celsius.** However, in the **presence of condensed water** (at near ambient temperatures) **or water vapor** (at elevated temperatures), **re-equilibration of CO_2 isotopologues is far faster, presumably facilitated by CO_2 - H_2O exchange."**

Please see: *H. Affek and J. Eiler, "Abundance of mass 47 CO_2 in urban air, car exhaust, and human breath," Geochimica at Cosmochimica Acta **70** pp. 1 - 12 (2006)*

Free copy of full paper available online:

http://earth.geology.yale.edu/~hpa3/Affek%20and%20Eiler%202006%20car%20exhaust%2047.pdf

On pp. 6, they further explain that:

*"In this case, CO_2 re-equilibration must be accompanied by changes in its $\delta^{18}O$ value, by an amount that depends on the relative amounts of CO_2 and H_2O, and the temperature of exchange. The temperature dependency of oxygen isotopic fractionation between CO_2 and liquid H_2O is summarized in Friedman and O'Neil (1977). **Data from Figs. 5 and 6 of that reference up to 300 ^{o}C were used to estimate fractionation at higher temperatures by fitting a second order polynomial of 1/T (K) and extrapolating to high temperature by forcing the fractionation factor to zero at 1/T = 0, giving a correlation of R^2 = 0.999."***

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LENRs in catalytic converters of cars and trucks

Oxygen (O) - three stable isotopes: ^{16}O, ^{17}O, ^{18}O - 2

- ✓ **Affek & Eiler 's motivation in measuring mass 47 CO_2 (rare, isotopically heavy Carbon Dioxide) was to develop a new methodology (using the so-called Δ_{47} anomaly) that could reliably distinguish between CO_2 that was emitted by "high temperature processes, such as combustion, vs. low temperature processes, such as [biological] respiration."**

- ✓ **Affek & Eiler obtained some interesting data: first, they discovered that Δ_{47} in auto exhaust was nonzero, which surprised them, given that "it is generated by combustion at temperatures of at least 900°C."**

- ✓ **Second, they realized that the presumed chemical "isotopic exchange" mechanism had to operate very rapidly, given relatively short residence times (under ~100 msec - Vollmer et al. 2010) of reactants and products inside catalytic converters and exhaust systems. That issue lead them to propose a temperature dependent "CO_2 - H_2O [isotope] exchange" process that they believed could account for the observed fractionation during the short time available for such a kinetic process to take place**

- ✓ **Third, "Samples of CO_2 from human breath were found to have $\delta^{13}C$ and $\delta^{18}O$ values broadly similar to those of car exhaust-air mixtures, -22.3 ± 0.2 and 34.3 ± 0.3‰, respectively, and Δ_{47} of 13.4 ± 0.4‰. [by contrast] Δ_{47} in *human breath* was 0.76 ± 0.03‰, similar to that of ambient Pasadena air and higher than that of the car exhaust signature."**

<u>On pp. 7 they go on to say that</u>:

"We conclude that ***both the Δ_{47} and $d^{18}O$ values of CO_2 in car exhaust can be understood as a consequence of isotopic re-equilibration between CO_2 and H_2O in the exhaust stream, quenching at ca. 200°C****. The exhaust does not cool to such a temperature until it exits the catalytic converter, and so presumably this quenching occurs between the downstream side of the catalytic converter and the tail pipe ... Alternatively, both Δ_{47} and $d^{18}O$ values in the car exhaust may also be explained by only partial exchange with exhaust water at a lower temperature … In an attempt to resolve these two alternative interpretations, we sampled exhaust gas at depths of 15 - 40 cm within the tail pipe (Table 2). These measurements were performed a year after the above data were obtained, when gasoline composition was potentially different … Although inconclusive, these results support the interpretation that CO_2 is homogeneously reset to ~200°C…* ***It is conceivable that cars of different engine designs and possibly even different driving conditions would have different re-equilibration temperatures and therefore different values for both Δ_{47} and $d^{18}O$ …"***

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LENRs in catalytic converters of cars and trucks

Oxygen (O) - three stable isotopes: ^{16}O, ^{17}O, ^{18}O - 3

- ✓ **On page 8, Affect & Eiler make an intriguing comment in a discussion of their Δ_{47} measurements in human breath,**

  "Eiler and Schauble (2004) observed a preliminary value for Δ_{47} in human breath of 0.66‰, slightly lower than the value observed in the current study (0.74‰). The current value of 0.74‰ is closer to, though still slightly lower than the value predicted based on equilibrium with water at body temperature (0.89‰ predicted for 37°C, Wang et al., 2004), **suggesting that Δ_{47} values of human breath, and possibly other respiration processes, are affected by an additional unknown process and do not carry a pure equilibrium signal.** The key for our purposes, however, is that Δ_{47} in breath is within measurement error of that in ambient air samples and differs significantly from that of car exhaust.."

- ✓ **They finally conclude that,**

  "Thus, the isotopic index Δ_{47} can be used to distinguish CO_2 from combustion sources vs. respiration sources (and other sources involving low-temperature isotopic equilibration with water)."

- ✓ **<u>Comments</u>: again, while their hypothesized CO_2 - H_2O chemical fractionation mechanism is plausible and is consistent with the data, we believe LENR ULM neutron captures on Carbon & Oxygen atoms at scattered <micron locations on interior working surfaces of the TW catalytic converter might provide yet another alternative explanation for the isotope shifts observed in $\delta^{13}C$ and $\delta^{18}O$, and in Δ_{47}**

<u>For a concise explanation of the Δ_{47} isotope anomaly and Eiler's latest thinking on a brand new area of isotope studies please see recent review paper</u>:

*J. Eiler, "Clumped isotope geochemistry --- The study of naturally-occurring, multiply-substituted isotopologues," Earth and Planetary Science Letters **262** pp. 309 - 327 (2007)*

<u>Free copy of full paper available online at</u>:

http://courses.washington.edu/oc583/Papers/Eiler07.pdf

Table 2 (adapted from Affek & Eiler (2006) pp. 3

Isotopic composition of "tail pipe CO_2" collected at depths of 15 - 40 cm in the tail pipe of a Ford Taurus 2001 (average ± 1σ , n = 5 - 6)

Depth in tail pipe (cm)	$\delta^{13}C_{VPDB}$(‰)	$\delta^{18}O_{VSMOW}$(‰)	Δ_{47} (‰)
15	-25.168	29.737	0.460
20	-24.363	30.624	0.346
25	-24.858	29.993	0.380
30	-24.911	29.893	0.341
40	-25.026	30.374	0.361

All data are corrected for N_2O abundance
Samples were collected in June 2005

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LENRs in catalytic converters of cars and trucks

Nitrogen (N) - two stable isotopes: ^{14}N, ^{15}N - 1

- ✓ **Outside air coming into an internal combustion engine is a gaseous mixture consisting of approximately: 78.1% Nitrogen as N_2; 20.1% Oxygen as O_2; 0.1% Argon as Ar; 0.03% Carbon dioxide as CO_2; as well as trace amounts of methane as CH_4, Neon as Ne, and Helium as He**

- ✓ **Results of Google searches for papers about measurements of Nitrogen isotopes ($\delta^{15}N$) in vehicle exhaust NO_x were a little puzzling because, in contrast to other elements, there seems to be much smaller numbers of publications. While this could be a result of our lacking long years of familiarity with this literature, new papers such as Hastings (2010) paint a murky picture of the current state of knowledge about sources and spatial distribution of ^{15}N; Hastings' remarks below are telling,**

> "The lifetime of tropospheric NO_x against conversion to HNO_3 in the modern atmosphere is on the order of less than a day to about a week depending upon latitude and altitude … current state of knowledge of the isotopic signatures associated with NO_x sources is weak ... isotopic signatures of NO_x emitted from 'natural' soils, biomass burning, and North American fossil fuels combustion are currently unknown. There is a clear need to better quantify and/or quantify for the first time the isotopic signatures associated with these NO_x sources."

Please see – very worthwhile to read:

*M. Hastings, "Evaluating source, chemistry and climate change based upon the isotopic composition of nitrate in ice cores," IOP Conf. Series: Earth and Environmental Science **9** pp. 012002 (2010)*

Free copy available online at:

http://iopscience.iop.org/1755-1315/9/1/012002/pdf/1755-1315_9_1_012002.pdf *[6 pages]*

Quoting further:

"The relatively short lifetime of NO_x (and HNO_3) and the temporal and spatial variability of emissions sources result in a very non-uniform distribution of NO_x, making it difficult to understand the variability of NO_x with measurements alone ... most observations are from North America and Europe … It has been difficult to prove a direct connection between $\delta^{15}N$ of NO_3 - and NO_x sources for several reasons …after the nitrate is deposited it can undergo biological processing … isotopic signatures of atmospheric nitrate sources are not well quantified."

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LENRs in catalytic converters of cars and trucks

Nitrogen (N) - two stable isotopes: ^{14}N, ^{15}N - 2

- ✓ **That having been said, there have been a number of publications in which increases in $\delta^{15}N$ have been linked to vehicle exhaust emissions. In an interesting paper often cited by others, Saurer et al. (2004) concluded,**

  "NO_2-incorporation close to the motorway was reflected in the tree rings as increased N-concentration and $\delta^{15}N$ values after 1965 … simultaneous occurrence of high N-concentrations and high $\delta^{15}N$ values gives us a good means to reliably detect the car emissions … As the increased N-values are only found at the site closest to the motorway, this signal can be unambiguously related to the NO_2 emitted by the traffic."

- ✓ **While $\delta^{15}N$ values are quite variable, the conclusions of Saurer et al. are essentially echoed by others (see right)**

- ✓ **<u>Comments</u>: published literature provides evidence that values of $\delta^{15}N$ tend to increase in vehicle exhaust gas in comparison to ambient input air. While such data can be explained by chemical fractionation processes, it is also consistent with LENR ULM neutron capture on ^{14}N**

<u>Please see</u>:

M. Sauer, P. Cherubini, M. Ammann, B. De Cinti, and R. Siegwolf, "First detection of nitrogen from NO_x in tree rings: a $^{15}N/^{14}N$ study near a motorway," Atmospheric Environment ***38*** *pp. 2779 - 2787 (2004)*

<u>Free copy available online at</u>:

http://www.wsl.ch/staff/paolo.cherubini/saureretalatmenv.pdf

<u>Also see</u>:

M. Savard, C. Begin, and A. Smirnoff, "Tree-ring Nitrogen isotopes reflect anthropogenic NO_x emissions and climatic effects," Environmental Science & Technology ***43*** *pp. 604 - 609 (2009)*

E. Elliott, C. Kendall, S. Wankel, D. Burns, E. Boyer, K. Harlin, D. Bain, and T. Butler, "Nitrogen isotopes as indicators of NO_x source contributions to atmospheric nitrate deposition across Midwestern and Northeastern United States," Environmental Science & Technology ***41*** *pp. 7661 - 7667 (2007)*

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LENRs in catalytic converters of cars and trucks

Palladium (Pd) - six stable isotopes: ^{102}Pd, ^{104}Pd, ^{105}Pd, ^{106}Pd, ^{108}Pd, ^{110}Pd - 1

- ✓ **Palladium is one of three principal metallic catalysts used in most converters: nat. ab. ^{102}Pd = 1.02%; ^{104}Pd = 11.14%; ^{105}Pd = 22.33%; ^{106}Pd = 27.33%; ^{108}Pd = 26.46%; ^{110}Pd = 11.72%; ^{103}Pd - unstable, h.l. = 17 days, decays via electron capture to stable ^{103}Rh; ^{107}Pd - unstable; h.l. = 6.7 x 10^6 yrs, β^- decays to stable ^{107}Ag; and ^{109}Pd - unstable, h.l. = 13.7 hrs, β^- decays to stable ^{109}Ag; ^{105}Pd also has very small cross-section for α-decay to ^{101}Ru on ULMN capture**

- ✓ **<u>Comments</u>: of six stable isotopes, ^{105}Pd has the largest neutron capture cross-section = ~22 barns (b) at thermal energies, then ^{102}Pd = ~3.2 b, and ^{107}Pd = ~1.8 b; other stable Pd isotopes have smaller capture cross-sections; ULMN c-s are 10^3x - 10^6x larger!**

- ✓ **All other things being equal, at low rates of LENR ULM neutron production where only 1 - 2 neutrons are captured per 'lucky' Pd atom, there would be tendency to *deplete* ^{105}Pd, ^{102}Pd, and ^{107}Pd (if present) and *<u>enrich</u>* ^{106}Pd, ^{103}Pd (which then decays via e.c. to stable ^{103}Rh if ULM neutron is not captured fast enough) and ^{108}Pd. Unsurprisingly, such tendencies are reflected in nat. abundances**

- ✓ **<u>Key point</u>: to the best of our knowledge, no one has ever published a detailed and *exhaustive* analysis of <u>all</u> Palladium isotopes present inside a <u>used</u> catalytic converter; nor has there been such an analysis of Pd particles emitted in exhausts, either**

<u>Emission of small Pd, Pt, and Rh particles from vehicle exhausts is well known; please see</u>:

*A. Dubiella-Jackowska, Z. Polkowska, and J. Namiesnik, "Platinum Group elements: A challenge for environmental analytics," Polish Journal of Environmental Studies **16** pp. 329 – 345 (2007)*

<u>Free copy of this review paper online at:</u>

http://www.pjoes.com/pdf/16.3/329-345.pdf

*S. Rauch, H. Hemond, C. Barbante, M. Owari, G. Morrison, B. Peucker-Ehrenbrink, and U. Wass, "Importance of automobile exhaust emissions for the deposition of Platinum, Palladium, and Rhodium in the Northern Hemisphere," Environmental Science & Technology **39** pp. 8156 - 8162 (2005)*

*J. Whiteley, "Seasonal variability of Platinum, Palladium, and Rhodium (PGE) levels in road dusts and roadside soils of Perth, Western Australia," Water, Air & Soil Pollution **160** pp. 77 - 93 (2005)*

*S. Rauch, M. Lu, and G. Morrison, "Heterogeneity of Platinum Group metals in airborne particles," Environmental Science & Technology **35** pp. 595 - 599 (2000)*

*M. Moldovan, M. Milagros-Gomez, and M. A. Palacios, "Determination of Platinum, Rhodium, and Palladium in car exhaust fumes," Journal of Analytical Atomic Spectrometry **14** pp. 1163 - 1169 (1999)*

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LENRs in catalytic converters of cars and trucks

Palladium (Pd) - six stable isotopes: ^{102}Pd, ^{104}Pd, ^{105}Pd, ^{106}Pd, ^{108}Pd, ^{110}Pd - 2

- ✓ **<u>Second point</u>: we are presently unaware of any published work which provides a plausible explanation for effective chemical fractionation of Palladium or Platinum isotopes. That being the case, any significant isotopic shifts from natural abundances observed in well-used Pd or Pt from catalytic converters (and/or detection of traces of "new elements,' e.g., Ag, Ru, Au, etc.) on interior working surfaces and/or in particles emitted from exhausts could potentially represent a telltale 'signature' of nuclear processes taking place, namely LENRs and ULM neutron-capture on Pd or Pt atoms inside catalytic converters**

- ✓ **<u>Comments</u>: in that regard, a very interesting and perhaps important paper by Kanitsar et al. (2003) is cited at right. The purpose of this study was to measure, "… Pt, Pd, and Rh concentration levels … in Viennese aerosol … emitted from car catalysts."**

- ✓ **Of note is Fig. 1, where they plot values of $^{194}Pt/^{196}Pt$ vs. $^{195}Pt/^{196}Pt$ for field samples, which happen to fall along a straight line connecting an "isotopically enriched spike sample" (97.25% ^{196}Pt) with the x, y coordinate for the standard natural abundance ratios of these particular Pt isotopes. They then plot the same graph for Pd with $^{106}Pd/^{108}Pd$ vs. $^{105}Pd/^{108}Pd$ for field samples, which also fall neatly along a straight line connecting an "enriched spike sample" (98.25% ^{106}Pd) with the x, y coordinate for the standard natural abundance ratios of these Pd isotopes. Importantly, field samples are not distributed randomly along the lines, nor are they clustered close to the natural abundance values**

<u>In this interesting paper, Pd and Pt isotopes are analyzed in small particles emitted from vehicle exhausts</u>:

*K. Kanitsar, G.Koellensperger, S. Hann, A. Limbeck, H. Puxbaum, and S. G. Stingeder, "Determination of Pt, Pd, and Rh by inductively coupled plasma sector field mass spectroscopy (ICP-SFMS) in size-classified urban aerosol samples," Journal of Analytical Atomic Spectrometry **18** pp. 239 - 246 (2003)*

<u>Free copy available online at</u>:

http://www.rsc.org/delivery/_ArticleLinking/DisplayArticleForFree.cfm?doi=b212218a&JournalCode=JA

<u>Regarding Fig. 1 in Kanitsar et al. above, for comparison purposes see Fig.2 in</u>:

*E. Rudolph, A. Limbeck, and S. Hann, "Novel matrix separation – on-line pre-concentration procedure for accurate quantification of palladium in environmental samples by isotope dilution inductively coupled plasma sector field mass spectrometry," Journal of Analytical Atomic Spectrometry **21** pp. 1287 - 1293 (2006)*

See Figs. 1 and 2 on the next slide ……..

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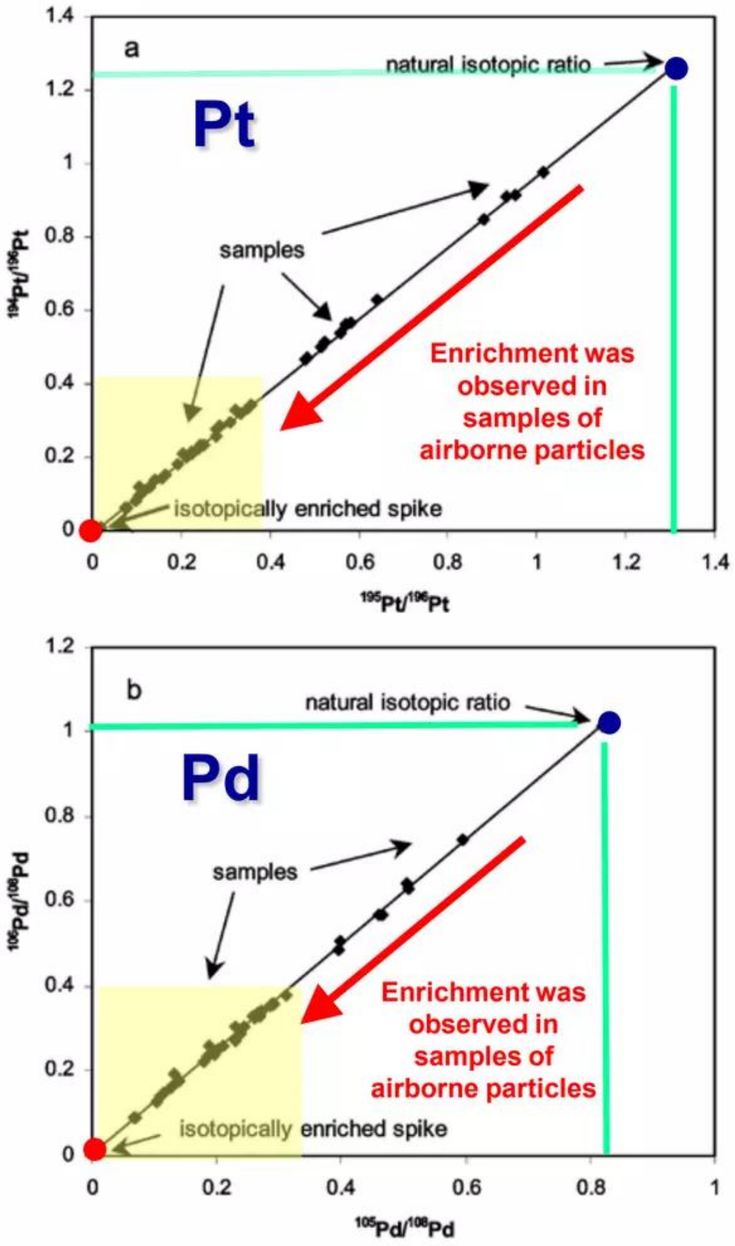
LENRs in catalytic converters of cars and trucks

Palladium (Pd) - six stable isotopes: ^{102}Pd, ^{104}Pd, ^{105}Pd, ^{106}Pd, ^{108}Pd, ^{110}Pd - 3



Note: green lines show x,y intercept of ratios of standard natural abundances

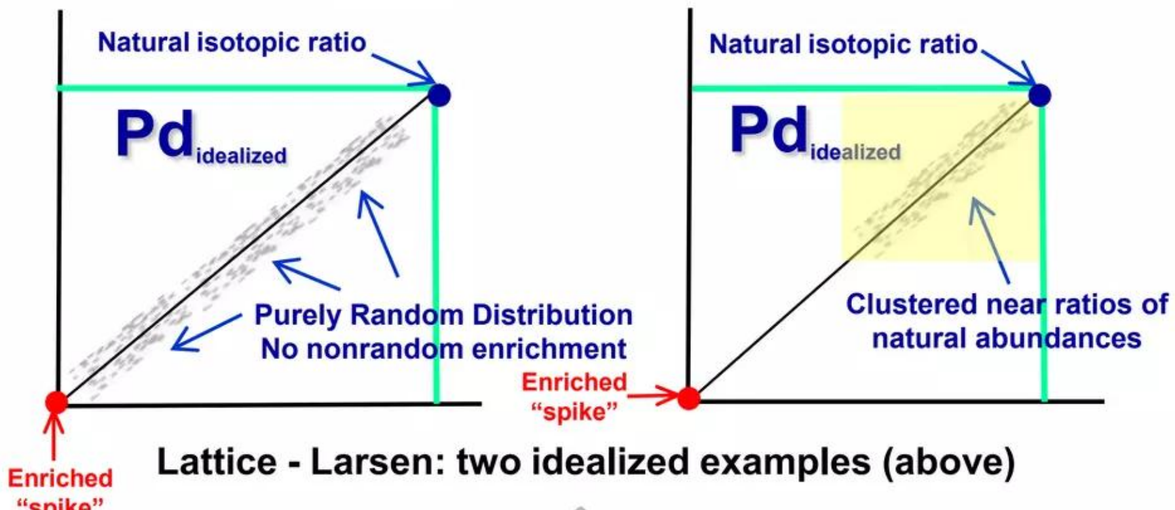
Region of enrichment highlighted in yellow

Pt "spike" was 97.25% ^{196}Pt from Russian Federation

Pd "spike" was 98.25% ^{106}Pd from Russian Federation

Pt and Pd samples in adapted Fig. 1 to left show signs of enrichment

Note: x and y axes are reversed for Pd on Fig. 1 to left versus Fig. 2 to right



Lattice - Larsen: two idealized examples (above)

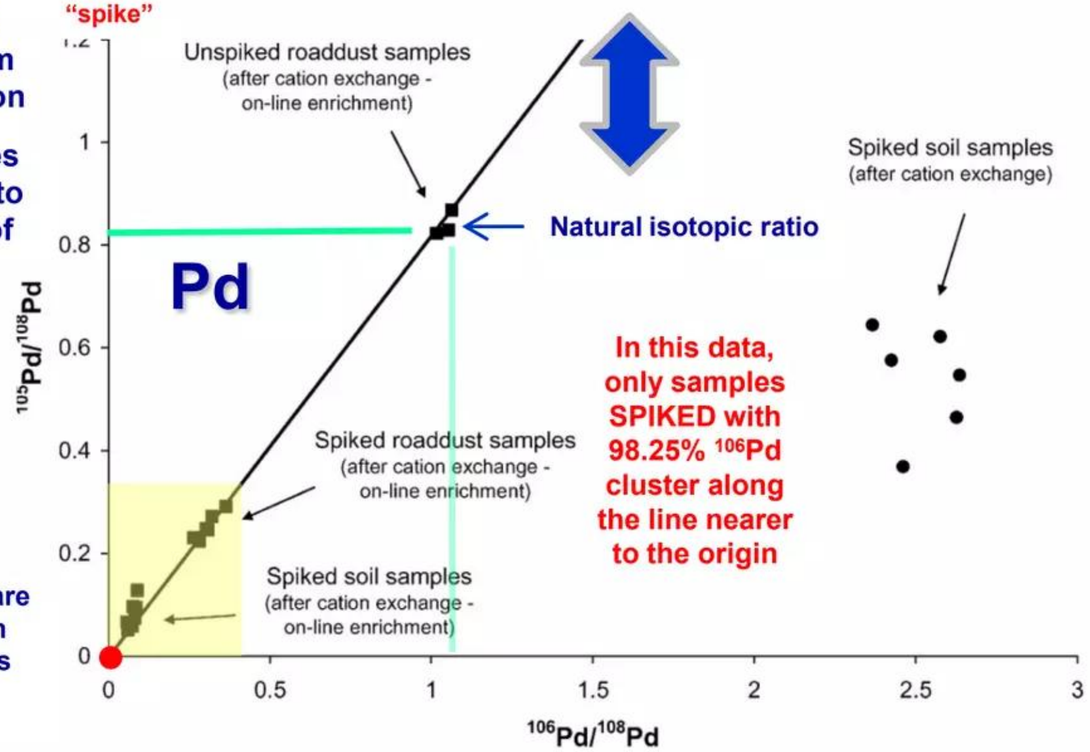


Fig.1 was adapted from Kanitsar et al. (2003)

Fig.2 was adapted from Rudolph et al. (2006)

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LENRs in catalytic converters of cars and trucks

Palladium (Pd) - six stable isotopes: ^{102}Pd, ^{104}Pd, ^{105}Pd, ^{106}Pd, ^{108}Pd, ^{110}Pd - 4

- ✓ **Discussion of previous slide: presuming that we are not misinterpreting sample isotope data presented in Fig. 1 of Kanitsar et al. (2003), it appears that some nonrandom isotopic enrichment process took place in Pd and Pt found in small airborne particles emitted from vehicle exhausts**
- ✓ **Three slides ago, please recall we said that of the six stable isotopes, "^{105}Pd [22.33% nat. ab.] has the largest neutron capture cross-section of ~22 barns … All other things being equal, at low rates of LENR ULM neutron production where only 1 - 2 neutrons are captured per Pd atom, there would be a tendency to *deplete* ^{105}Pd, ^{102}Pd and … *enrich* ^{106}Pd …" Such processes are possible in the W-L theory and LENRs**
- ✓ **Now please also recall we stated that we are unaware of any chemical fractionation theories that could plausibly explain significant isotopic shifts in Pd and Pt. That being the case, while perhaps some new novel chemical process(es) could be proposed that could produce such results, the data in Kanitsar et al. can be explained by a nuclear process, that is, LENRs and ULM neutron-captures on Pd or Pt atoms in catalytic converters per W-L theory in condensed matter**

LENR Pd isotope shifts reported by EPRI:

EPRI = the Electric Power Research Institute

"Trace elements added to Palladium by electrolysis in heavy water," EPRI Report # TP-108743 Technical Progress, ***November 1999***
EPRI Project Managers: A. Machiels & T. Passell
Contract Investigators in the Dept. of Chemistry at University of Texas - Austin: B. Bush & J. Lagowski
EPRI public release date: October 22, 2009

Free copy of report available at EPRI website:

http://my.epri.com/portal/server.pt?Abstract_id=TP-108743

Comments - VERY HIGH rate of ULMN production:

Results of neutron activation analysis (NAA) reported in #TP-108743 appear to show production of LENR transmutation products starting from ULM neutron capture on Lithium (adsorbed on the cathode surface from the LiOD electrolyte) all the way out to Iron (Fe), as well as transmutation of Pd-108 to Pd-110 via ULM neutron capture on the Palladium (Pd) cathode surface itself. Laboratory work that produced the virgin and post-experiment Pd cathodes analyzed with NAA was conducted in 1998 at a laboratory in France (IMRA) that had been funded and staffed for Pons & Fleischmann by Toyoda family of Japan; ironically, Prof. Stan Pons himself supervised this experiment

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LENRs in catalytic converters of cars and trucks

Palladium (Pd) - six stable isotopes: ^{102}Pd, ^{104}Pd, ^{105}Pd, ^{106}Pd, ^{108}Pd, ^{110}Pd - 5

- ✓ **Discussion (continued): at any given instant inside a converter at its normal operating temperature, LENR-active sites on Palladium catalyst metal inside it would probably comprise only a very tiny % of total interior surface area. Such minute nuclear-active, LENR 'patches' would be scattered randomly across surfaces and range in size from a nanometer or so up to perhaps as large as 100 microns**
- ✓ **LENR-active surface sites are not permanent entities; they will form spontaneously, 'light up' for several hundred nanoseconds, and then 'die.' Endless cycles of 'birth', nuclear energy release, and 'death' would be repeated over and over again at many thousands of different locations over time. While such LENRs are occurring, the tiny 'patches' can get quite hot --- very briefly, all the way up to 4,000 - 6,000°K. That is roughly as hot as the surface temperature of the sun and hot-enough to melt and/or even boil essentially all metals, including tungsten (b.p. = 5,666°C). Such intense local heating events can create numerous explosive melting features and 'craters' that are often observed in post-experiment SEM images (see right)**
- ✓ **While purely chemical and/or mechanical processes are capable of eroding/ablating interior surfaces of catalytic converters, it is easy to imagine that LENR 'micro-explosions' might be very effective at 'blasting' nano- to micro-sized pieces of surfaces into hot, turbulent exhaust gases flowing rapidly through converters; such particles would then be emitted through vehicle tailpipes into the atmosphere**

Pd has had long history with the field of LENRs:

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

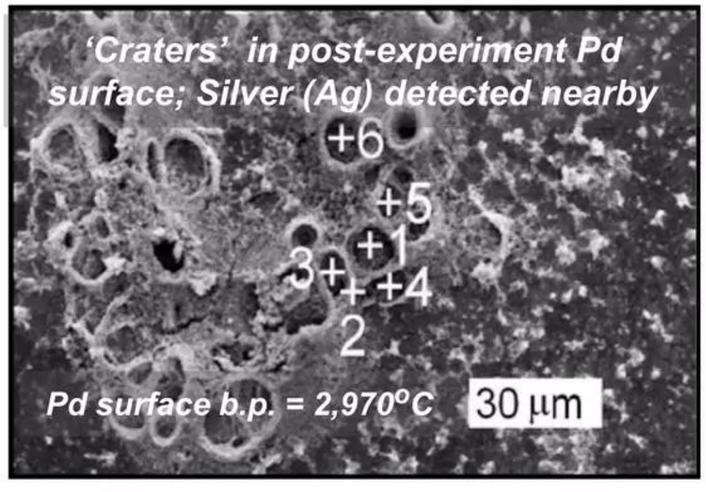
Free copy of paper available at:

http://www.lenr-canr.org/acrobat/ZhangWSexcessheat.pdf

Following likely took place in these experiments:

neutron capture — Beta⁻ decay

Pd + n ⟶ unstable n-rich Pd isotope ⟶ Ag isotopes



SEM image - Fig. 8 on p. 14: "most common finding is that Ag occurs in craters"

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Platinum (Pt) - six stable isotopes: ^{190}Pt, ^{192}Pt, ^{194}Pt, ^{195}Pt, ^{196}Pt, ^{198}Pt

- ✓ Platinum is one of three principal metallic catalysts used in most converters: nat. ab. ^{190}Pt = 0.01% (in fact, ^{190}Pt is a very long-lived unstable isotope, h.l. = 4.5 x 10^{11} yrs --- it α-decays into ^{186}Os - Osmium which is stable); ^{192}Pt = 0.79%; ^{194}Pt = 32.9%; ^{195}Pt = 33.8%; ^{196}Pt = 25.3%; ^{198}Pt = 7.2%

- ✓ ^{191}Pt - unstable, h.l. = 2.8 days, decays via electron capture into stable ^{191}Ir - Iridium; ^{193}Pt - unstable; h.l. = 51 yrs, decays via electron capture into stable ^{191}Ir - Iridium; and ^{197}Pt - unstable, h.l. = 19.9 hrs, β^- decays into stable ^{197}Au - Gold

- ✓ Platinum is an unusual non-radioactive element in that many of its stable isotopes have tiny cross-sections for α-decay upon the capture of a neutron. Specifically: ^{190}Pt - see above; ^{192}Pt → stable ^{188}Os; ^{194}Pt → stable ^{190}Os; ^{195}Pt → unstable ^{191}Os, h.l. = 15.4 days which β^- decays into stable ^{191}Ir – Iridium

- ✓ <u>Comments</u>: of six stable isotopes, ^{190}Pt has largest neutron capture cross-section = 1.5 x 10^2 barns (b) at thermal energies, then ^{195}Pt = ~28 b, and ^{192}Pt = ~2.0 b; other stable isotopes have much smaller capture cross-sections; again note that LENR n_{ULM} capture c-s can be >10^3x - 10^6x larger than $n_{thermal}$ c-c-s! Unsurprisingly, ^{190}Pt's nat. abundance is lowest of all six stable isotopes because capture c-s is so high

- ✓ All other things being equal, at low rates of LENR ULM neutron production no more than 1 - 2 neutrons may be captured per 'lucky' Pd atom located in or around a given LENR-active site, should be significant depletion of ^{190}Pt, which has a huge neutron capture cross-section. ULM neutron fluxes would have a strong tendency to *deplete* ^{192}Pt, ^{194}Pt and *especially* ^{195}Pt (nat. ab. 33.8% and capture c-s of 28 barns) and *progressively enrich* ^{196}Pt and ^{198}Pt. If 'virgin' Platinum initially at 'normal' isotopic abundances were exposed to ULM neutron fluxes over time, enrichment would be expected as observed by Kanitsar et al.

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LENRs in catalytic converters of cars and trucks

Rhodium (Rh) - one stable isotope: ^{103}Rh

- ✓ **Unlike Palladium and Platinum, Rhodium only has one stable isotope, ^{103}Rh, which comprises 100% of its earthly natural abundance**
- ✓ **^{103}Rh has a neutron capture cross section = ~11 barns at thermal energies; ULMN cross-sections are vastly higher**
- ✓ **Capture of one ULM neutron results in ^{104}Rh which is an unstable isotope having a h.l. = 42.3 seconds; ^{104}Rh then β^- decays into ^{104}Pd, which is stable, nat. ab. = 11.14%**
- ✓ **Capture of a second ULM neutron before unstable ^{104}Rh can decay produces ^{105}Rh which is also unstable with a h.l. = ~1.5 days; it β^- decays into ^{105}Pd which is stable, nat. ab. = 22.33%**
- ✓ **Comments: ULM neutron captures on Rhodium would tend to produce additional ^{104}Pd and ^{105}Pd inside catalytic converters. If this were to happen on a significant scale, it would have the effect of increasing the Pd/Rh ratio**

Production of Rhodium isotopes has been observed in Russian LENR glow-discharge experiments with Palladium cathodes in Deuterium; please see:

*A. Karabut, Y. Kucherov, and I. Savvatimova, "Nuclear product ratio for glow discharge in deuterium," Physics Letters A **170** pp. 265 - 277 (1992)*

Free copy of paper available online at:

http://www.lenr-canr.org/acrobat/KarabutABnuclearpro.pdf

Excerpted from Table 1 in this paper:

Table 1 – Abbreviated list of gamma lines for the Pd cathode	
keV	isotope
51	^{104m}Rh ($T_{1/2}$=4.4 min)
78	^{104m}Rh
129	^{105m}Rh?
305	^{105}Rh ($T_{1/2}$ = 35 hrs)
320	^{105}Rh

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LENRs in catalytic converters of cars and trucks

Osmium (Os) - 7 stable isotopes: ^{184}Os, ^{186}Os, ^{187}Os, ^{188}Os, ^{189}Os, ^{190}Os, ^{192}Os - 1

- ✓ **Natural abundances of stable Osmium isotopes are as follows: ^{184}Os = 0.020%; ^{186}Os = 1.58%; ^{187}Os = 1.6%; ^{188}Os = 13.3% ; ^{189}Os = 16.1%; ^{190}Os = 26.4%; and ^{192}Os = 41.0%**
- ✓ **^{185}Os - unstable, h.l. = 93.6 days, decays via electron capture into stable ^{185}Re – Rhenium, nat. ab. = 37.4%; ^{191}Os - unstable; h.l. = 15.4 days, it then β^- decays into stable ^{191}Ir – Iridium, nat. ab. = 37.3%**
- ✓ **Upon neutron capture, ^{192}Os is transmuted to ^{193}Os which is unstable, h.l. = 1.3 days, which β^- decays into ^{193}Ir which is stable, nat. ab. = 62.7%; similarly, if another neutron is captured before ^{193}Os can decay, ^{194}Os is created, which is unstable, h.l. = 6.0 years, which then β^- decays into ^{194}Ir which is unstable, h.l. = 19.3 hrs, which in turn β^- decays into ^{194}Pt, which is stable, nat. ab. = 32.9%**
- ✓ **Osmium's thermal neutron capture cross-sections vary greatly between its different isotopes; their distribution and values are such that exposure to neutron fluxes tends to *deplete* ^{184}Os, ^{186}Os, and ^{187}Os and *enrich* ^{188}Os, ^{189}Os, ^{190}Os, and ^{192}Os; this tendency is reflected in the natural abundances. On neutron capture, following have α-decay channels to Tungsten with tiny cross-sections: ^{184}Os, ^{186}Os, ^{187}Os, ^{188}Os, ^{189}Os, ^{190}Os, and ^{192}Os**

Interestingly, Osmium is found inside catalytic converters as well as in exhaust emissions from vehicles:

Please see a previously cited paper by Dubiella-Jackowska et al. (2007); in Table 1 they refer to 3 locations in Austria where Ru, Os, and Ir isotopes were detected in samples of soils heavily exposed to vehicular traffic. They also comment that, "In the cases of Ir, Ru, and Os, only very scarce data are available. This is mainly due to the fact that the available analytical techniques and methodologies are also limited. Determination of Ru and Os is particularly difficulty because both elements form volatile oxides."

Paper reporting, "the first direct Os concentrations and isotopic measurements of catalytic converters for major automobile brands to test the assumption that car catalysts release Os with a distinct signature in the environment" is as follows:

*A. Poirier and C. Gariepy "Isotopic signature and impact of car catalysts on the anthropogenic Osmium budget," Environmental Science & Technology **39** pp. 4431 - 4434 (2005)*

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LENRs in catalytic converters of cars and trucks

Osmium (Os) - 7 stable isotopes: ^{184}Os, ^{186}Os, ^{187}Os, ^{188}Os, ^{189}Os, ^{190}Os, ^{192}Os - 2

- ✓ **Poirier & Gariepy's (2005) measured $^{187}Os/^{188}Os$ ratios in four new (unused) catalytic converters, obtaining values of 0.1 – 0.2; their numbers are later cited by Chen et al. (2007). Poirier & Gariepy (2005) further state that, "We show that Os loss from catalysts as volatile OsO_4 [b.p.=105°C] is important at car catalyst operating temperatures."**

- ✓ **Poirier & Gariepy then go on to make an intriguing statement, "The NIST car catalyst standard (SRM-2557, made from recycled used catalysts) yields higher concentrations (up to 721 ppt Os) and a more radiogenic isotopic composition (approximately 0.38), perhaps indicative of Os contamination during its preparation."**

- ✓ **Comments: before proceeding further, we need to revisit the key issue of underlying assumptions. Specifically, there is a widely held belief that: *no geochemically significant amounts of natural nuclear (nucleosynthetic) processes besides radioactive decay of long-lived isotopes (e.g., ^{187}Re decaying via β^- to ^{187}Os, h.l. = 4.1 x 10^{10} yrs) have taken place in the earth or its atmosphere since planetary materials condensed from the protosolar nebula, nor are they occurring anywhere in or around the terrestrial environs in the present era***

  As previously noted herein, if ULM neutron-catalyzed LENRs are truly occurring in Nature, this assumption may not be valid in all circumstances --- we will explore specific implications momentarily

Please see:

*C. Chen, P. Sedwick, and M. Sharma., Anthropogenic Osmium in rain and snow reveals global-scale atmospheric contamination," PNAS **106** pp. 7724 - 7728 (2009)*

Free copy of paper available online at:

http://www.pnas.org/content/106/19/7724.full.pdf+html

Quoting:

"… an unintended consequence of using catalytic converters is that the Platinum Group Elements (PGEs: Os, Ir, Pt, Pd, Ru, Rh) are now polluting the environment. Although most of fine particulate matter from automobile exhaust containing PGEs settles close to highways and in urban areas, increasing PGE concentrations have been noted in ice cores and snow in remote regions. In general, all PGEs are immobile except Os, which can form volatile OsO_4 during high-temperature … processes … we show that the $^{187}Os/^{188}Os$ ratios measured in rain and snow collected around the world range from 0.16 to 0.48, much lower than expected (>1), but similar to the isotope composition of ores (0.2) that are processed to extract platinum and other metals … used … in automobile catalytic converters."

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LENRs in catalytic converters of cars and trucks

Osmium (Os) - 7 stable isotopes: ^{184}Os, ^{186}Os, ^{187}Os, ^{188}Os, ^{189}Os, ^{190}Os, ^{192}Os - 3

- ✓ **Comments (continued): as explained in Shirey & Walker (1998) the $^{187}Os/^{188}Os$ ratio is widely measured and utilized in various types of isotopic studies. It makes fundamental underlying assumptions implied in the previous slide, namely that: (a) ^{188}Os is not being presently produced via nucleosynthetic processes anywhere in the earth or its immediate environs; and, (b) the *only* source of newly produced atoms of ^{187}Os in the present terrestrial environment is radiogenic β^- decay of ^{187}Re to ^{187}Os**

- ✓ **Unfortunately, according to the W-L theory of LENRs it is quite possible that the following nucleosynthetic reactions (i.e., ULM neutron captures) could be occurring at not insignificant rates somewhere on surfaces inside catalytic converters and in high-heat industrial processes such as smelting:**

Note: these reactions are exothermic

$$^{186}Os + n_{ulm} \rightarrow {}^{187}Os$$

$$^{187}Os + n_{ulm} \rightarrow {}^{188}Os$$

Note: ^{186}Os and ^{187}Os both have very high neutron capture cross-sections

- ✓ **If such ULM capture reactions were to occur elsewhere in nature, then in different geochemical environments, values for numerator and denominator of the $^{187}Os/^{188}Os$ ratio could change in very complex, unpredictable ways that are: (a) totally unrelated to the β^- decay of ^{187}Re; and (b) somewhat unrelated to each other, if LENR surface sites have isotopic heterogeneity on small length scales**

Please see:

*S. Shirey and R.. Walker, "The Re-Os isotopic system in cosmochemistry and high-temperature geochemistry," Annual Reviews of Earth and Planetary Science **26** pp. 423 - 500 (1998)*

Free copy of paper available online at:

http://www.geo.arizona.edu/tectonics/Ducea/teaching/ShireyWalker.pdf

Quoting:

"Re-Os isotope system, based on the long-lived β^- transition of ^{187}Re to ^{187}Os, has matured to wide use in cosmochemistry and high-temperature geochemistry … Precise and accurate determination of … ^{187}Re decay constant has remained elusive .. Rhenium and Os … among the first elements to condense from … solar nebula as a consequence of their extremely high condensation temperatures .. Application of the Re-Os system to cosmochemical issues originated in the early 1960s … development of high-precision NTIMS techniques provided the necessary boost in analytical precision to exploit the system fully in order to resolve Os isotopic differences … highly evolved irons have unexpectedly high concentrations of Re and Os relative to those predicted by fractional crystallization models … least evolved (lowest Ni, highest Os) IIB irons crystallized from a melt that may have had a $^{187}Re/^{188}Os$ ratio as high as 1.8 …yet … most evolved IIB (and IIIB) subgroup irons have $^{187}Re/^{188}Os$ ratios identical to those of chondrites."

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Other oddities

Regarding anomalous Gold (Au) please see:

G. Dongarra, D. Varrica, and G. Sabatino, "Occurrence of Platinum, Palladium, and Gold in pine needles of Pinus pinea from the city of Palermo (Italy)," Applied Geochemistry ***18*** *pp. 109 - 116 (2003)*

Quoting: *"Preliminary data on the presence of Pt, Pd and Au in airborne particulate matter from the urban area of Palermo (Sicily, Italy) are presented. They were obtained by analysing 40 samples of pine needles (Pinus pinea L.) collected in and around the city. Observed concentrations range from 1 to 102 μg/kg for Pt, 1 to 45 μg/kg for Pd and* ***22 to 776 μg/kg for Au. Platinum and Pd concentrations in pine needles are up to two orders of magnitude higher than their crustal abundances. They exhibit a high statistical correlation (R^2=0.74)*** *which suggests a common origin. Precious metal concentrations measured within the city centre are much higher than those occurring outside the town. The distribution patterns of Pt and Pd in the study area are compared to the distributions of Au and Pb.* ***Gold is enriched at the same sites where Pt and Pd are enriched, while Pb shows some discrepancies. The most probable local source of all of these elements is traffic.*** *Average Pt and Pd emissions in the city area are estimated to be about 136 and 273 g/a, respectively."*

Regarding anomalous Platinum (Pt) see:

R.. Fernandez-Ruiz, F. Galisteo, C. Larese, M. Granados, R. Mariscal, and J. Fierro, "TXRF analysis of aged three-way catalysts," Analyst ***131*** *pp. 590 - 594 (2006)*

Free copy of paper available online at:

http://www.rsc.org/delivery/_ArticleLinking/DisplayArticleForFree.cfm?doi=b513508g&JournalCode=AN

Quoting: *"Fig. 4 shows the axial profile of the contaminant elements, Pb, Zn, Ca, Ni, P and Pt, so that XY00 (XY59) belong to the element XY in the fresh (used) catalyst. The provenances of these elements are as follows: Pb, Zn and Pt from the gasoline and P, Ca and Ni from the lubricant oils. As can be seen from Fig. 4, in all cases the elemental concentrations in catalyst 00 are less than in catalyst 59. This fact, indicates an absorption of these elements in the catalytic cartridge.* ***In principle, analyzed TWCs are not formulated with Pt in their composition but, as Fig 4 shows, Pt was detected in the used monolith, whereas the fresh monolith did not show it. The traces of Pt arising from the re-forming catalysts used in refineries to improve the octane number have been detected in gasoline, therefore, this could be the reason for the presence of Pt in the front block of the catalyst.*** *"*

Regarding anomalous elements please see:

M. Moldovan, M. Milagros-Gomez, and M. A. Palacios, "Determination of Platinum, Rhodium, and Palladium in car exhaust fumes," Journal of Analytical Atomic Spectrometry ***14*** *pp. 1163 - 1169 (1999)*

Free copy of paper available online at:

http://www.rsc.org/delivery/_ArticleLinking/DisplayArticleForFree.cfm?doi=a901516g&JournalCode=JA

Quoting: "… relatively low Pd concentration found was surprising *because it is the main noble metal in catalysts A and B. … relatively high concentrations of the three elements were found in all catalysts, even those denoted by the name of the Pt catalyst (catalyst D) or Pd/Rh catalyst (catalyst C) … proportion among the PGE released was not the same as the labeled proportion stated on the catalyst … authors attributed the Pd measured to other automobile sources such as fuel, oil, spark plug electrodes or engine abrasion. However, the relatively high concentrations found in our samples suggests that* ***non-labeled elements are also present on the catalyst*** *… release of PGE on fresh catalyst was found to vary from catalyst to catalyst and between samples of the same catalyst.* ***Appreciable amounts of Pd and Rh were found in a diesel catalyst labeled as Pt only. Also, appreciable amounts of Pt were found in the exhaust fumes from the Pd/Rh catalyst."***

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LENRs in catalytic converters of cars and trucks

Opportunities for experimentalists

- ✓ **We have reviewed selected experimental data which suggests that LENRs could well be occurring inside vehicle catalytic converters**
- ✓ **That having been said, we believe evidence to date is suggestive, but not truly conclusive**
- ✓ **What is vitally needed to determine where the chemical fractionation paradigm might end and a new condensed matter nuclear paradigm might begin, are efforts by other scientists who are experts in isotopic studies to design specific experiments that can differentiate between the two paradigms**
- ✓ **If LENR processes can be unequivocally shown to occur in catalytic converters, it would be an interesting start to mapping the 'borderlands' in parameter space where nuclear science ultimately meets chemistry**
- ✓ **As they say in Russia, we shall live and we shall see …..**

Rough sketch of an idea for two interesting experiments:

1. *Start with a brand new (unused) computer- controlled, gasoline-powered automobile engine, chassis, drive train, wheels, and tires (no body) on a test bed where it can be run and varying loads put on the engine as if it were actually being driven on the road*
2. *Treat the engine, exhaust system, and catalytic converter as if it were a closed system. It has measurable inputs that can be isotopically characterized and sampled: air (gaseous), gasoline (liquid), and lubricants (liquid). The measured outputs to be analyzed are whatever elements/isotopes are present in the catalytic converter in solid form at the beginning and end of an experiment, as well as whatever gaseous and particulate matter has been emitted and periodically sampled at the end of the exhaust pipe*
3. *Specially construct two types of otherwise identical 3 three-way catalytic converters (TWCs) containing customary amounts and ratios of Pd, Pt, and Rh and washcoat: (a) standard honeycomb ceramic 'monolith' support structure; (b) stainless steel honeycomb support structure (there will be a total of four TWCs)*
4. *When preparing washcoat with its Pd, Pt, and Rh particles, make certain that all catalyst metals used in it are certified 'virgin' – that is, they have come directly from a miner/refiner (e.g., Johnson-Matthey or Tanaka Metals) and have never previously been recycled or used in catalytic converters or in any industrial processes (we now have 2 ceramic TWCs and 2 stainless steel; one of each will be set aside as control)*
5. *Exhaustively characterize all elements/isotopes present inside catalytic converters at the beginning of a experiment with whatever mass spectroscopy techniques are needed to accomplish that goal. If possible, purchase one lot of fuel and lubricants that will be enough for all experiments and characterize them prior to starting*
6. *With whatever mass spectroscopy techniques are needed, exhaustively analyze periodic samples of input air and exhaust emissions (gaseous and particulate) to characterize all elements/isotopes present to whatever degree is technologically possible; idea here is to be able to see whether elements are created or destroyed*
7. *Run each of two experiments for total of 1,000 - 1,500 engine operating hours. At the very end of each experiment, remove the TWC, tear it apart, and exhaustively analyze the elements/isotopes in it to whatever degree is technologically possible*

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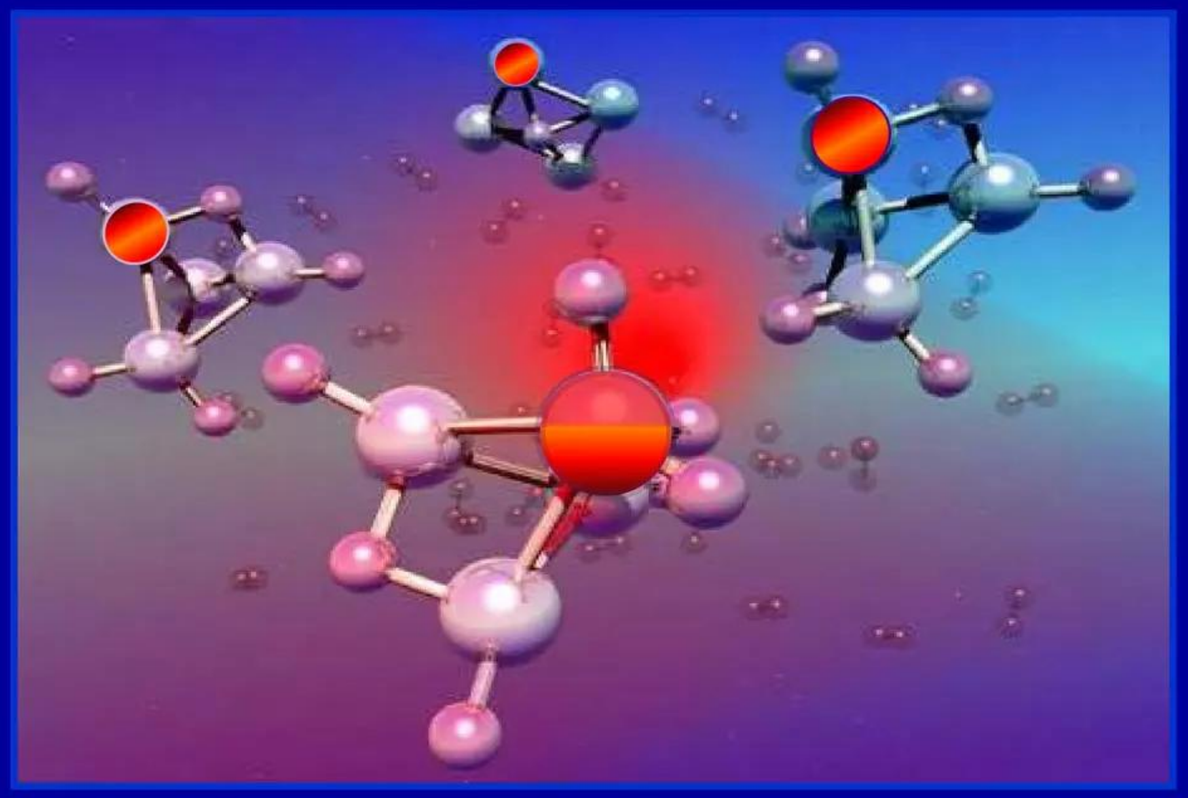
More evidence chemical fractionation paradigm is strained



"The usual prelude to changes of this sort is … the awareness of anomaly, of an occurrence or set of occurrences that does not fit existing ways of ordering phenomena. The changes that result therefore require 'putting on a different kind of thinking-cap', one that renders the anomalous lawlike …"

Thomas Kuhn, "The Essential Tension," xvii, 1977

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More evidence chemical fractionation paradigm is strained

Briani et al. - extraordinary Nitrogen-15 anomalies in primordial chondrite

- ✓ **Paper: isotopic data reported in Briani et al.'s paper is truly fascinating. To obtain it, they utilized a unique, multi-million $ mass spectroscopy instrument, a CAMECA NanoSIMS 50, that has the ability to perform detailed isotopic analyses on surface 'spots' down to 50 nm in size**
- ✓ **Quoting: "Pristine meteoritic materials carry light element isotopic fractionations that constrain physiochemical conditions during solar system formation. Here we report the discovery of a unique xenolith in the metal-rich chondrite Isheyevo … PX-18 is a dark xenolith (380 x 470 microns^2), dominated by a very fine-grained matrix, mainly composed of anhydrous Mg-rich silicates with tiny Fe-Ni sulfides grains and magnetite … In addition to the diffuse distribution of ^{15}N-enriched material, forty-six ^{15}N hotspots with extremely high $^{15}N_{AIR}$ were observed in PX-18 (Fig. 2B). These hotspots, with areas of approximately 1 micron^2, are distinct from the aforementioned, broad ^{15}N-enriched zones … These hotspot subregions are the highest $^{15}N_{AIR}$ values ever measured in solar system material … Together, these observations lead to the conclusion that ^{15}N hotspots in PX-18 are due to the presence of organic matter (OM)."**
- ✓ **Comment: consistent with W-L LENRs, they observed a high localization of ^{15}N isotope anomalies in micron-scale 'hot spots' that were clearly associated with organic matter. Briani et al. could not fully explain the anomalies with chemical "fractionation" processes; they concluded that, "The results call for a new theoretical and experimental approach."**

Please see:

G. Briani, , M. Gounelle, Y. Marrocchi, S. Mostefaoui, H. Leroux, E. Quirico, and A. Meibom, "Pristine extraterrestrial material with unprecedented nitrogen isotopic variation," PNAS 10.1073 – pnas 0901545106 May 2009

Six-page article can be purchased from PNAS for $10 and downloaded from following URL:

http://www.pnas.org/content/early/2009/06/15/0901546106.abstract

Free package of supplementary technical information may be downloaded from:

http://www.pnas.org/content/suppl/2009/06/15/0901546106.DCSupplemental/0901546106SI.pdf

A free copy of a conference presentation summary may be downloaded from:

http://www.lpi.usra.edu/meetings/lpsc2009/pdf/1642.pdf [two Figs. from this appear on the next slide]

Quoting from the abstract:

"An extreme continuum of N isotopic variation is present in this xenolith: from very light N composition similar to that inferred for the solar nebula to the heaviest ratios measured in any solar system material."

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More evidence chemical fractionation paradigm is strained

"These results call for a new theoretical and experimental approach"

Quoting from their conference presentation: "These observations lead to the conclusion that ^{15}N isotopic variation in PX-18 are due to the presence of diffuse organic matter with a range in $\delta^{15}N^{AIR}$ that greatly expands the range for a single extraterrestrial object or isolated IOM. Excluding a stellar nucleosynthesis origin (i.e. related to presolar grains) for the observed N isotopic anomalies, values of $\delta^{15}N^{AIR}$ as high as those observed in PX-18 can be produced only by low-temperature ion-molecule reactions. In the most recent model for N-containing molecules chemistry under dark molecular cloud conditions [15], values of $\delta^{15}N^{AIR} > 9000‰$ are obtained for external layers of NH^3 ice accreted on dust grains. Transfer of fractionated N from NH^3 ice to organic matter is possible by UV-induced transformations in poly-cyclic aromatic hydrocarbons [16]. However, a fundamental problem is that low temperature ion-molecule reactions are also predicted to produce strong deuterium enrichments in organic matter [17], which are not found in Isheyevo PX-18 or any other xenolith in Isheyevo. **These results call for a new theoretical and experimental approach, which must be able to provide an explanation for the decoupling of these light elements isotopic variations as well as for the high values measured in the hotspots.**"

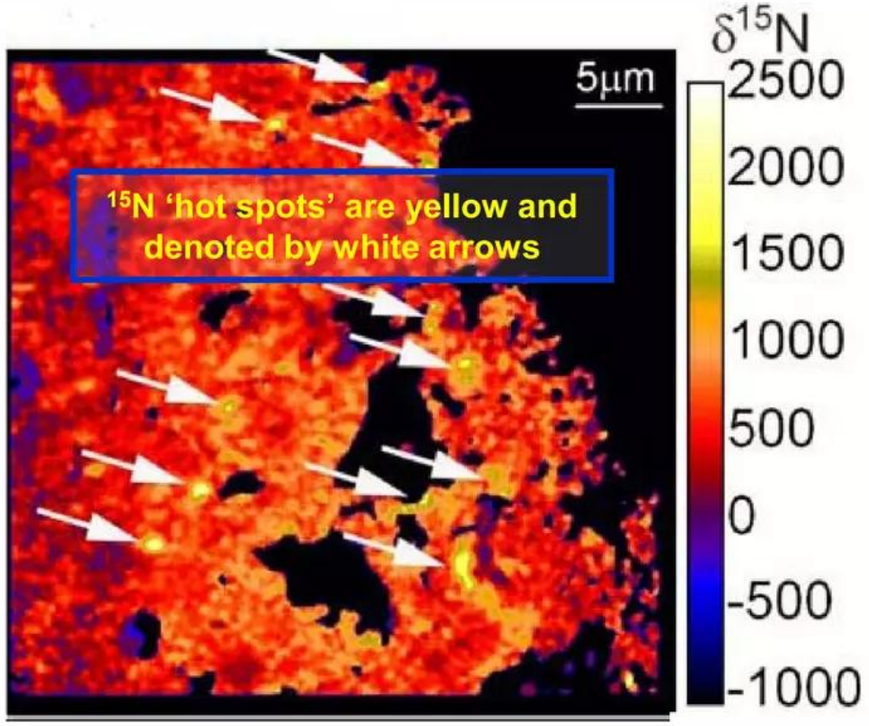

Figure 2. $\delta^{15}N^{AIR}$ distribution of a 40×40 μm^2 region in PX-18, with mean $\delta^{15}N^{AIR}$ = 640 ± 11‰. About 90% of this image is characterized by $\delta^{15}N^{AIR} \geq$ 250‰. Several hotspots are also visible (white arrows).

Source: http://www.lpi.usra.edu/meetings/lpsc2009/pdf/1642.pdf

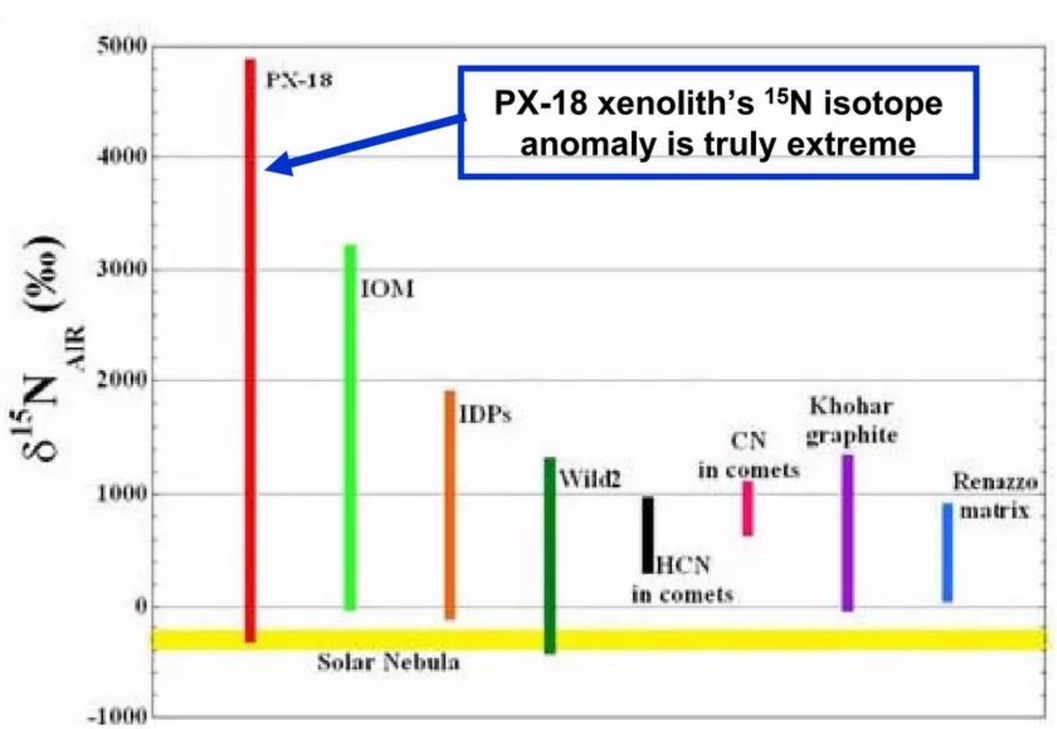

Figure 3. $\delta^{15}N^{AIR}$ values measured in PX-18, compared with previous measurements in other Solar System materials. Ranges reported in the figure comprise results from bulk measures as well as from hotspots (data from literature).

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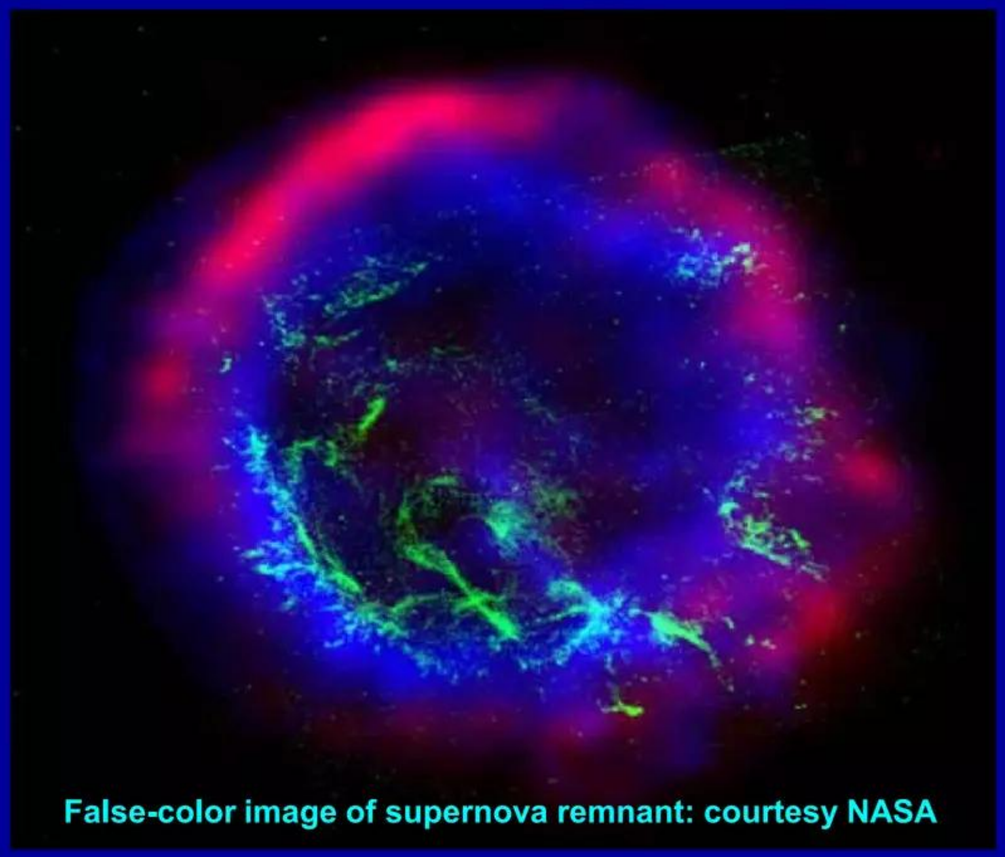
Further Thoughts and Future Possibilities



False-color image of supernova remnant: courtesy NASA

Violent extreme environments and stars not necessarily required

“I have learned to use the word ‘impossible’ with the greatest caution.”

Wernher von Braun

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Further Thoughts and Future Possibilities

Four items

- ✓ Worldwide, it is presently estimated that at least 500 million cars and trucks are operating with installed catalytic converters. If it should turn-out that LENRs are in fact occurring inside them, it would be the ultimate testimonial to vastly greater environmental safety and 'greenness' of LENRs as a power generation technology compared to fission and fusion
- ✓ In our opinion, there are many opportunities in the field of LENRs for daring experimentalists to make new and very important discoveries
- ✓ About 18 months ago, we made a prediction based on W-L theory that LENRs occurring in sub-micron-scale dendrites inside Li-ion batteries can trigger chemical fires under certain conditions. New data has just been published that conclusively links such problems to dendrites; we will be releasing a new SlideShare presentation on that subject very soon
- ✓ Similar to LENRs, many-body, collective coherent quantum effects also appear take place in photosynthesis; namely in the dynamical behaviors of electrons and protons in and around the light-harvesting 'antenna' structures. We will be releasing some thoughts on this in the near future

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Further Thoughts and Future Possibilities

Thomas Kuhn opines on good theories

"What, I ask to begin with, are the characteristics of a good scientific theory?"

"First, a theory should be accurate: within its domain, that is, consequences deducible from a theory should be in demonstrated agreement with the results of existing experiments and observations. Second, a theory should be consistent, not only internally or with itself, but also with other currently accepted theories applicable to related aspects of nature. Third, it should have broad scope: a theory's consequences should extend far beyond the particular observations, laws, or subtheories it was originally designed to explain. Fourth, and closely related, it should be simple, bringing order to phenomena that in its absence would be individually isolated and, as a set, confused. Fifth --- a somewhat less standard item, but one of special importance to actual scientific decisions --- a theory should be fruitful of new research findings: it should, that is, disclose new phenomena or previously unnoted relationships among those already known."

"These five characteristics --- accuracy, consistency, scope, simplicity, and fruitfulness … provide the [standard criteria] … for theory choice."

Source: Thomas Kuhn, "Objectivity, Value Judgment, and Theory Choice" pp. 321 - 322 in Chapter 13 of "The Essential Tension - Selected Studies in Scientific Tradition and Change", The University of Chicago Press, 1977

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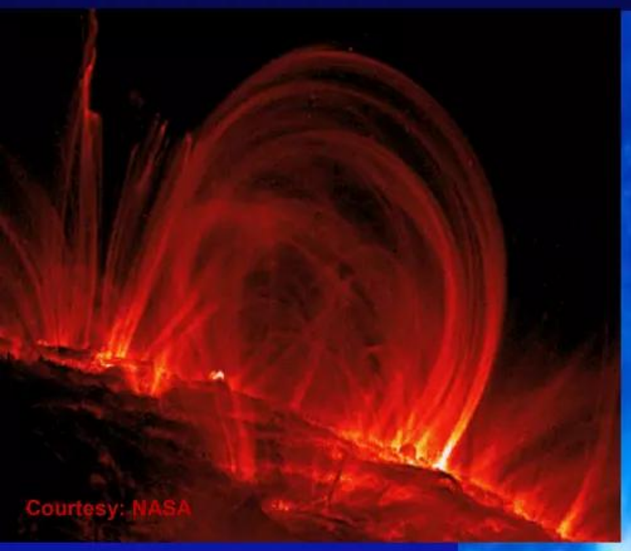
Further Thoughts and Future Possibilities

Expanded version of "Primer" to publish soon in Pramana



A new, expanded version of our "Primer" paper has been accepted for publication and will publish soon in *Pramana - Journal of Physics*

Please watch for it at URL = http://www.ias.ac.in/pramana/

"A Primer for Electro-weak Induced Low Energy Nuclear Reactions"

Y.N. Srivastava, A. Widom, and L. Larsen

Abstract: Under special cirumstances, electromagnetic and weak interactions can induce low energy nuclear reactions to occur with observable rates for a variety of processes. A common element in all these applications is that the electromagnetic energy stored in many relatively slow moving electrons can - under appropriate circumstances - be collectively transferred into fewer, much faster electrons with energies sufficient for the latter to combine with protons (or deuterons, if present) to produce neutrons via weak interactions. The produced neutrons can then initiate low energy nuclear reactions through further nuclear transmutations. The aim of this paper is to extend and enlarge upon various examples analyzed previously, present order of magnitude estimates for each and to illuminate a common unifying theme amongst all of them.

Courtesy: NASA