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Low Energy Nuclear Reactions (LENRs)

Condensed matter nuclear science meets chemistry – Mizuno experiments with polycyclic aromatic hydrocarbons (PAHs)

Technical Overview

Lewis Larsen, President and CEO

"Out of intense complexities , intense simplicities emerge."

Winston Churchill

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Contents

Overview I

- ✓ **For more detailed explanation of various concepts and information underlying this presentation, please see 78-slide Lattice SlideShare Technical Overview dated June 25, 2009, a 65-slide Lattice SlideShare Technical Overview dated September 3, 2009, as well as a periodically updated Resource Guide for Readers that was initially published on SlideShare during September 2009.**

- ✓ **Recapping – in the September 3 Overview we discussed W-L theory in context of experiments involving LENR carbon-seed nucleosynthetic networks. On Slide #59, we hypothesized that the π electrons found on surfaces of planar graphene or curvilinear fullerene carbon structures oscillate collectively, just like SPP electrons on metals; that hydrogen atoms (protons) sticking 'above' the surfaces of such hydrogenated graphene and/or fullerenes also oscillate collectively, thus forming many-body, potentially nuclear-active 'patches' analogous to those that can form on surfaces of hydrogen-loaded metals; and that the Born-Oppenheimer approximation breaks down on such surfaces.**

- ✓ **Herein - using W-L theory and extending the above hypothesis to PAHs, we will analyze Mizuno's LENR experiments with phenanthrene to see whether we can understand his results; whether there are analogues to his data; and if our new insights can be applied to explain certain astrophysical isotopic data.**

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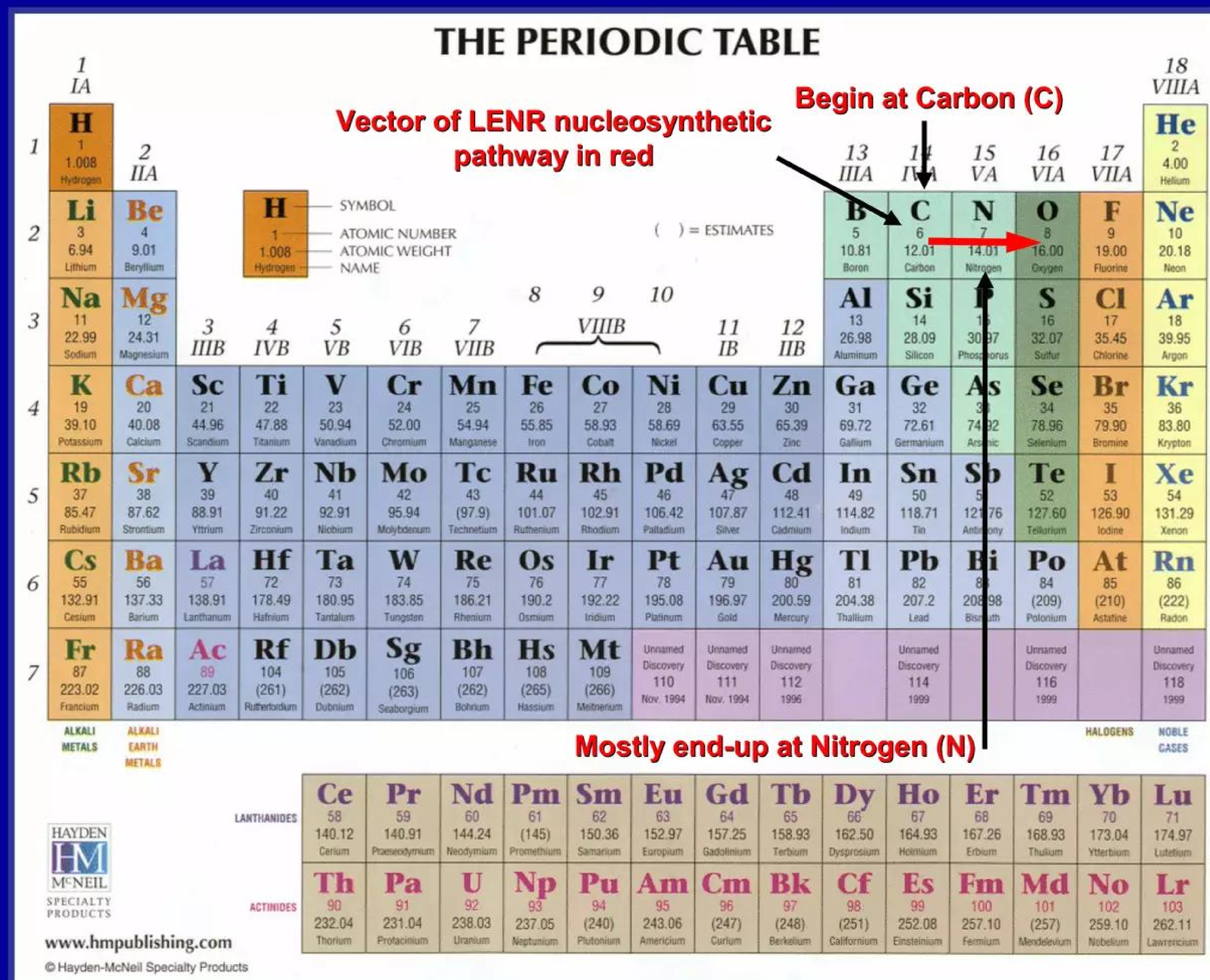
Overview II - Nucleosynthetic Pathway



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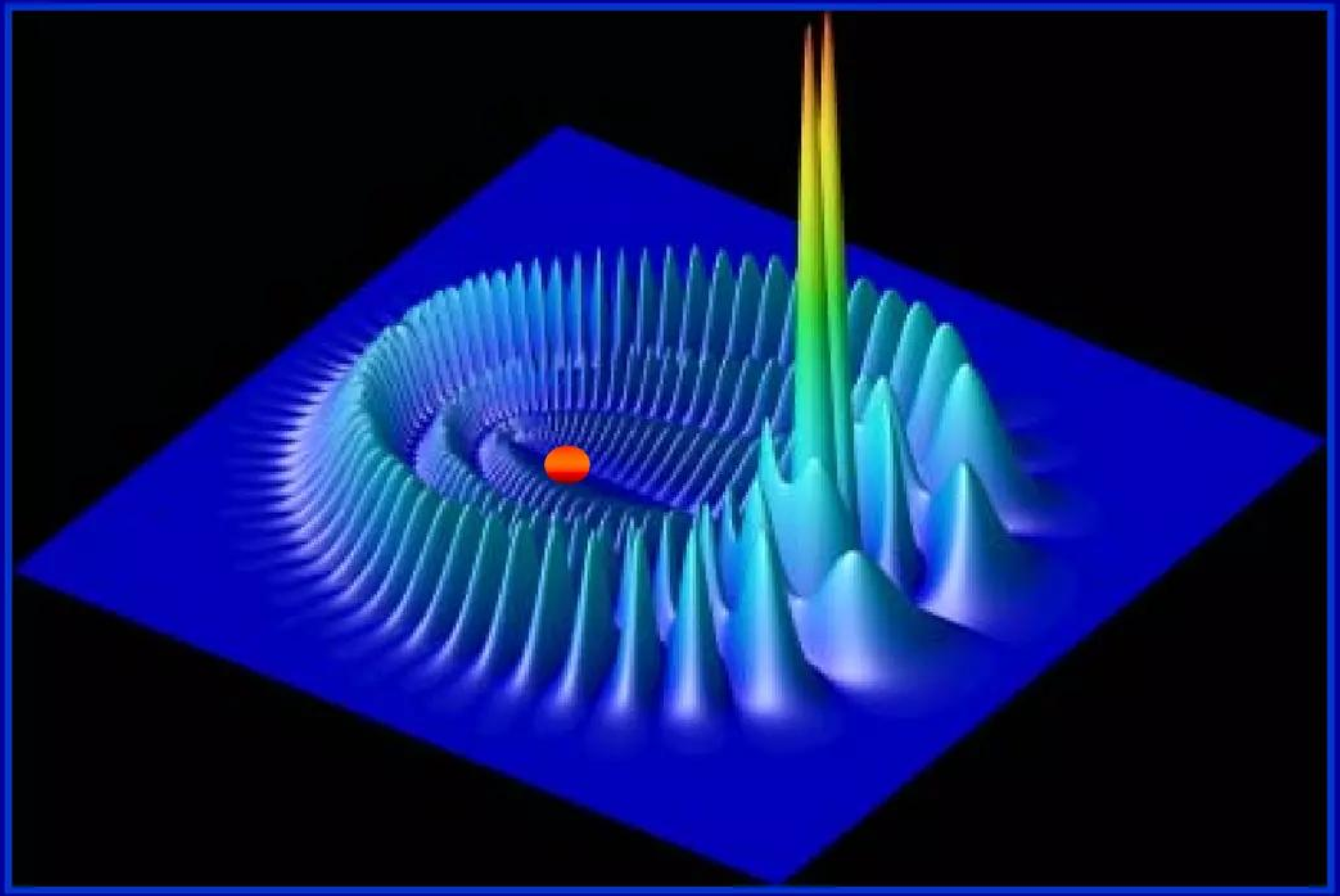
Historical perspective: alchemy, chemistry, and LENRs - I



"Grow your tree of falsehood from a single grain of truth."

Czeslaw Milosz, poem "Child of Europe," New York, 1946

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Historical Perspective - II

"The delusion of transmutation"

"As we peer down the vista of the past we find the delusion of transmutation holding the most prominent place in the minds of thinking men. Frenzied alchemy held the world in its grip for seventeen centuries and more of recorded history. This pseudoscience with its alluring goal and fascinating mysticism dominated the thoughts and actions of thousands. In the records of intellectual aberrations it holds a unique position. Even Roger Bacon of Oxford, easily the most learned man of his age, the monk who seven hundred years ago foresaw such modern scientific inventions as the steamship and the flying machine, believed in the possibility of solving this all-consuming problem … Sir Isaac Newton, one of the clearest scientific thinkers of all time, bought and consulted books on alchemy as late as the eighteenth century … The power and the influence of many of the alchemists can hardly be exaggerated … While among the alchemists there were some genuine enthusiasts like Bernard Trevisan, the annals of this queer practice are filled with accounts of charlatans and spurious adepts who, with a deluge of glib words but with only a drop of truth, turned alchemy into one of the greatest popular frauds in history."

Bernard Jaffe, "Crucibles: the story of chemistry" 4th Revised ed., pp. 7-8 Dover 1976

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Historical Perspective - III

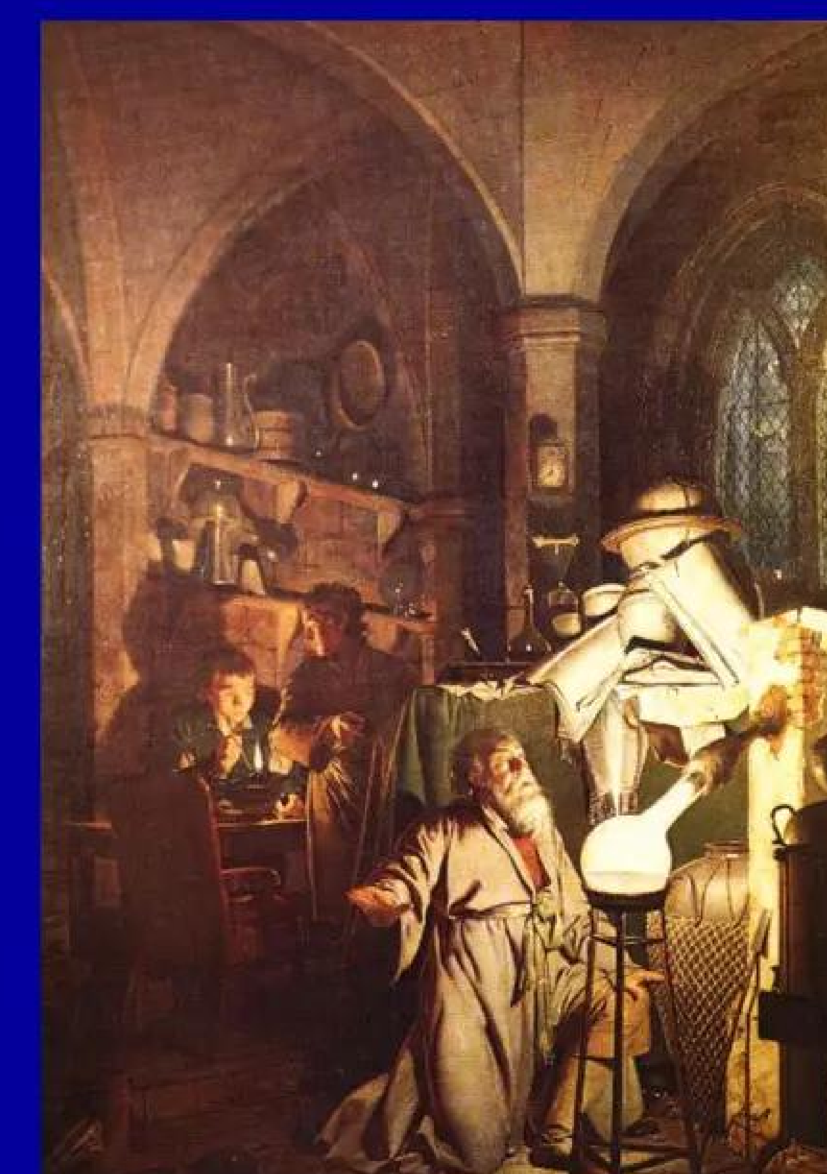
"For Mike's sake Soddy, don't call it transmutation.
They'll have our heads off as alchemists."

Comment made by Ernest Rutherford to Frederic Soddy (1901)

"The Alchemist's Workshop" by Jan van der Straet (1570)

"In 1901, twenty-four year-old chemist Frederick Soddy and Ernest Rutherford were attempting to identify a mysterious gas that wafted from samples of radioactive thorium oxide. They suspected that this gas - they called it an 'emanation' - held a key to the recently discovered phenomenon of radioactivity. Soddy had passed the puzzling gas over a series of powerful chemical reagents, heated white-hot. When no reactions took place, he came to a startling realization. As he told his biographer many years later, ´I remember quite well standing there transfixed as though stunned by the colossal import of the thing and blurting out-or so it seemed at the time, *'Rutherford, this is transmutation: the thorium is disintegrating and transmuting itself into argon gas.'* Rutherford's reply was typically aware of more practical implications."

J. Magill, "Decay Engine" at www.nucleonica.net



"The Alchymist in Search of the Philosophers' Stone Discovers Phosphorous" by Joseph Wright of Derby (1771)

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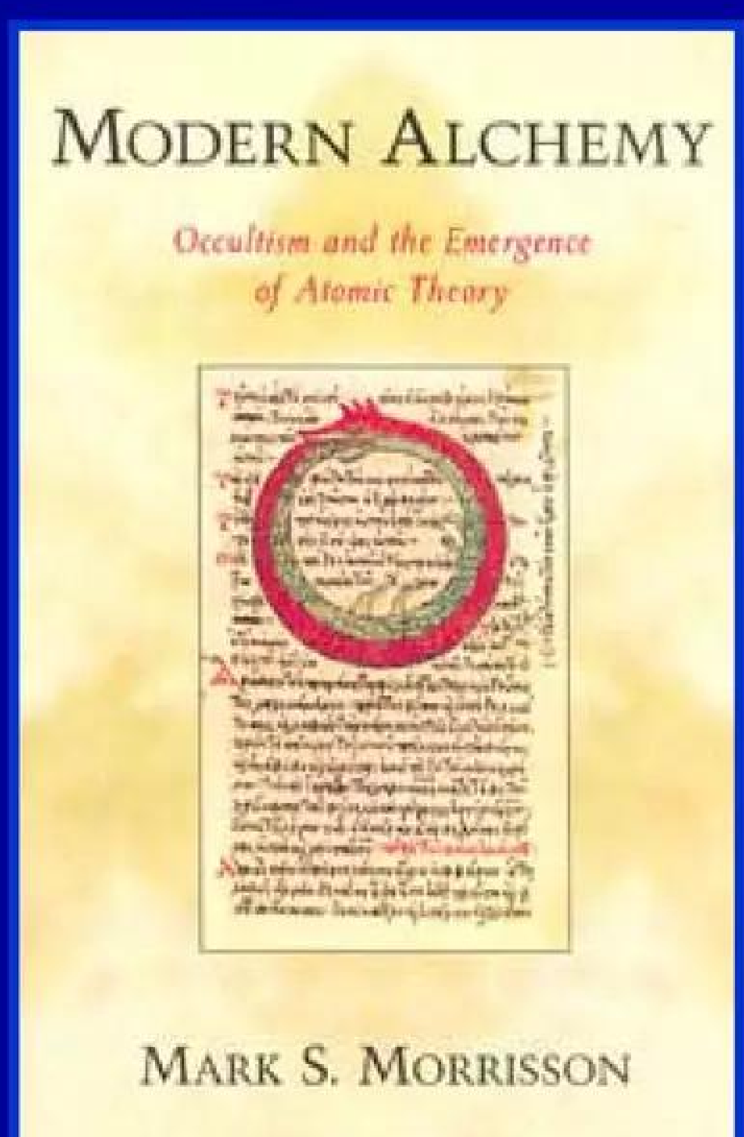
Historical Perspective - IV

"Plus ça change, plus c'est la même chose."

Epigram by Jean-Baptiste Alphonse Karr in the January 1849 issue of his journal "Les Guêpes" (The Wasps)



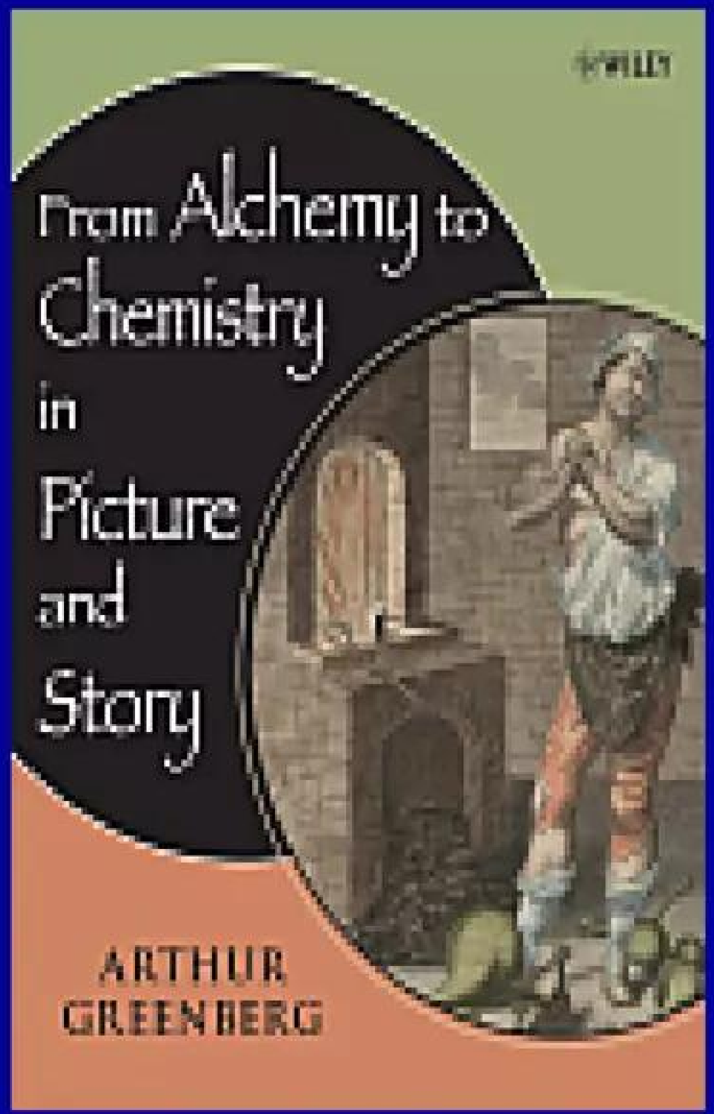
Oxford University Press (2007)

"The energy produced by the atom is a very poor kind of thing. Anyone who expects a source of power from the transformation of these atoms is talking moonshine."

Prof. Ernest Rutherford, 1933 [fission discovered by Hahn and Strassmann in 1938; Fermi's first reactor went critical in 1942; use of nuclear weapons,1945; first commercial reactor, 1957]

"The idea of producing useful energy from room temperature nuclear reactions is an aberration."

Prof. John Huizenga, chemist and physicist, referring to "cold fusion" in his 1993 book, "Cold fusion – The scientific fiasco of the century"



Wiley – Interscience (2007)

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Historical Perspective - V

"God made the neutron"

"The neutron plays a pivotal role in manmade transmutations. In the words of Bronowski, 'At twilight on the sixth day of Creation, so say the Hebrew commentators to the Old Testament, God made for man a number of tools that gave him also the gift of creation. If the commentators were alive today, they would write, 'God made the neutron.' Is it far-fetched to consider the neutron to be the Stone of the Philosophers (and atom smashers to be athanors – the furnaces of the Philosophic Egg)? Frankly, yes. But, in 1941, fast neutrons were used to transmute mercury into a tiny quantity of gold[1]. Was the age old dream realized? Would a modern day version of the Roman Emperor Diocletian have to burn all the notebooks and journal articles and destroy the atom smashers in order to protect the world's currency? Well, probably not. It is likely that an ounce of such gold would cost more than the net worth of the planet. Also, the gold so obtained is radioactive and lives for only a few days at most. But, we are not always logical when it comes to gold. In the words of Black Elk, a holy man of the Oglala Lakota-Sioux on the Pine Ridge Reservation in South Dakota, ' … Our people knew there was yellow metal in little chunks up there, but they did not bother with it, because it was not good for anything'." [1][Sherr et al., The Physical Review 60:473-479 1941]

Arthur Greenberg, "From Alchemy to Chemistry in Picture and Story" pp. 571 2007

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Historical Perspective - VI

Chemistry and nuclear science come full-circle

"There is first the groping after causes, and then the struggle to frame laws. There are intellectual revolutions, bitter controversial conflicts, and the crash and wreck of fallen philosophies."

Francis Venable "A Short History of Chemistry," pp. 1 D. C. Heath 1894

The field of chemistry has spent nearly 300 years distancing itself from the 'fallen angel' of alchemy. This 'safe distance' has been maintained until the present era, mainly because of wide disparities in energy scales between chemical and nuclear processes. Today, chemistry primarily involves the dynamics of outer valence electrons and bonding reactions between atoms of various elements on electron Volt (eV) energy scales. By contrast, nuclear physics mostly involves strong and weak interaction dynamics of nucleons and inner-shell electrons, as well as other types of energetic particles, with binding energies on scales ranging from kilo electron Volts (keVs) up to mega electron Volts (MeVs) and higher. "Never the twain shall meet." --- until now.

Historical Perspective – VII

"Oh, East is East, and West is West, and never the twain shall meet."

Rudyard Kipling, "The Battle of East and West" (1889)

Since the inception of nuclear science, it has been widely believed that the only nuclear processes suitable for commercial power generation were strong interaction fission or fusion; it was also widely held that nuclear transmutation reactions could only take place within certain environments, e.g., in fission reactors, weapons, or stars. Pons & Fleischmann's 1989 discovery of what appeared to be nuclear processes operating inside what would otherwise be ordinary D_2O electrolytic chemical cells challenged long-established conceptual paradigms about nuclear science. Sadly, P&F rashly speculated that their observed radiation-free "excess heat" resulted from a D-D "cold fusion" process. That claim, coupled with irreproducible experimental results, resulted in sustained attacks on such work by mainstream science that have continued to the present. Starting with the release of our first arXiv preprint in 2005, the Widom-Larsen theory of LENRs has shown, using known physics, how energetic nuclear reactions can take place in ordinary chemical cells. According to W-L, key aspects of LENRs involve weak interactions that can occur in a variety of different environments under relatively 'mild' physical conditions. 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.

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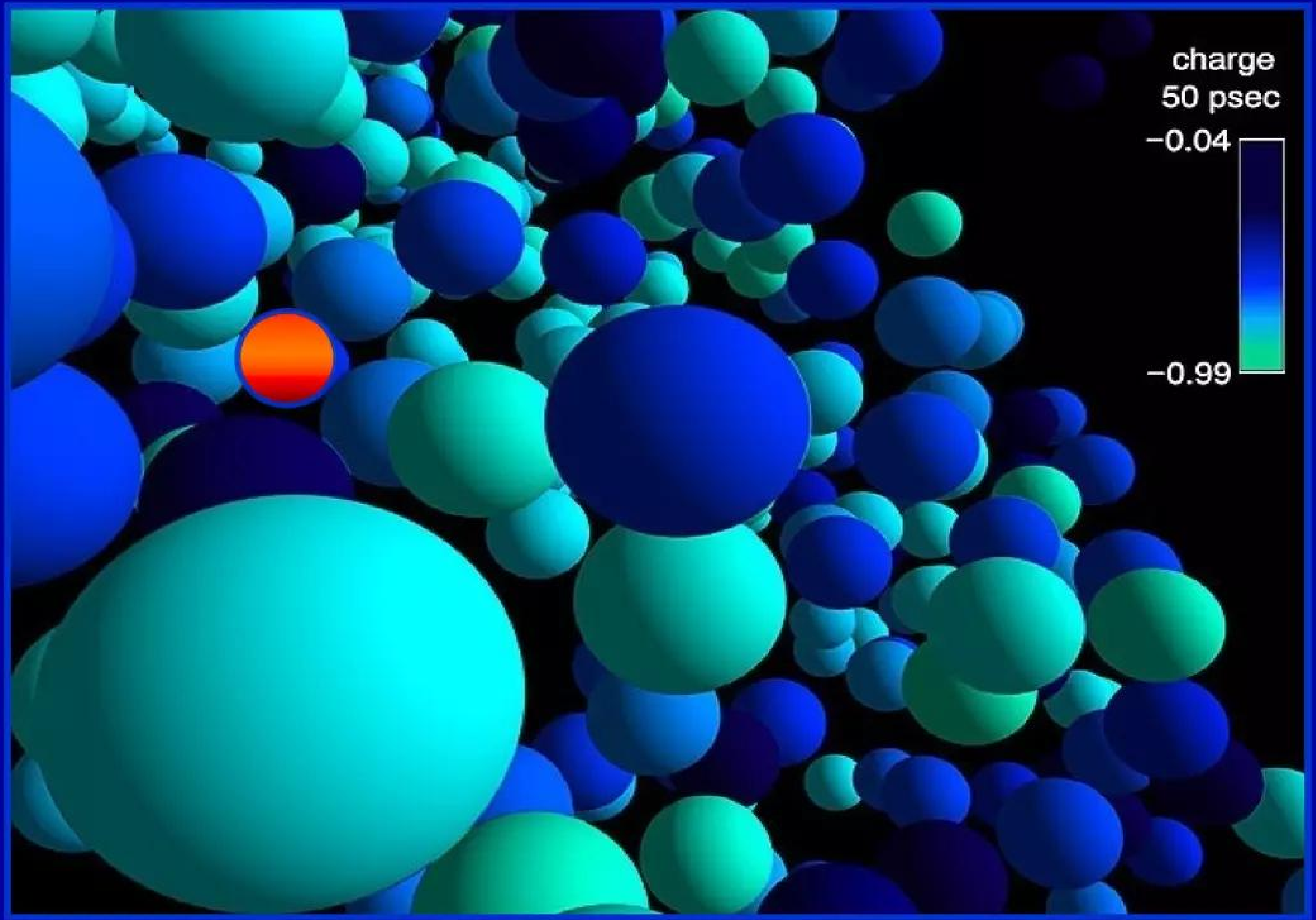
Recapping W-L in condensed matter metallic hydrides

Many-body collective effects are very important in LENRs



"I am increasingly persuaded that all physical law we know about has collective origins, not just some of it."

Robert Laughlin, "A Different Universe – Reinventing Physics from the Bottom Down," 2005

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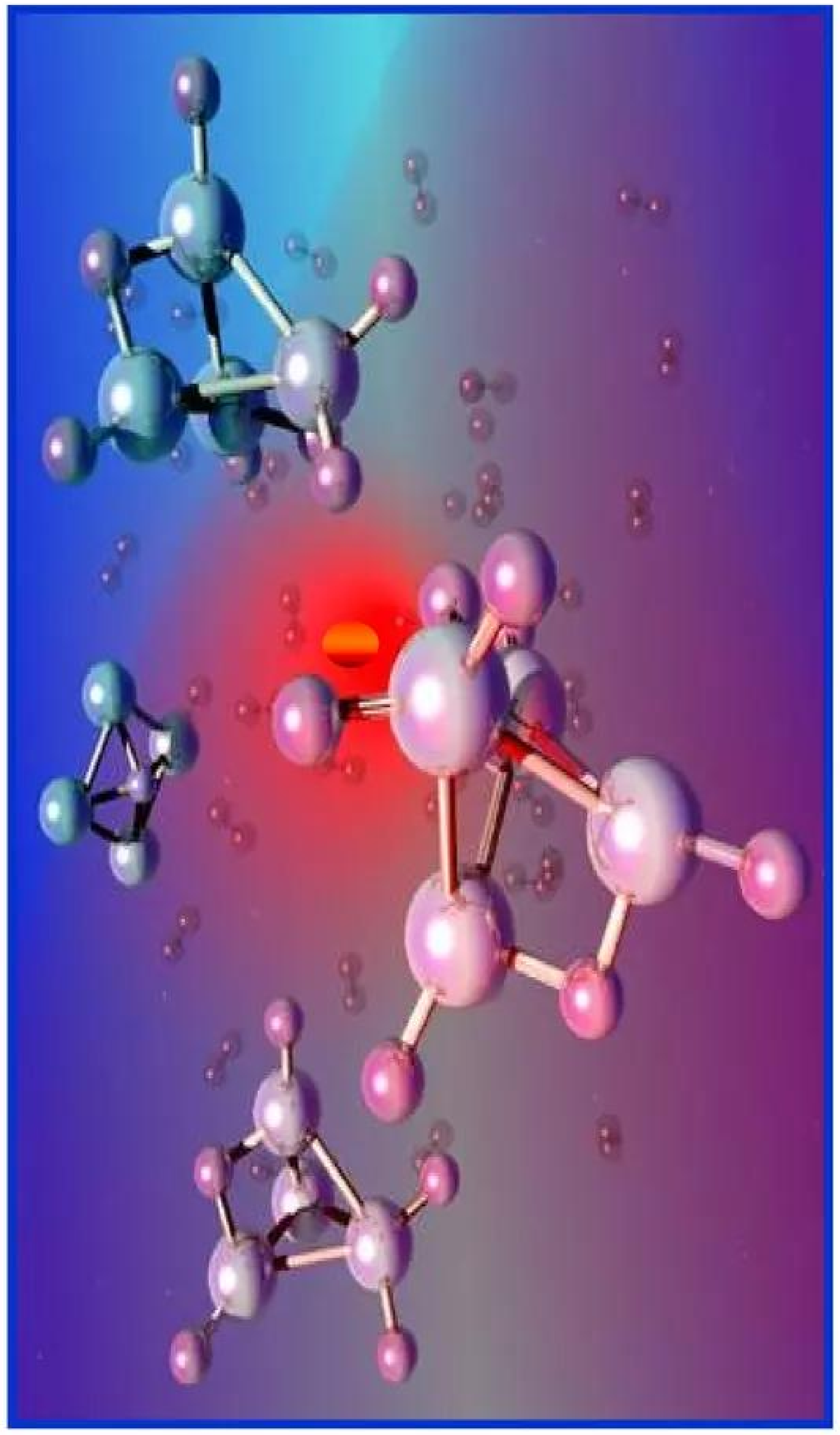
Creation of ULM neutrons on loaded hydride surfaces - I

- ✓ Hydride forming elements, e.g., Palladium (Pd), Nickel (Ni), Titanium (Ti), etc. can be viewed as akin to metallic 'sponges' that can absorb significant amounts of hydrogen isotopes in atom % via 'loading' mechanisms
- ✓ Analogous to loading a bone-dry sponge with H_2O by gradually spilling droplets of water onto it, hydrogen isotopes can actually be 'loaded' into hydride-forming metals using different techniques, e.g., various levels of DC electric currents, pressure gradients, etc.
- ✓ Just prior to entering a metallic lattice, molecules of hydrogen isotopes dissociate, become monatomic, and then ionize by donating their electrons to the metallic electron 'sea,' thus becoming charged interstitial lattice protons (p^+), deuterons (d^+), or tritons (t^+) in the process
- ✓ Once formed, ions of hydrogen isotopes migrate to and occupy specific interstitial structural sites in metallic hydride bulk lattices; this is a material-specific property



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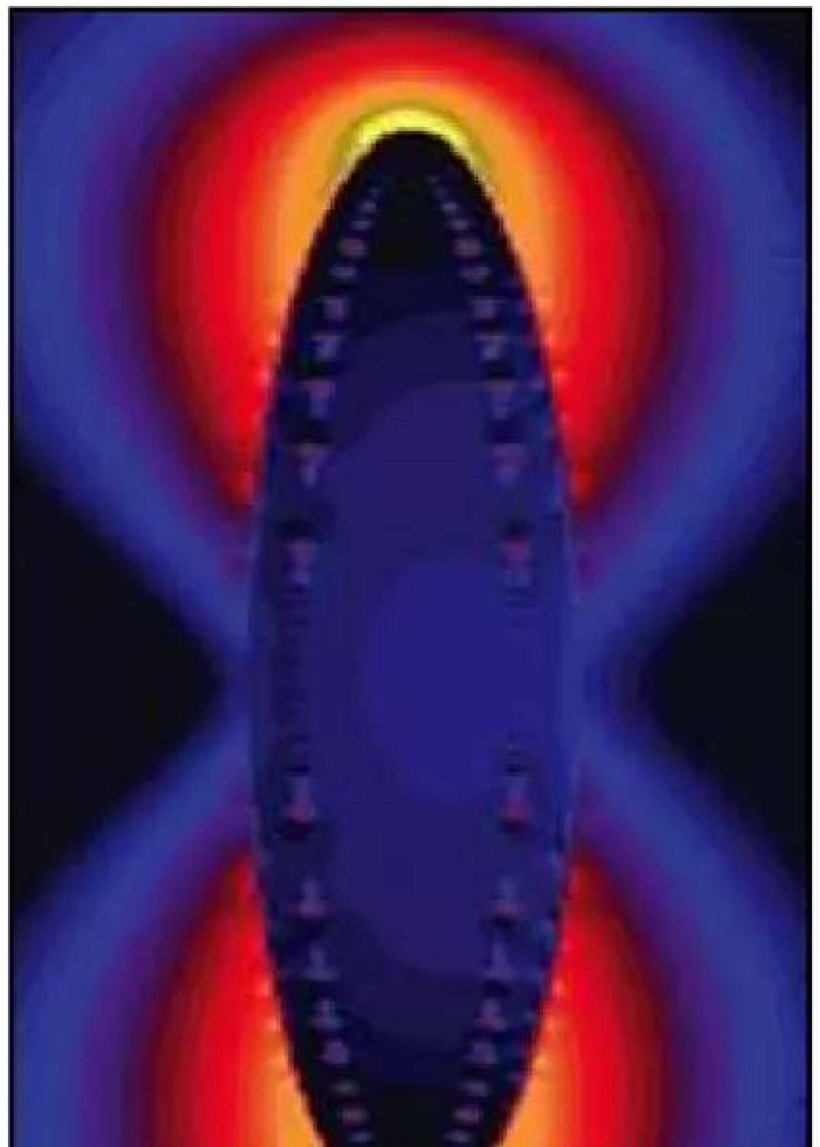
Creation of ULM neutrons on loaded hydride surfaces - II

- ✓ When all available interstitial sites in the interior of a bulk lattice are occupied by hydrogenous ions, a metallic hydride is 'fully loaded,' i.e., saturated. At that point, a dynamic balance between loading and deloading begins (so-called "breathing" mode) during which some of those ions start 'leaking back out' of the bulk onto the surface. This localized deloading is a dynamic process, occurring in discrete, island-like, micron-scale surface 'patches' or 'droplets' (scattered randomly across the surface) comprised of many contiguous p+, d+, and/or t+ ions (or admixtures thereof)
- ✓ Homogeneous (limited % admixtures; too large % will destroy coherence) collections of p^+, d^+, or t^+ found in many-body patches on loaded metallic hydride surfaces oscillate in unison, collectively and coherently; their QM wave functions are effectively 'entangled.' Such coherence has been demonstrated in many experiments involving deep inelastic neutron- and electron-scattering measurements on loaded hydrides
- ✓ Collective oscillations of hydrogenous ions in many-body surface patches set the stage for local breakdown of the Born-Oppenheimer approximation; this enables loose electromagnetic coupling between p^+, d^+, or t^+ ions located in patches and nearby 'covering' surface plasmon polariton (SPP) electrons. B-O breakdown creates nuclear-strength local electric fields (above 10^{11} V/m) in and around such patches. Effective masses of SPP electrons (e-) exposed to very large local electric fields are thereby increased (e-*), enabling neutron production via e-* + p^+, e-* + d^+, e-* + t^+ reactions above isotope-specific threshold values for E-M field strength



Electric fields surrounding "nanorice" – Au coating on hematite core

<u>**See**</u>*: A. Bushmaker et al., "Direct observation of Born-Oppenheimer approximation breakdown in carbon nanotubes" in Nano Lett. 9 (2) pp. 607-611 Feb. 11, 2009*

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Local capture of ULM neutrons on loaded hydride surfaces

- ✓ 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), ULMNs have huge QM DeBroglie wavelengths (up to <u>microns</u>) and extraordinarily large capture cross-sections on nearby nuclei; virtually all will be locally absorbed; not detectable as 'free' neutrons

- ✓ For the vast majority of stable and unstable isotopes, ULM neutron capture cross-sections are directly related to ~1/v, where v is the neutron velocity in m/sec. Since v is extremely small for ULM neutrons, their capture cross-sections on atomic nuclei will therefore be correspondingly large relative to cross-sections measured at thermal energies where v = 2,200 m/sec and the neutron DeBroglie wavelength is ~2 Angstroms. After being collectively created, virtually all ULMNs will be locally absorbed <u>before</u> any scattering on lattice atoms can elevate them to thermal kinetic energies; per S. Lamoreaux (Yale) thermalization would require ~0.1 to 0.2 msec, i.e. 10^{-4} sec., a long time on typical 10^{-19} - 10^{-22} sec. time-scale of nuclear reactions

→ *Ultra low momentum neutrons have enormous absorption cross-sections on 1/v isotopes. For example, Lattice has estimated ULMN fission capture cross-section on U-235 @ ~1 million barns and on Pu-239 @ 49,000 barns (b), vs. ~586 b and ~752 b, respectively, for neutrons @ thermal energies. A neutron capture expert recently estimated ULMN capture on He-4 @ ~20,000 b vs. value of <1 b for thermal neutrons*

By comparison, the highest known thermal capture cross section for any stable isotope is Gadolinium-157 @ ~49,000 b. The highest measured cross-section for any unstable isotope is Xenon-135 @ ~2.7 million b

Weak interaction processes are very important in LENRs

1. **E-M radiation on metallic hydride surface increases mass of surface plasmon electrons**

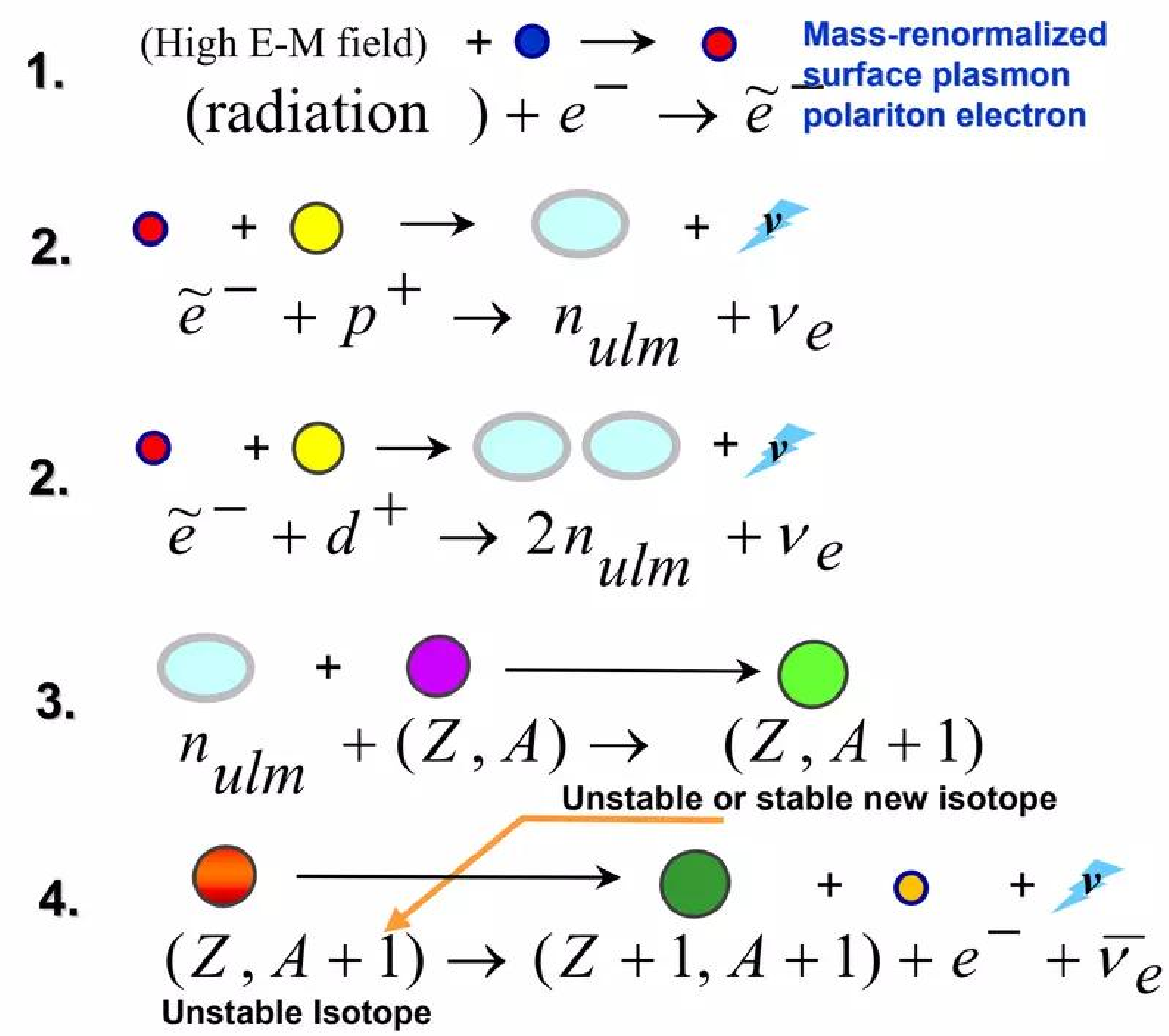
2. **Heavy-mass surface plasmon polariton electrons react directly with surface protons (p^+) or deuterons (d^+) to produce ultra low momentum (ULM) neutrons (n_{ulm} or $2n_{ulm}$, respectively) and an electron neutrino (ν_e)**

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

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

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

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

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

➡ ***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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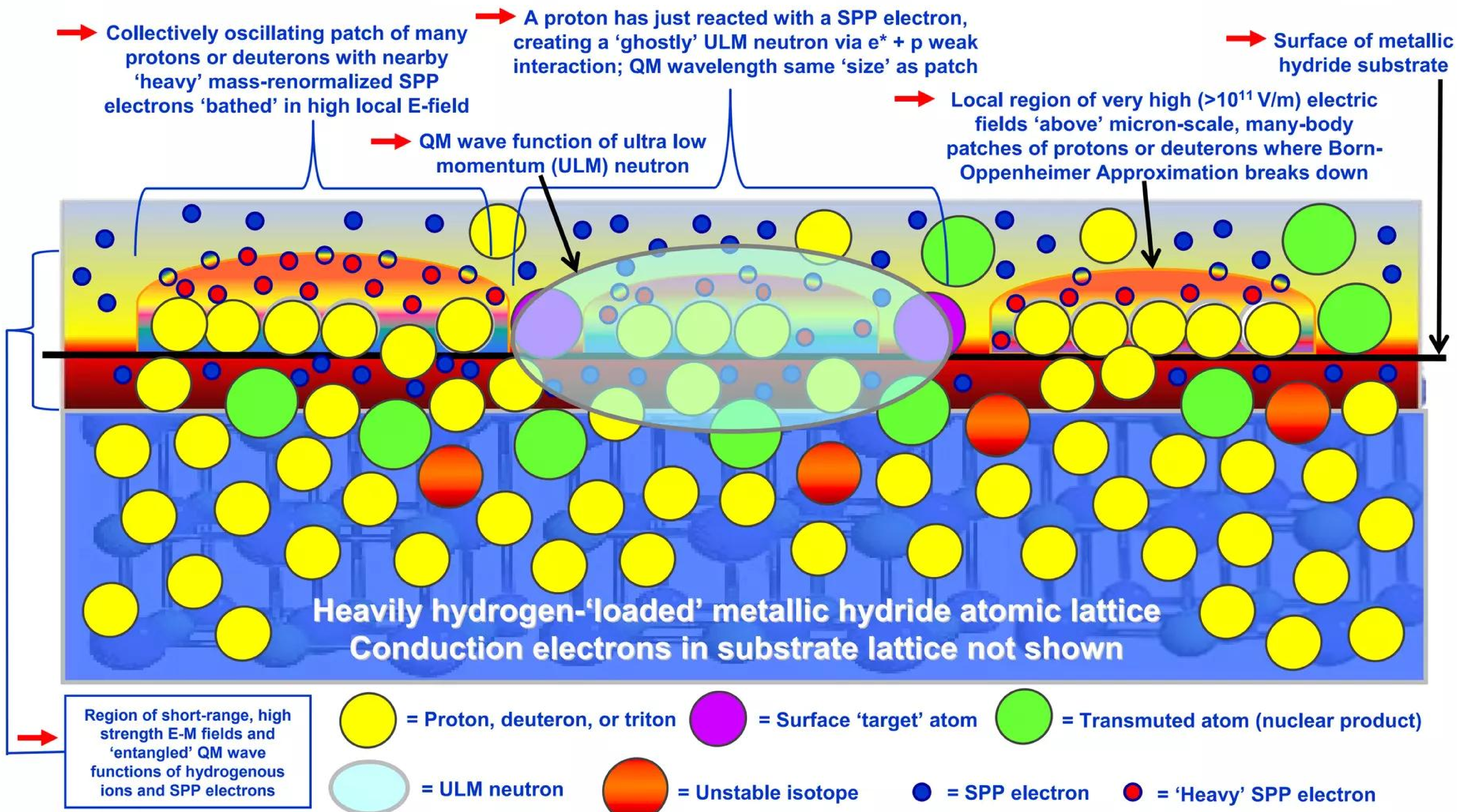
Conceptual details: W-L mechanism in metallic hydrides

Side view – not to scale – charge balances in diagram only approximate



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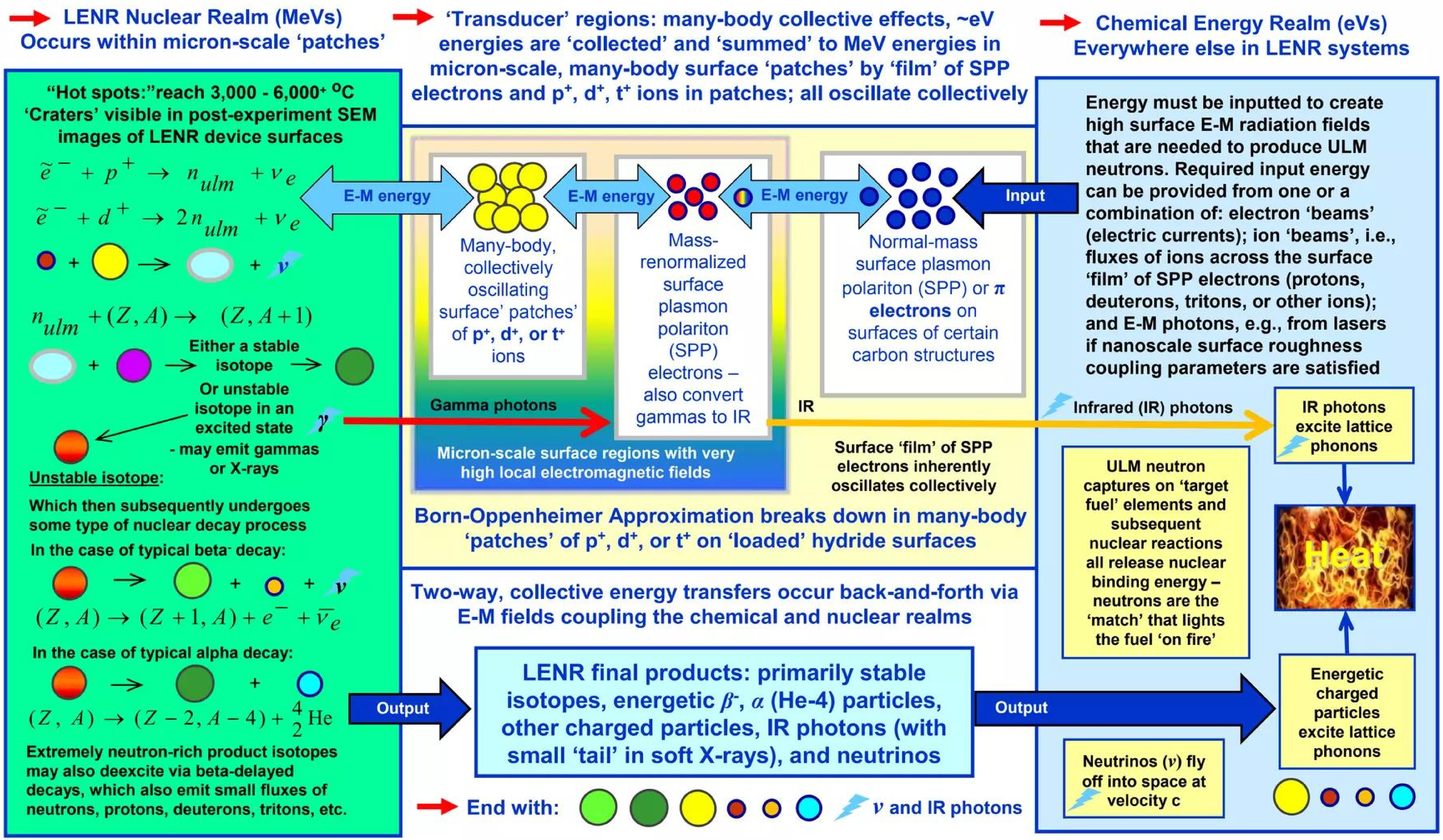
High level overview: W-L mechanism in condensed matter

Chemical and nuclear energy realms can interconnect in small regions



Transmutation products correlated with surface structures

Nuclear products associated with intense localized heat production

- ✓ Please see Zhang and Dash paper for details
- ✓ With Palladium (Pd) as a 'target element' present on Pd cathode surface, Silver (Ag) is experimentally observed; likely to be direct product of ULM neutron captures on Pd with beta decays to Ag isotopes
- ✓ In a SEM image from their paper (copied below) they directly correlate LENR transmutation products with specific sites on post-experiment surface structures:

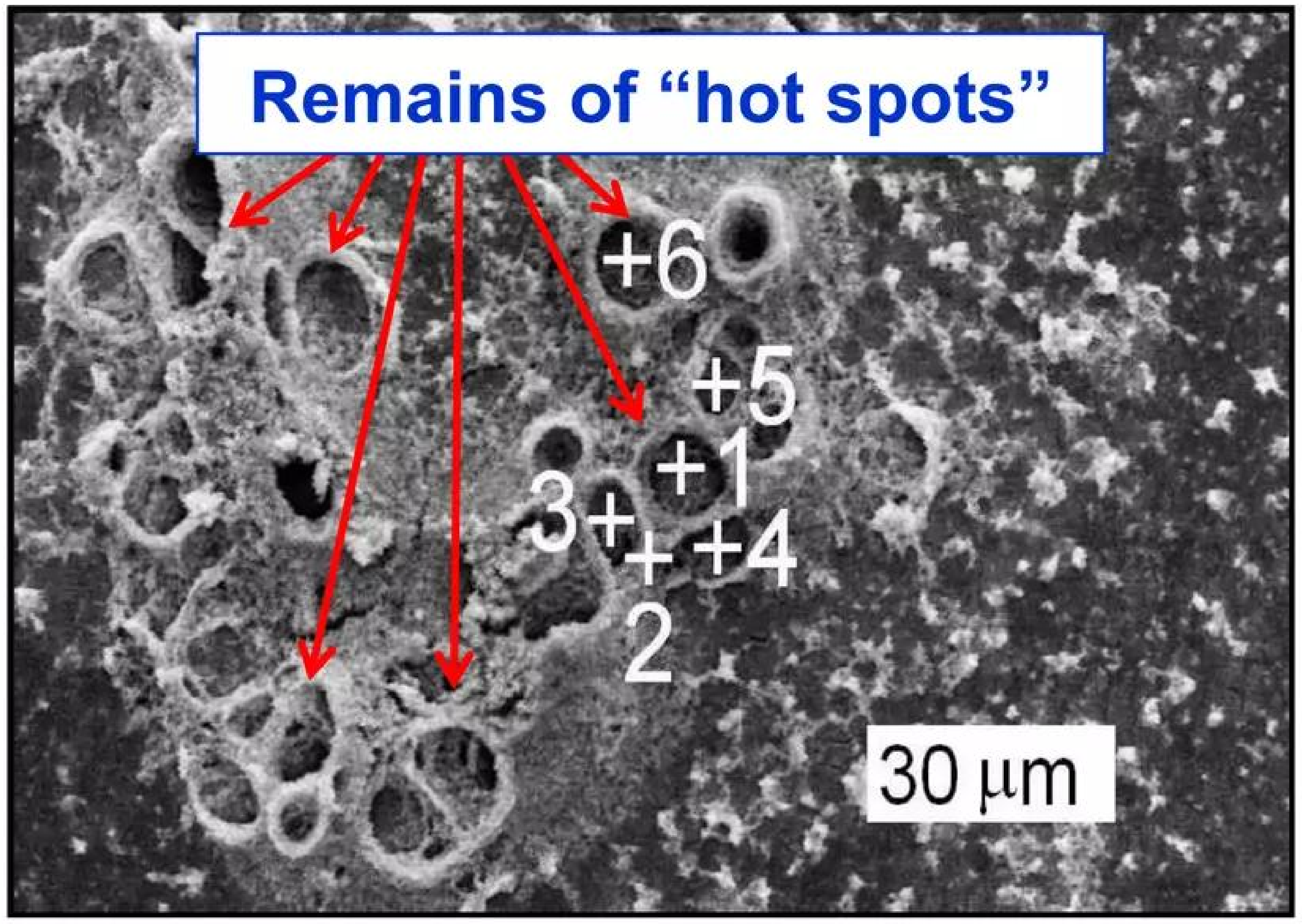


Fig. 8 on p. 14: "most common finding is that Ag occurs in craters"

➞ ***See**: 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

➞ ***Note**: Their observations of Nickel (Ni) on the Pd cathode surfaces, if correct, may have resulted from LENR ULM neutron captures on Iron (Fe) that somehow 'leached-out' of the walls of the Pyrex glass vessel comprising the cell containing the electrolyte. It is well known that metallic elements that are compositionally present in Pyrex can leach from glass during very long exposure to hot electrolytes under such experimental conditions. Fe is known to be a minor constituent in many types of Pyrex, e.g., Corning #7740 Fe_2O_3 = 0.04%. Such embedded Fe could potentially leach out of the walls of a Pyrex electrolytic cell into the electrolyte and migrate to the cathode surface, where it could provide yet another local 'target element' able to absorb LENR ULM neutrons and be transmuted*

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Can't boil tea, but LENRs can boil metals on a 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

→ ***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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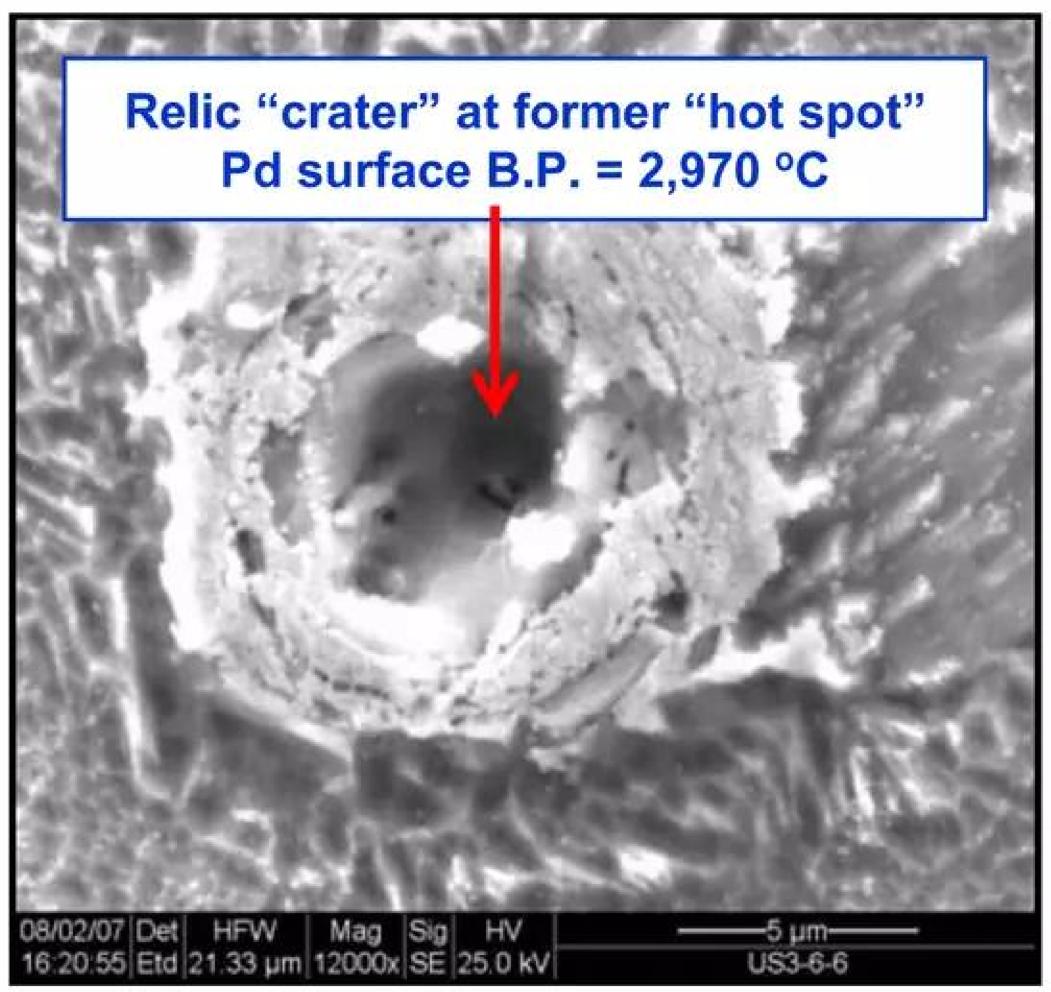
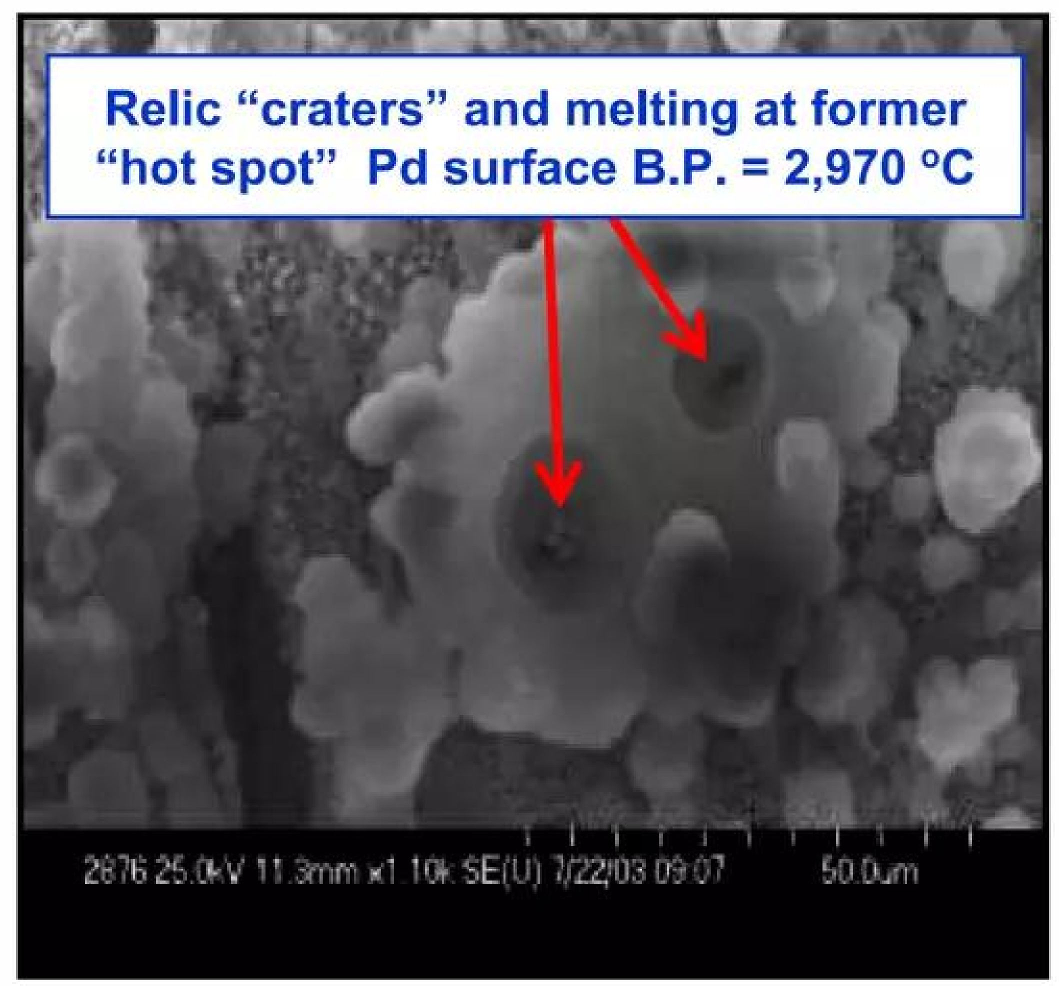
SEM images of LENR post-experiment surface features

View the evidence and form your own conclusions about such structures

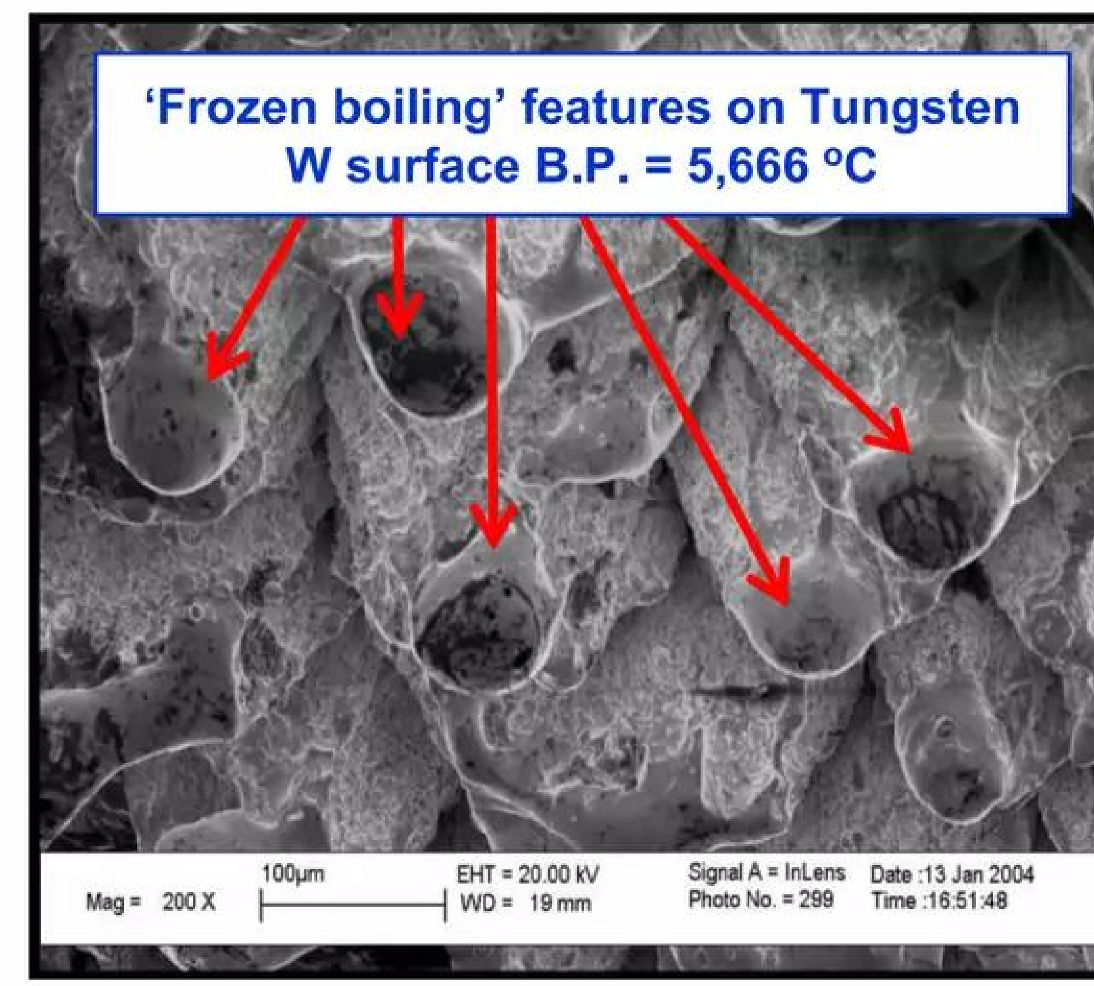
- ✓ Readers encouraged to examine reported SEM images of LENR surface features
- ✓ To find more images, please go to the free website: www.lenr-canr.org as noted before, several hundred downloadable papers are available thereon
- ✓ Here are additional examples of SEM images from various LENR researchers:



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

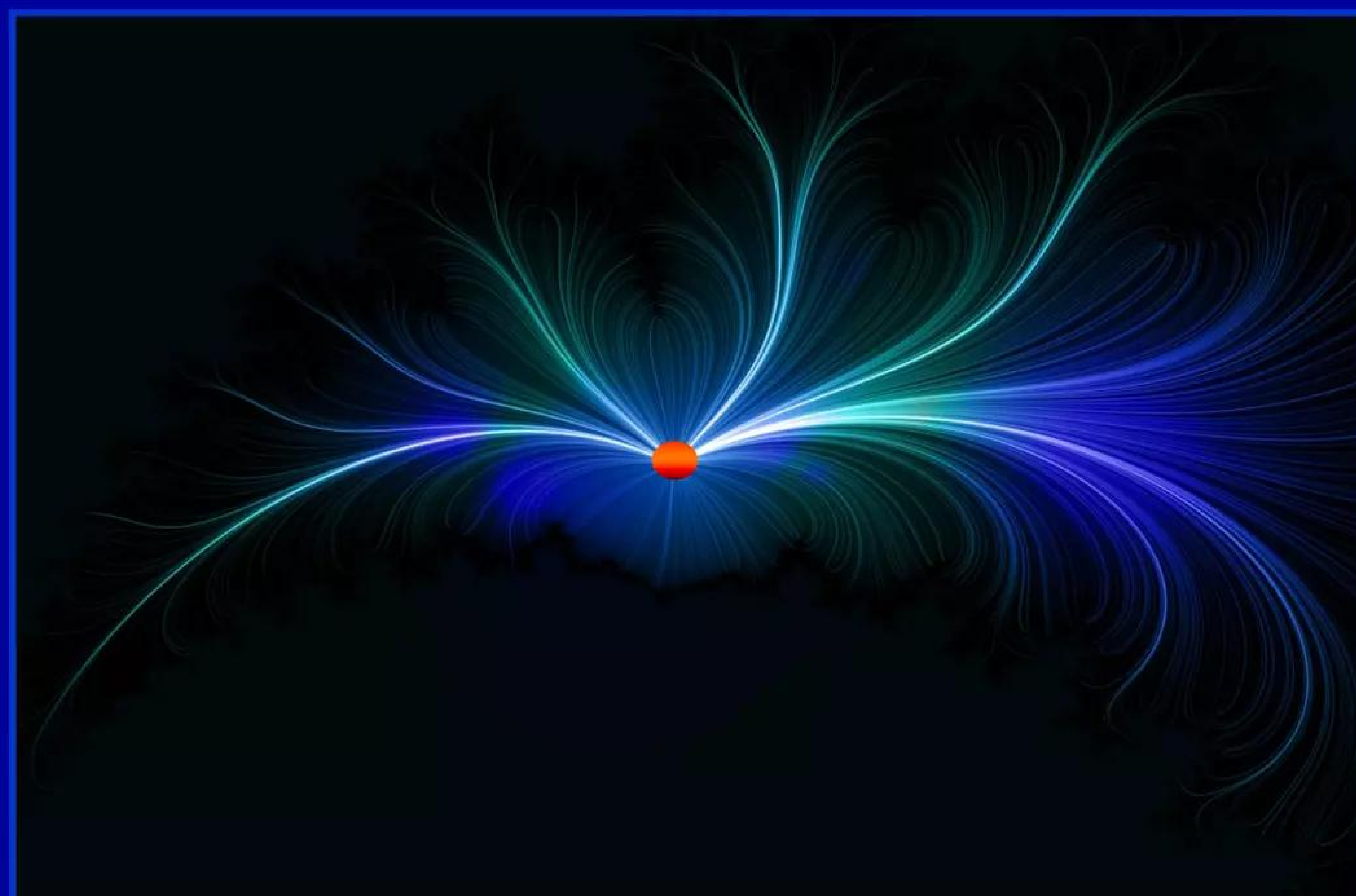


Pd surface: image source is US Navy SPAWAR (San Diego, CA)



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

Recapping LENR carbon-seed nucleosynthetic networks



Advance of a new scientific paradigm involves, "… handling the same bundle of data as before, but placing them in a new system of relations with one another by giving them a different framework."

Herbert Butterfield, "The Origins of Modern Science," London 1949

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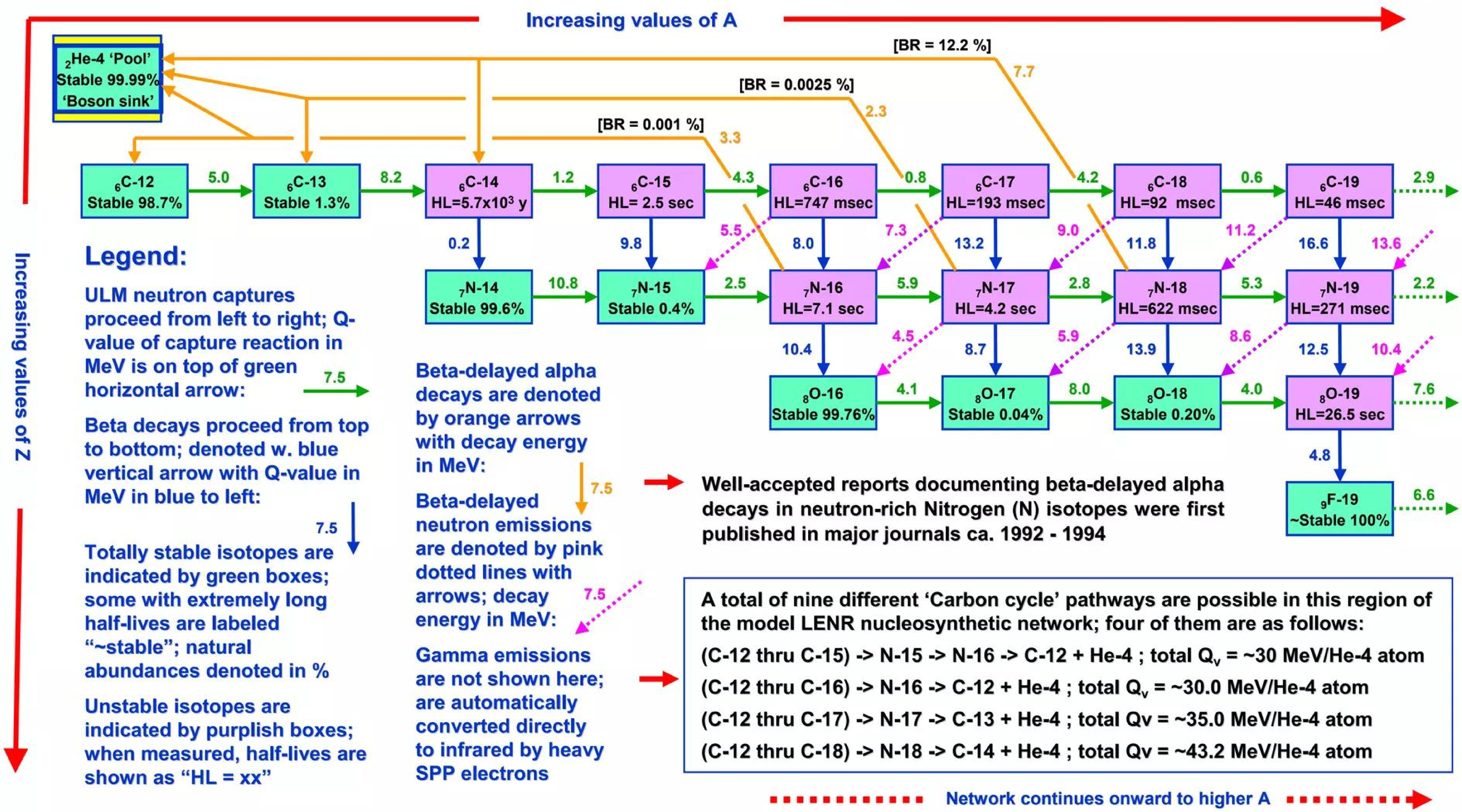
ULMN catalyzed LENR network starting from $_6C^{12}$ - I

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



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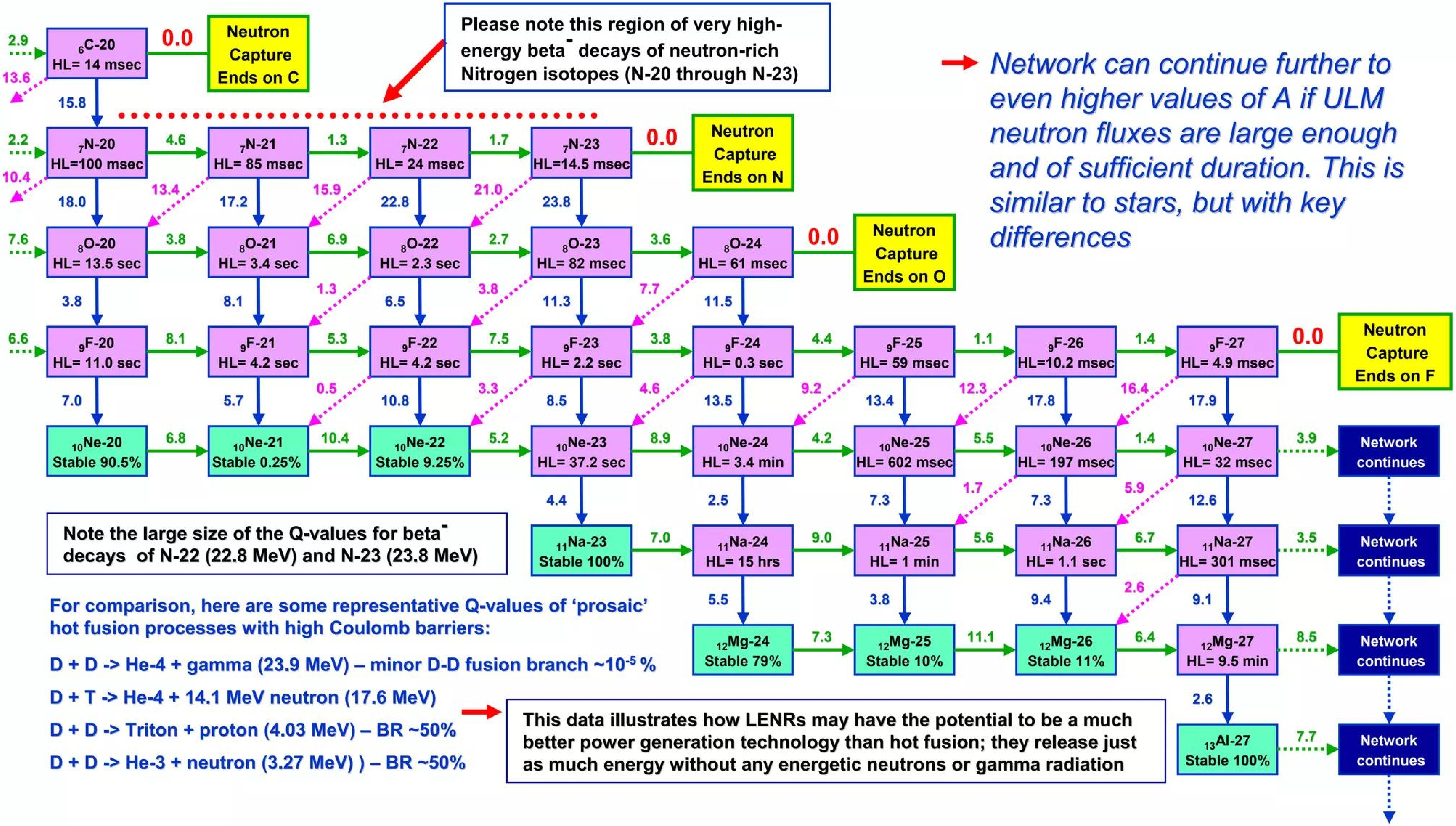
ULMN catalyzed LENR network starting from $_6C^{12}$ - II



Please note this region of very high-energy beta$^-$ decays of neutron-rich Nitrogen isotopes (N-20 through N-23)

Network can continue further to even higher values of A if ULM neutron fluxes are large enough and of sufficient duration. This is similar to stars, but with key differences

Note the large size of the Q-values for beta$^-$ decays of N-22 (22.8 MeV) and N-23 (23.8 MeV)

For comparison, here are some representative Q-values of 'prosaic' hot fusion processes with high Coulomb barriers:

D + D -> He-4 + gamma (23.9 MeV) – minor D-D fusion branch ~10^{-5} %

D + T -> He-4 + 14.1 MeV neutron (17.6 MeV)

D + D -> Triton + proton (4.03 MeV) – BR ~50%

D + D -> He-3 + neutron (3.27 MeV)) – BR ~50%

This data illustrates how LENRs may have the potential to be a much better power generation technology than hot fusion; they release just as much energy without any energetic neutrons or gamma radiation

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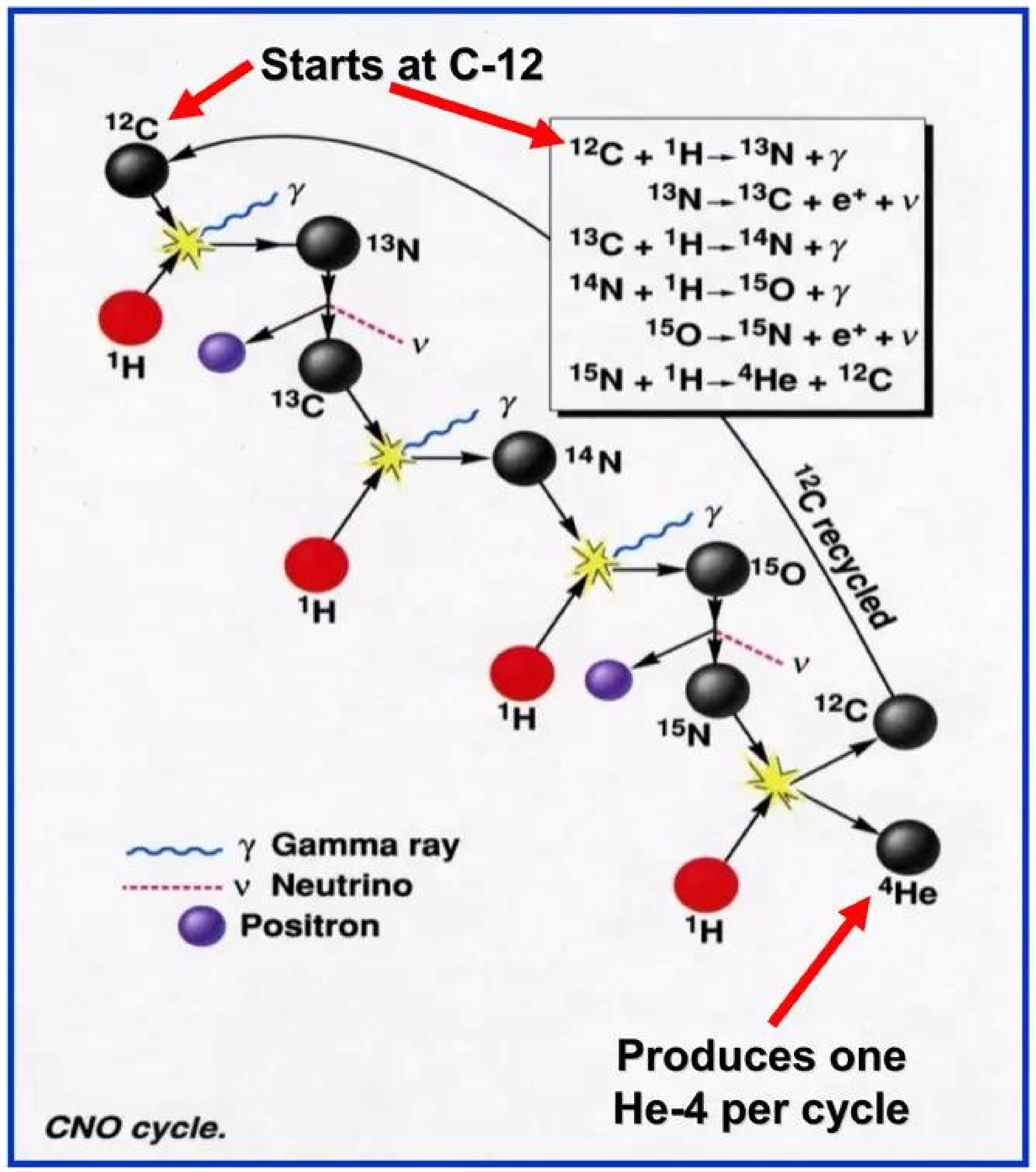
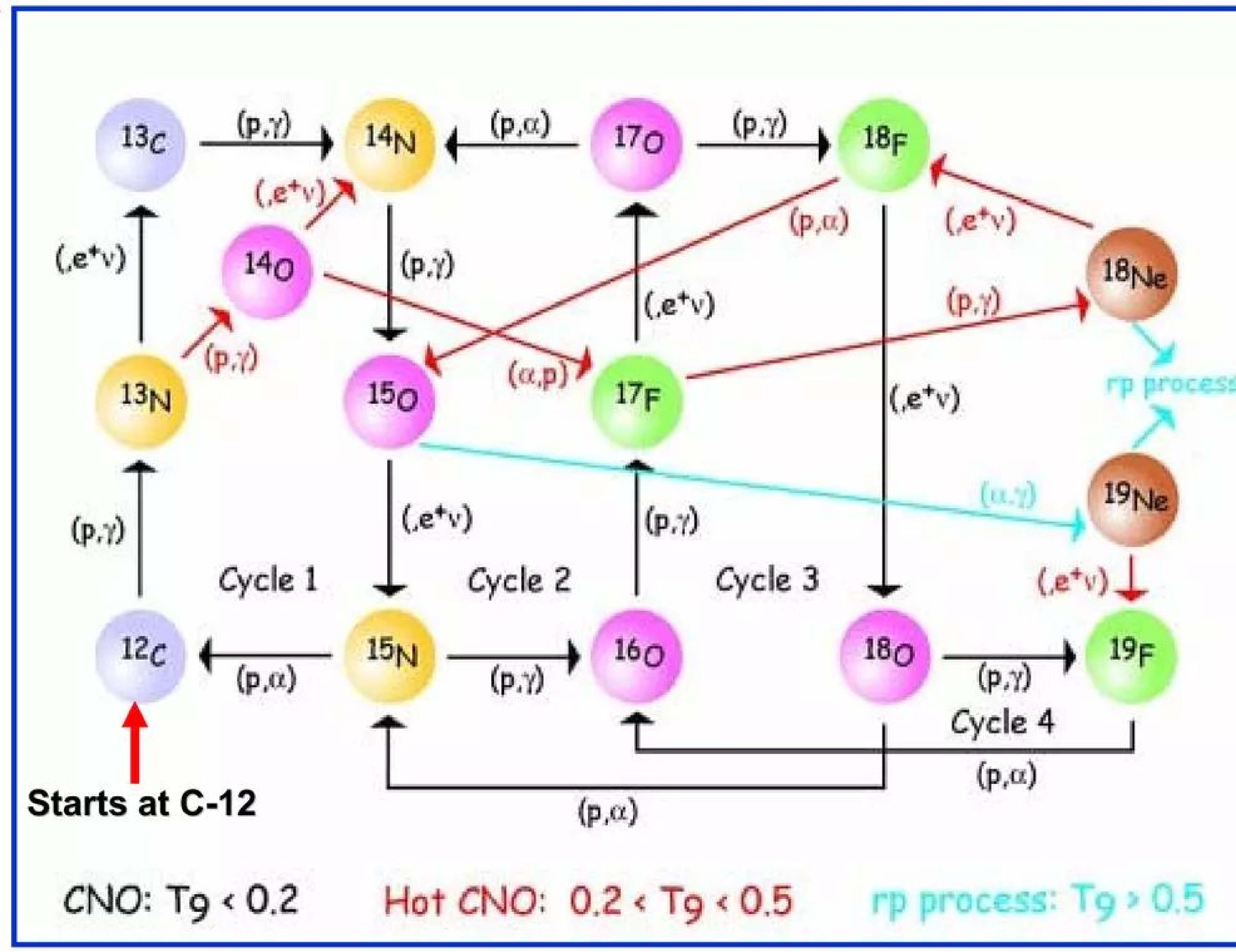
ULMN catalyzed LENR network starting from $_6C^{12}$ - III

Here is how <u>fusion-based</u> carbon cycles are thought to operate in stars

Cycle 1: stellar CNO nucleosynthetic cycle



Cycles 1 – 4: CNO + 3 nucleosynthetic cycles thru Ne-18 and Ne-19



<u>Comments</u>: in the stellar CNO cycle only C-12 is recycled; in LENR-based carbon cycles, C-12, C-13, and C-14 are all potentially regenerated. In general, ULMN catalyzed nucleosynthetic networks involve production of substantially more neutron-rich isotopes than stellar networks, e.g., C-14⇨C-20; N-14⇨N-23; O-19⇨O-24; F-19⇨F-27; and Ne-20 ⇨Ne-27. Alpha decays are far more common events in low-A stellar fusion processes

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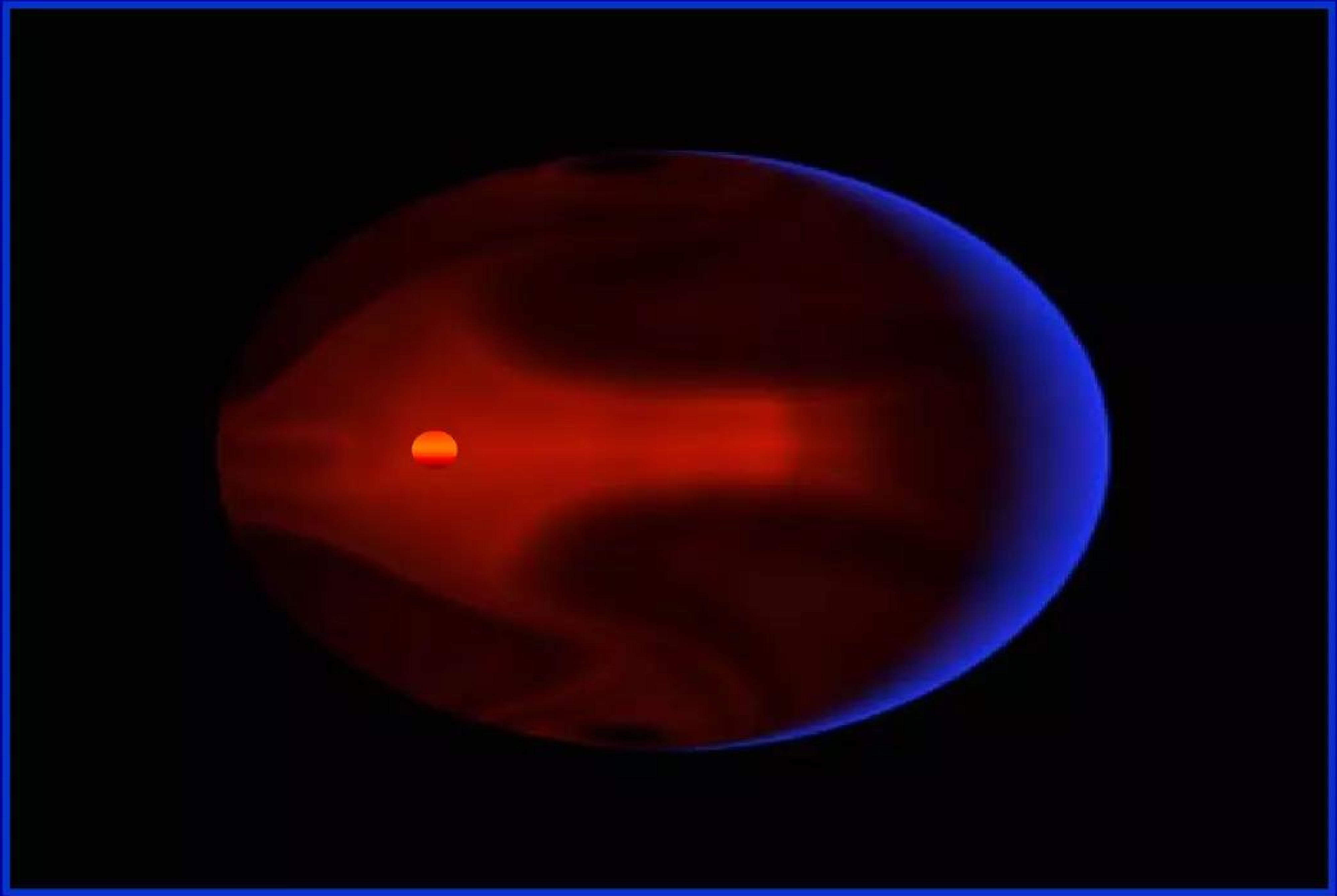
2008: Mizuno's LENR experiments with phenanthrene



"The central theme of alchemy is the search for the secret of transmutation … Alchemists believed that the transmutation of metals was physically possible and they strived to bring this about in their laboratories. As historians of science grudgingly admit, many useful chemical processes came to light through these experiments." The centerpiece apparatus of a well-equipped medieval alchemist's laboratory was an "athanor," a large tower-shaped clay or brick oven which functioned as "a self-feeding furnace, designed to maintain a uniform temperature and provide heat for alchemical digestion."

Quoted from multiple modern sources

Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - I

Gas phase hydrogenation - measured excess heat and transmutation products

- ✓ Details of these experiments are described in the two different, non-refereed papers cited to the right
- ✓ Primary goals of the experiments were to measure: (a.) excess heat with crude calorimetry based on temperature differentials observed between 4 calibrated R-type thermocouples (87% Pt; 13% Rh); (b.) nuclear transmutation products using an ULVAC REGA201 mass spectrometer; and (c.) high energy photon (X-ray or gamma) emissions, if any, using an Aloka TCS-161 NaI scintillation detector
- ✓ **Comments:** Mizuno has successfully measured heat and transmutation products many times in the past; those results in this new phenanthrene work can potentially be useful measurements. By contrast, his reported "gamma" emissions in these two papers are rather unclear and questionable. Beyond a nonstandard presentation format, a nationally recognized expert on gamma spectroscopy examined his claimed gamma observations and concluded that they were "unclear, inconclusive, and indeterminate."

Please see:

→ *T. Mizuno and S. Sawada., "Anomalous heat generation during hydrogenation of carbon (phenanthrene)" ICCF-14 conference, Washington, DC (2008)*

Free document available online at:

http://www.lenr-canr.org/acrobat/MizunoTanomaloushb.pdf [23 pages]

A differently reported version of much of the same experimental data can be found in:

→ *H. Kozima and T. Mizuno, "Nuclear transmutations in hydrocarbons: polyethylene (XLPE) films and phenanthrene on Pt mesh substrate," Reports of CFRL (Cold Fusion Research Laboratory), 8-4, pp. 1 – 18, October 2008*

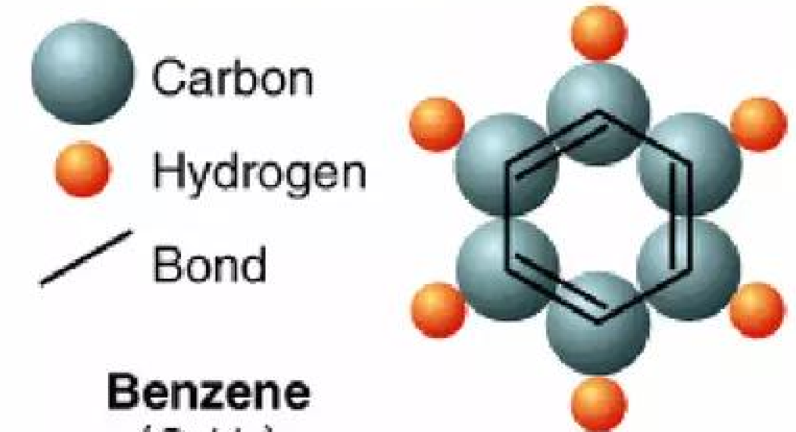
Free document available online at:

http://www.geocities.jp/hjrfq930/Papers/paperr/paperr18.pdf [18 pages]

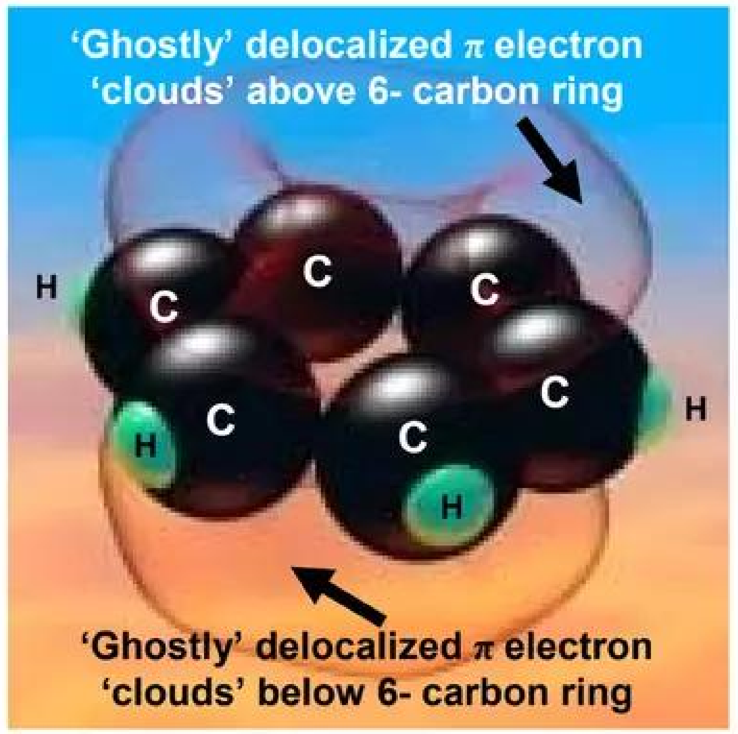
Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - II

Polycyclic aromatic hydrocarbons (PAHs) and phenanthrene

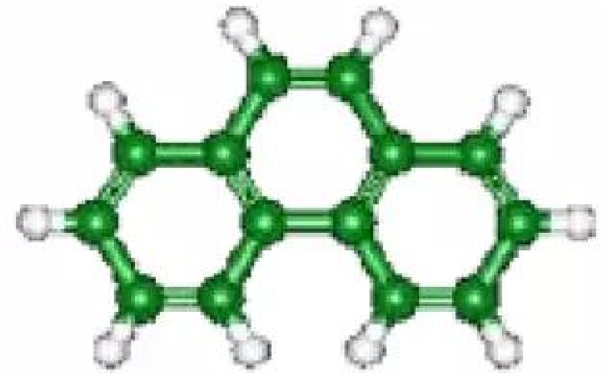
- ✓ These are new, innovative, and very different types of LENR experiments - have not previously been done in the field
- ✓ Specifically, hydrogenation of relatively common type of aromatic hydrocarbon, phenanthrene, appears to be associated with nuclear reactions and transmutations
- ✓ Phenanthrene is member of large family of C-H organic molecules: polycyclic aromatic hydrocarbons (PAHs); they are distinguished by having from two up to ten 6-carbon benzene rings bonded along their 'edges' – are pollutants produced during incomplete combustion of hydrocarbons
- ✓ <u>Unsaturated</u> phenanthrene has chemical formula $C_{14}H_{10}$ - additional hydrogen atoms (effectively protons) can be added to 'load' or 'saturate' its three benzene rings via catalytically assisted hydrogenation that consists of heating solid phenanthrene under pressure in the presence of hydrogen gas and a Pt catalyst in a sealed reactor vessel
- ✓ Assisting hydrogenation is one role of Pt in experiments; is analogous to loading H/D into Pd in an LENR electrolytic cell



Benzene
(C_6H_6)



Benzene showing π electron 'clouds': π electrons, carbon atoms and protons (H) all in very close physical proximity



Unsaturated phenanthrene
($C_{14}H_{10}$)

Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - III

High-level overview of the experiments

- Solid phenanthrene (1 gram – 99.5% pure) and Pt "catalyzer" (5 cm x 10 cm rectangular mesh weighing ~27.8 gms – 99.99% pure) were placed into a metallic reactor vessel; its top lid was then bolted shut
- Reactor vessel was then connected to a vacuum system and pumped down to ~10^{-3} mm/Hg
- Hydrogen gas (99.99% pure: impurities in ppm were O_2 = 5; N_2 = 50; CO = 1; CO_2 = 21; hydrocarbons <1) was then admitted into the reactor vessel (Inconel 625 is 56 mm OD, 26 mm ID, 160 mm in length, 0.1 L volume, rated for 500 atm; SUS 316L vessel is 15 mm OD, 9 mm ID, 300 mm in length, 0.02 L volume, rated for < 200 atm) – experimental pressures ranged from 37 - 60 atm
- After filling with pure hydrogen, an Inconel 625 or SUS 316L reactor vessel was heated with a 2 kW electric furnace; maximum temperatures reached was ~700^o C
- Reactor vessel was then allowed to 'cook' at various temperatures for varying periods that ranged up to ~10 days. During that time, heat production and radiation were monitored. At the end of a given experiment, gas and residues remaining in the metallic reactor vessel were analyzed with sensitive mass spectroscopy

Composition of vessels and Pt mesh "catalyzer" in contact with hydrogen gas and gasified hydrocarbons:

→ ***Inconel 625:*** *family of austenitic nickel-chromium (Ni-Cr) based superalloys that are typically used in high temperature applications. Forms passive oxidized layer upon heating that resists corrosion. Inconel 625 contains approximately: 58% Ni; 20 – 23% Cr; 5% Fe; as well as 8 - 10% Mo; 3.15 – 4.15% Nb; 1% Co; 0.5% Mn; 0.4% Al; 0.4% Ti; 0.5% Si; 0.1% C; 0.015% S; and 0.015% P*

→ ***SUS 316L:*** *family of standard, molybdenum-bearing austenitic stainless steels (Fe). Grade 316L is a low-carbon version that is immune to grain boundary carbide precipitation. This grade of stainless Fe contains a maximum of approximately: 0.03% C; 2.0% Mn; 0.75% Si; 0.045% P; 0.03% S; 18% Cr; 3% Mo; 14% Ni; and 0.10%N*

→ ***Pt mesh "catalyzer":*** *high purity (99.99%) Platinum mesh supplied by Tanaka Noble Metal Co., Ltd*

Note: from a compositional standpoint the materials found inside Mizuno's reactor vessels are relatively well-characterized. This is very important when assessing the results of mass spectroscopy analyses undertaken to detect the presence of nuclear transmutation products in LENR experiments

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Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - IV

Schematic diagram of Mizuno's experimental setup with reactor vessels

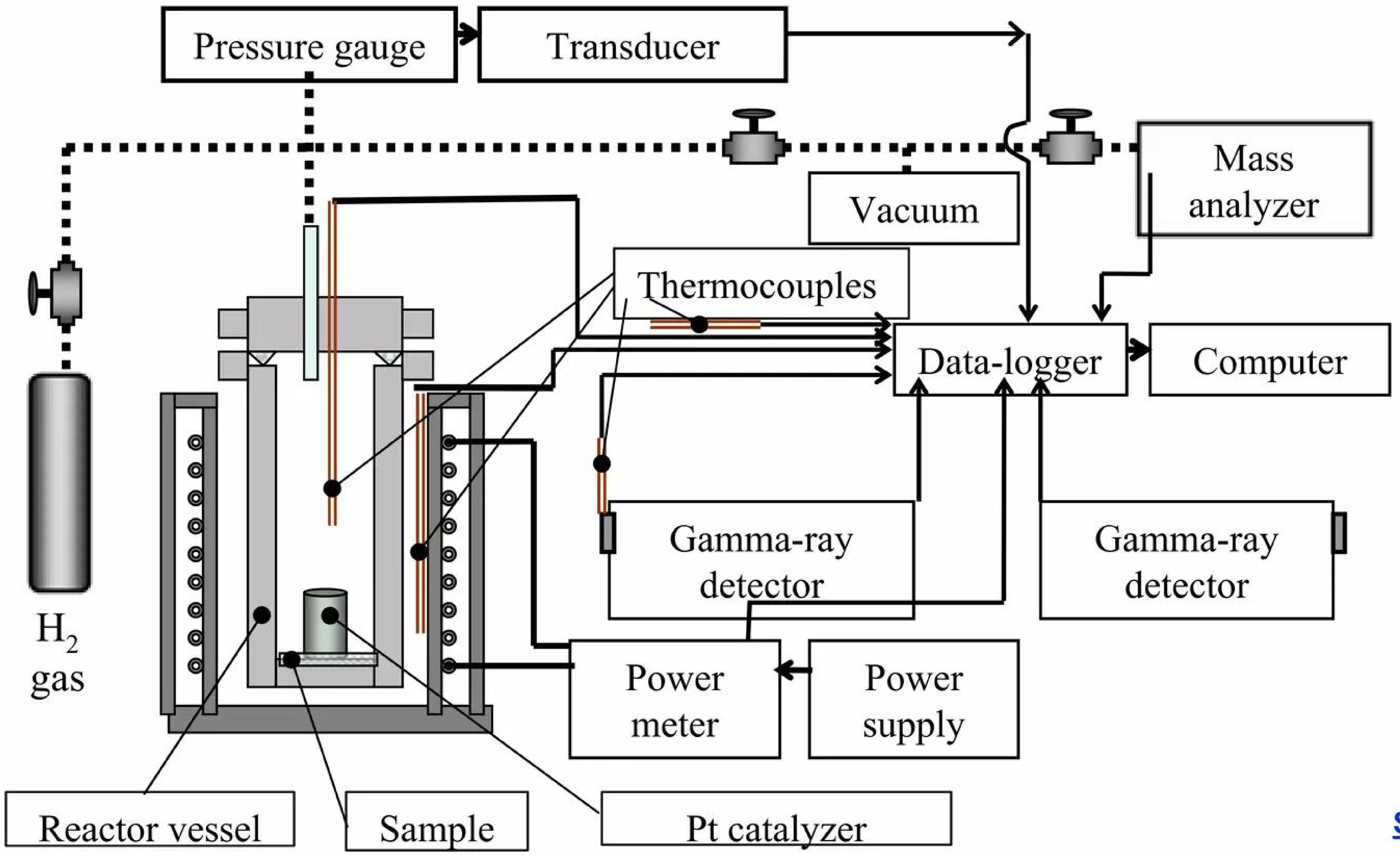
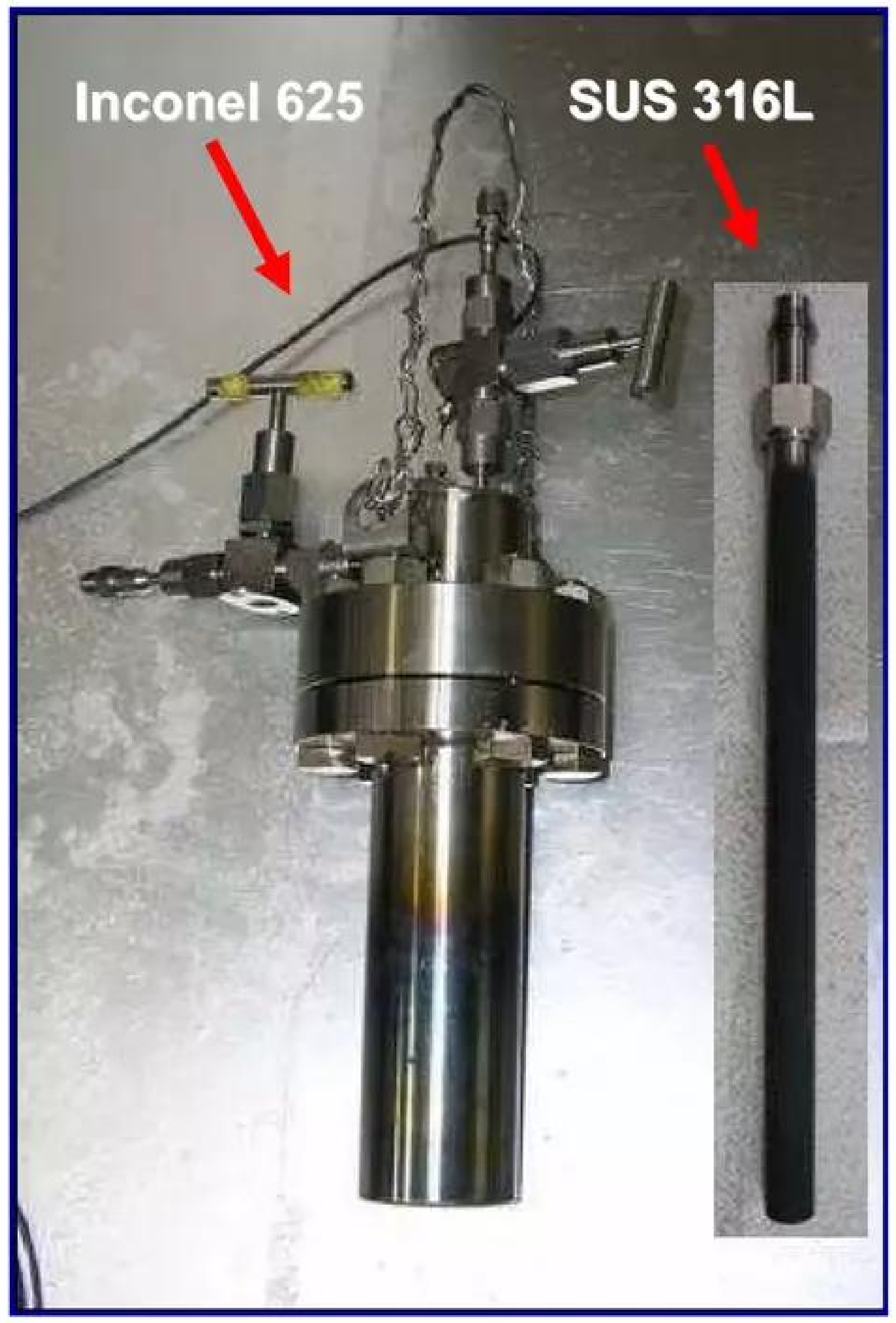


Photo of both reactor vessels



Source: Mizuno ICCF-14 presentation

Note: graphic adapted from Mizuno's 2009 ICCF-15 conference presentation

Source: T. Mizuno, ICCF-15 Presentation, Frascati, Italy October 2009, at http://iccf15.frascati.enea.it/ICCF15-PRESENTATIONS/S7_O8_Mizuno.pdf

Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - V

Summary of overall experimental conditions

Table 1. Cell conditions for the five runs shown in Fig. 20

		Reaction Cell Conditions		
Cell Status or Contents	Symbol	Pressure (atm)	Temperature (°C)	Gas Volume (L)
Excess heat made	● (red)	37	650	0.33
No excess heat	● (blue)	60	605	0.56
No Pt catalyst	▲	54	645	0.48
No phenanthrene	◆	38	660	0.33
No H_2 gas	□	0.33	350	0.004

Source: adapted directly from Mizuno and Sawada, ICCF-14 presentation, slide #19

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Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - VI

Summary of mass spectroscopy results for gaseous reaction products - I

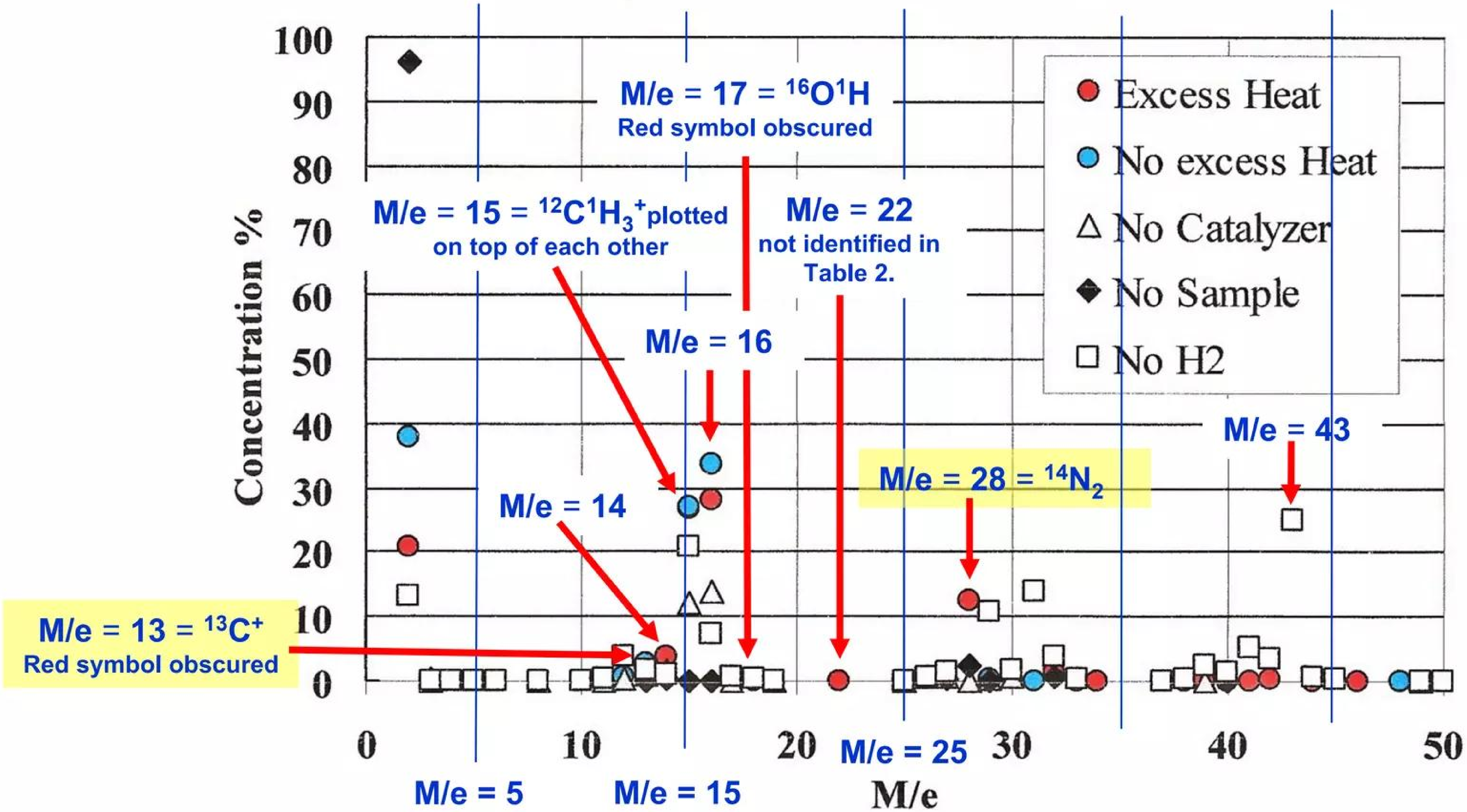

Figure 20. Mass spectrum of gas sample taken after the experiment.

Source: adapted directly from Mizuno and Sawada, ICCF-14 presentation, slide #18

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Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - VII

Summary of mass spectrometry results for gaseous reaction products - II

Table 2. Percent of each species found for the five runs shown in Fig. 20

Mass/ charge ratio (m/e)	Likely species [Mizuno]	Larsen comments –alternative interpretations/questions All of these singly-ionized species have same m/e ratio (see note re resolution below)	Percent of all gas				
			Excess heat produced	No excess heat observed	No Pt catalyst in metallic reaction cell	No $^{12}C_{14}{}^{1}H_{10}$ phenanthrene in reaction cell	No $^{1}H_2$ gas in metallic reaction cell
2	$^{1}H_2^+$	Same conclusion	21	37	68	96.2	13
12	$^{12}C^+$	Same conclusion	0.7	0.7	0.3	0	3.7
13	$^{13}C^+$	Same conclusion	2.5	2.6	1.0	0	1.8
14	$^{12}C^{1}H_2^+$	$^{13}C^{1}H^+$ [resolution needed = 2916] ?	3.8	1.0	1.6	0.36	1.1
15	$^{12}C^{1}H_3^+$	$^{14}C^{1}H^+$ [1210] ?	27	27	12	0	21
16	$^{12}C^{1}H_4^+$	$^{14}C^{1}H_2^+$ [952], $^{14}N^{1}H_2^+$ [1269], $^{15}N^{1}H^+$ [684] ?	28	34	12	0.1	7.5
17	$^{16}O^{1}H^+$	$^{14}N^{1}H_3^+$ [720] , $^{13}C^{1}H_4$+ [541], $^{15}N^{1}H_2^+$ [1328] ?	0.3	0	0.1	0	0.8
28	$^{14}N_2^+$	$^{1}H^{13}C^{14}N^+$ [3590], $^{12}C^{16}O^+$ [2545] ?	12.5	0	0.1	0.25	0
29	$^{12}C_2{}^{1}H_5^+$	$^{1}H^{13}C^{15}N^+$ [1028], $^{14}N^{15}N^+$ [805], $^{13}C^{16}O^+$ [707] ?	-	-	-	-	11
43	$^{12}C_3{}^{1}H_7^+$	$^{13}C_3{}^{1}H_4^+$ [2986] ?	-	-	-	-	25
	Symbols in Mizuno's previous Fig. 20		● (red)	● (blue)	▲	◆	□

Source: adapted directly from Mizuno and Sawada, ICCF-14 presentation, slide #19

Special note: in their paper, resolution of the mass spec used in these analyses was listed as, "*variable, 300, 3000, or 7500*." However, the actual resolution settings used in the above were not specified. Thus, please be aware that if resolution was set at 300, none of the species listed above with the same m/e ratio can be reliably discriminated from each other. If set at 3000, Mizuno's $^{12}C^{1}H_2^+$, $^{14}N_2^+$, and $^{12}C_3{}^{1}H_7^+$ may be mixtures.

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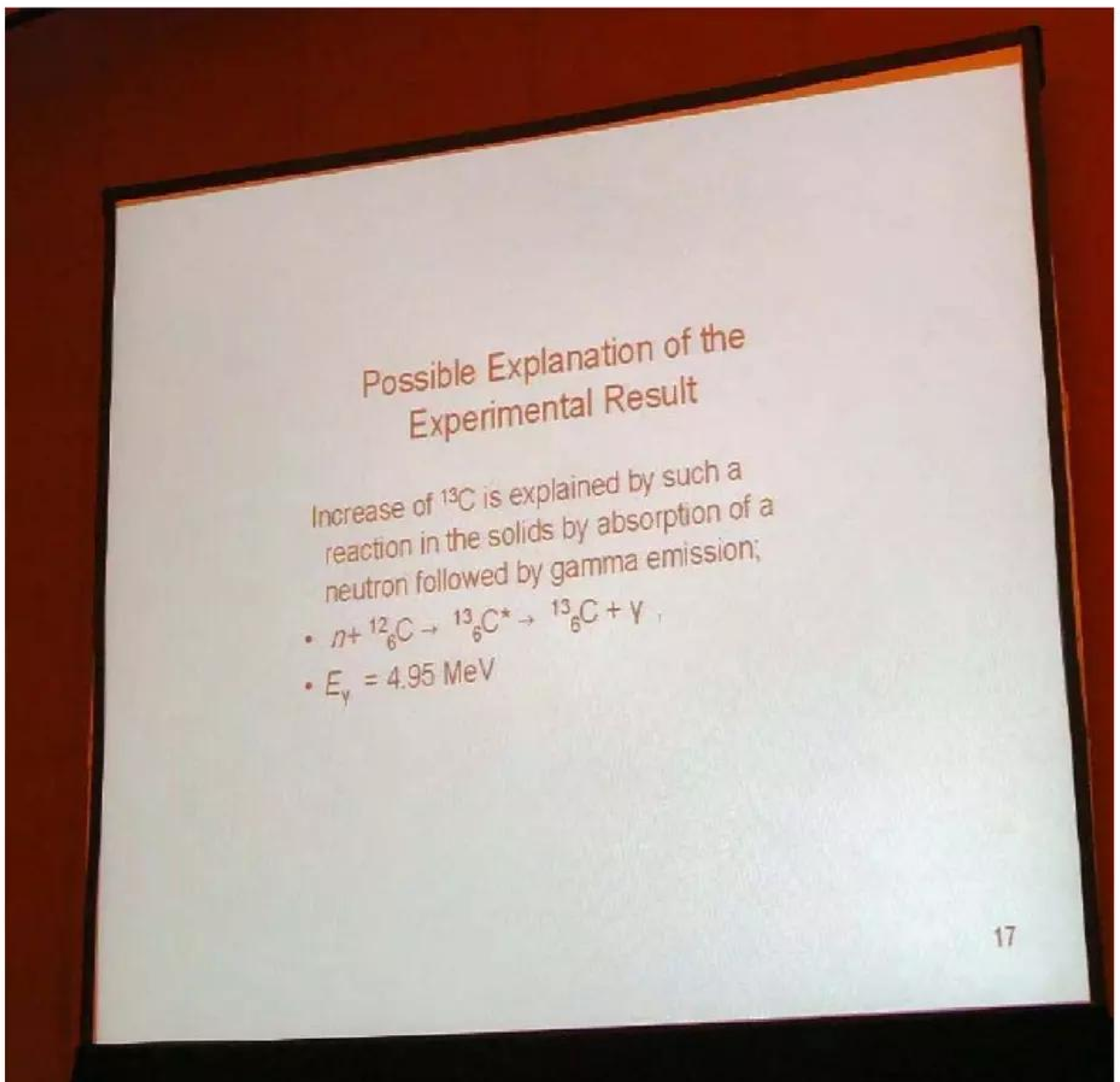
Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - VIII

Photo of PowerPoint slide presented by Mizuno at ICCF-14 in 2008



Possible Explanation of the Experimental Result

Increase of ^{13}C is explained by such a reaction in the solids by absorption of a neutron followed by gamma emission;

- $n + {}^{12}_{6}C \rightarrow {}^{13}_{6}C^* \rightarrow {}^{13}_{6}C + \gamma$
- E_γ = 4.95 MeV

***Note again**: a nationally recognized expert on gamma spectroscopy concluded that Mizuno's gamma measurements in these experiments were "indeterminate"; data as reported does not support claim of detecting 4.95 MeV gammas in Mizuno's experiments. Widom-Larsen theory predicts that gammas from ~0.5 – 1.0 to ~10^+ MeV will be heavily attenuated, being mostly converted to infrared photons by heavy electrons in LENR-active sites.*

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Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - IX

Discussion of central results – key points in mass spec measurements - I

- ✓ Mizuno clearly believed that neutron capture process was responsible for 13-C observed in experiments (Slide #34); the W-L theory of LENRs involves just such processes
- ✓ Relatively large quantities of 14-N (Nitrogen, N_2) observed in the experiments are very likely the result of a nuclear transmutation process; Mizuno's great care in rigorously characterizing compositions of materials as well as high pressures inside the reaction vessels mitigate strongly against possibility that anomalous Nitrogen observed resulted from some type of external N_2 contamination
- ✓ Please refer back to Slide #23, "ULMN catalyzed LENR network starting from $_6C^{12}$" which begins with ULMN neutron capture on stable 12-C (nat. abundance = 98.7%) and 13-C (nat. ab. = 1.3%) – note the products produced
- ✓ Nitrogen should be a major transmutation product of this LENR network, particularly if ULM neutron fluxes were generally not high enough to be able to cross the Fluorine "valley of death" (see Slide #17 in the September 3, 2009 SlideShare) – this prediction confirmed in Slide #33's data

Comments about Mizuno's heat measurements:

→ *Consisting of four calibrated, spatially separated thermocouples, Mizuno's 'calorimetry' in these experiments is rather crude compared to much more stable, sensitive, and accurate heat measurement instruments known as Seebeck 'envelope' calorimeters. Completely enclosing an experimental apparatus, a Seebeck is completely insensitive to the physical location of heat production inside a reaction vessel because it can measure virtually all of heat that may be produced by energetic chemical and/or nuclear processes within, regardless of location.*

→ *During previous experimental programs, Lattice funded development of an excellent custom Seebeck calorimetry instrument that was designed and built by a former employee, Dr. Edmund Storms. For an informative description of that system, please go to:*

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

→ *For reasons that will be discussed, it is very likely that chemical and/or nuclear heat-producing reactions took place at many different locations on surfaces comprising interiors of Mizuno's reaction vessels, not just on and around the Pt mesh catalyst. That being the case, and given the severe data sampling limitations of having only one interior and 3 exterior thermocouples, Mizuno's heat measurements herein have intrinsically poor quantitative accuracy; they could at best provide only very rough qualitative guidance as to whether excess heat was produced.*

Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - X

Discussion of central results – what types of reactions produced the heat? - II

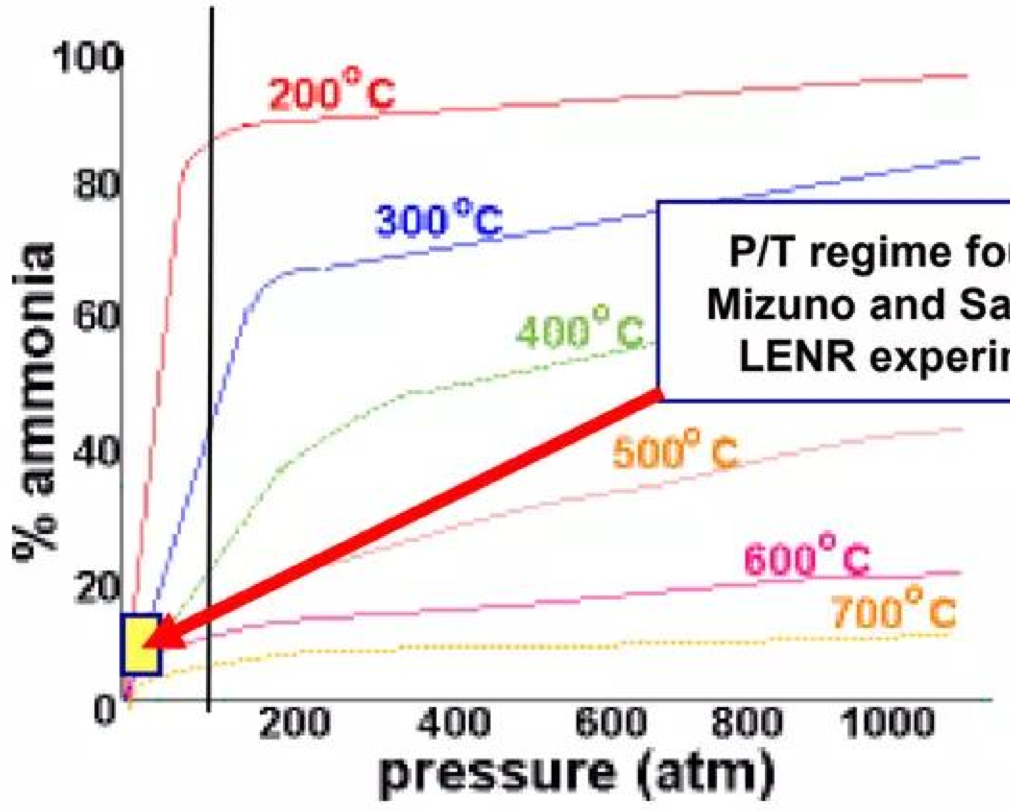
- ✓ Mizuno and Sawada state that, "At these temperatures [> 600° C within the reaction vessel as measured by a single inside thermocouple], hydrogenation reactions are endothermic," implying that any "excess heat" measured by their crude calorimetry set-up in that region of the P/T parameter space must be nuclear in origin
- ✓ They also comment that in one experiment, a measured mass of Phenanthrene equating to 5.6×10^{-5} Moles of $C_{14}H_{10}$ reacted exothermically with H_2 (was hydrogenated) releasing at most ~11.2 Joules of energy in the form of heat; they then note that during the same experiment, measured total heat production was 10^2 kJ. On the basis of that marked disparity between measured total heat and estimated heat of hydrogenation, they concluded that most of the observed heat came from nuclear processes
- ✓ Let it be clear that we firmly believe that the "excess heat" they measured at elevated vessel temperatures in their set-up did include heat from nuclear processes, just not effectively all of it as they asserted. Given the high degree of inaccuracy and low sensitivity of their relatively crude calorimetry, it appears they may have placed too much reliance on inherently flawed heat measurements - see discussion at right about the Haber-Bosch process

***Discussion of possibility of Haber-Bosch process**:*

While hydrogenation of Phenanthrene may be endothermic at such pressures and temperatures, production of Ammonia by the Haber-Bosch process is very exothermic:

$$N_2\ (g) + 3\ H_2\ (g) \rightarrow 2\ NH_3\ (g)\ (\Delta H = -92.4\ kJ \cdot mol^{-1})$$

This reaction uses an Iron catalyst; please note that Fe is present in the walls of both the Inconel 625 and SUS 316L reaction vessels (see Slide #28). The relationship between ammonia yield, pressure, and temperature is as follows:



Mizuno's experimental conditions fall in a regime where small amounts of Ammonia could have been produced. Potentially some of the reaction products at mass = 17 indentified as $^{16}O^{1}H^{+}$ might have actually been $^{14}N^{1}H_3^{+}$, ammonia, which is not fully dissociated at such temperatures/pressures

Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - XI

Discussion of central results – complex mix of chemical/nuclear reactions - III

- ✓ In certain experiments, substantial amounts of gaseous H_2, N_2, and Phenanthrene ($C_{14}H_{10}$) were present along with many hydrocarbon catalysts (e.g., Pt, Fe, Ni, Rh, Mo, Co, etc.) situated on the surfaces of various materials located throughout the entire interior of the reaction vessels. Such a combination of well-known catalysts and potential reactants, coupled with high temperatures/pressures and long reaction times, could readily produce a wide variety of organic-chemical and LENR reactions
- ✓ Thus, complex, time-varying arrays of exothermic chemical reactions involving Nitrogen, C, and H probably occurred at a variety of different locations on interior surfaces of the reaction vessels, including on their walls (e.g., Haber-Bosch process which produces ammonia, NH_3, in the presence of an Fe catalyst); Inconel 625 vessel walls contain 5% Fe and 58% Ni; SUS 316 walls have ~62% Fe and 14% Ni. It is also known that similar high temperature gas-phase, light Hydrogen/Nickel (Ni) LENR cells can produce very large fluxes of excess heat (see Focardi et al., "Il Nuovo Cimento" 107, pp. 163, 1994). Lastly, Nickel/light hydrogen LENR systems are also well-known to produce very complex arrays of transmutation products (see G. Miley et. al., "Journal of New Energy" 2, No. 3 – 4, pp. 6 – 13, 1997)
- ✓ That being the case, there could easily have been enormous variability in magnitudes of heat fluxes that passed through different parts of the Inconel 625 and SUS 316L reaction vessel walls at different times. Unfortunately, this situation would tend to greatly amplify measurement errors that are inherent in the type of crude, location-sensitive calorimetry (consisting of just one inside and three outside R-type thermocouples) used in the experiments. Thus "no excess heat" seen in a given experiment would not necessarily mean it was truly zero, merely that heat produced in that experiment was not measurable with their type of insensitive, inaccurate calorimetry. Since their mass spectrometry appears to have been OK, this could explain why "no excess heat" was measured when substantial ^{13}C was produced

Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - XII

Discussion of central results – addressing some problematic issues - IV

- ✓ To be fair, Mizuno and Sawada do take note and directly acknowledge some of these disquieting issues when they comment that:
  - "In tests without the catalyst [Pt mesh at bottom of reaction vessel], it is possible that the nickel in the cell wall alloy may act as a catalyst for the reaction." Sec. 4 pp. 20
  - "In the test that produced no heat, and the test with no catalyst, $^{13}C^+$ was detected. There does not appear to be a correlation between the amount of heat produced and the amount of $^{13}C^+$." Sec. 4 pp. 20
- ✓ Neutron capture on ^{12}C, which produces ^{13}C, releases ~5 MeV per reaction. If substantial amounts of ^{13}C were in fact produced as indicated by the mass spectrometry data, then it seems unlikely that zero detectable excess heat would be produced during the course of such transmutations. Either their heat measurements were inaccurate and insensitive (for various reasons), or the mass spec data was erroneous, or both. For reasons that have been noted, it appears that the problems lie in the accuracy/sensitivity of calorimetry, not in the mass spectroscopy isotopic data, which appears sound

<u>Further comments on their experiments</u>:

→ *Even with their inherent inaccuracy, Mizuno and Sawada's calorimetric measurements may still be able to provide limited qualitative guidance on the <u>relative</u> amounts of total excess heat produced in different experimental runs. That is to say, zero measured excess heat in a given experiment may not truly be zero. Nonetheless, one might be able to reasonably conclude that some of their experiments were likely to have produced more excess heat than others. If their heat data is viewed through such a less ambitious lens, only one apparent LENR transmutation product stands out: Nitrogen (N_2^+)*

→ *In the adapted version of Mizuno and Sawada's Table 20 on Slide #33, Nitrogen ($^{14}N_2^+$, m/e = 28) is the only mass/charge number identified by their spectroscopy that clearly seems to be associated with production of excess heat. Unlike species at other m/e numbers, it appears to be present in substantial amounts only when excess heat was detected. Interestingly, while definitely not at all conclusive, this result would consistent with the hypothesized Widom-Larsen carbon-seed, ULM neutron-catalyzed LENR network in which nucleosynthetic pathways beyond ^{13}C can be significantly more energetic (exothermic)*

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Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - XIII

Discussion of central results – further analysis of mass spectrometry data - V

- ✓ When one examines Mizuno and Sawada's mass spec data in light of the hypothesized W-L carbon-seed nucleosynthetic network outlined on Slides #23 and 24, some additional possibilities and potential complexities regarding likely species become apparent:

Note: only gaseous species here **Does not include surface residues**

***** See special note regarding mass spec resolution on Slide #33**

Mass/ charge ratio (m/e)	Likely Species [Mizuno]	Larsen comments – alternative interpretations and questions - All of these singly-ionized species have the same m/e ratio ***	Percent of all gas	
			Excess heat produced	No excess heat observed
2	$^{1}H_2^+$	Same conclusion	21	37
12	$^{12}C^+$	Same conclusion	0.7	0.7
13	$^{13}C^+$	Same conclusion	2.5	2.6
14	$^{12}C^{1}H_2^+$	$^{13}C^{1}H^+$ [2916] ?	3.8	1.0
15	$^{12}C^{1}H_3^+$	$^{14}C^{1}H^+$ [1210] ?	27	27
16	$^{12}C^{1}H_4^+$	$^{14}C^{1}H_2^+$ [952], $^{14}N^{1}H_2^+$ [1269], $^{15}N^{1}H^+$ [684] ?	28	34
17	$^{16}O^{1}H^+$	$^{14}N^{1}H_3^+$ [720] , $^{13}C^{1}H_4^+$ [541], $^{15}N^{1}H_2^+$ [1328] ?	0.3	0
28	$^{14}N_2^+$	$^{1}H^{13}C^{14}N^+$ [3590], $^{12}C^{16}O^+$ [2545] ?	12.5	0
29	$^{12}C_2^{1}H_5^+$	$^{1}H^{13}C^{15}N^+$ [1028], $^{14}N^{15}N^+$ [805], $^{13}C^{16}O^+$ [707] ?	-	-
43	$^{12}C_3^{1}H_7^+$	$^{13}C_3^{1}H_4^+$ [2986] ?	-	-

__Further comments on mass spec data__:

- *If W-L LENR carbon-seed network operated on metallic surfaces inside reaction vessels during the experiments, the array of possible transmutation products is much larger and more complex than what Mizuno and Sawada contemplated in their paper*
- *That particular nucleosynthetic network would be able to produce ^{13}C, ^{14}C, ^{14}N, and ^{15}N isotopes with only relatively small fluxes of W-L ULM neutrons produced in nuclear-active, micron-scale regions located on interior metallic surfaces and on any metallic nanoparticles that might be present in the gas*
- *At somewhat higher local neutron production rates, Oxygen isotopes could be produced, although if they were created during these experiments, it was in much smaller quantities in comparison to production of neutron-rich ^{13}C / ^{14}C and stable ^{14}N / ^{15}N isotopes*
- *So what may have occurred in their experiments were micron-scale LENR nucleosynthetic processes producing a variety of isotopes on metallic surfaces; those isotopes were then incorporated into complex, superimposed arrays of metal-catalyzed __chemical__ reactions that in turn produced a wide variety of different molecular species seen in mass spec data*

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Mizuno: H_2 loading of Phenanthrene w. Pt catalyst - IV

Conclusions

- ✓ While some details are still unclear, the results of Mizuno's Phenanthrene experiments appear to be broadly consistent with the Widom-Larsen theory of LENRs and the related hypothesized W-L ULM neutron-catalyzed, carbon-seed nucleosynthetic network shown in Slides #23 and 24
- ✓ While we may have identified some shortcomings in their experiments and do not fully agree with all their conclusions and/or interpretation of the data, our remarks should not detract from the possible importance and technological significance of what Mizuno and Sawada may have first discovered in their new, very innovative research on LENRs
- ✓ If the overall results of Mizuno's Phenanthrene experiments can be more-or-less replicated by other researchers, it would be an important step toward confirming their potentially very important work, which shows that ordinary aromatic organic molecules, e.g., PAHs, may support LENRs/transmutations in presence of H and certain metals inside P/T-driven reactors
- ✓ Improved measurements of heat production and radiation emissions (full spectra of counts versus photon energies) are much needed, as well as extensive pre/post-experiment SIMS analyses of reaction vessels' interior metallic surfaces

<u>Final comments on their experiments</u>:

When Mizuno and Sawada say that there was "no H_2" [gas] in a particular experiment, it can be slightly misleading in that there may well be a large supply of Hydrogen (protons) attached to the 6-carbon Benzene rings that comprise any Phenanthrene that may be present in the reaction vessel

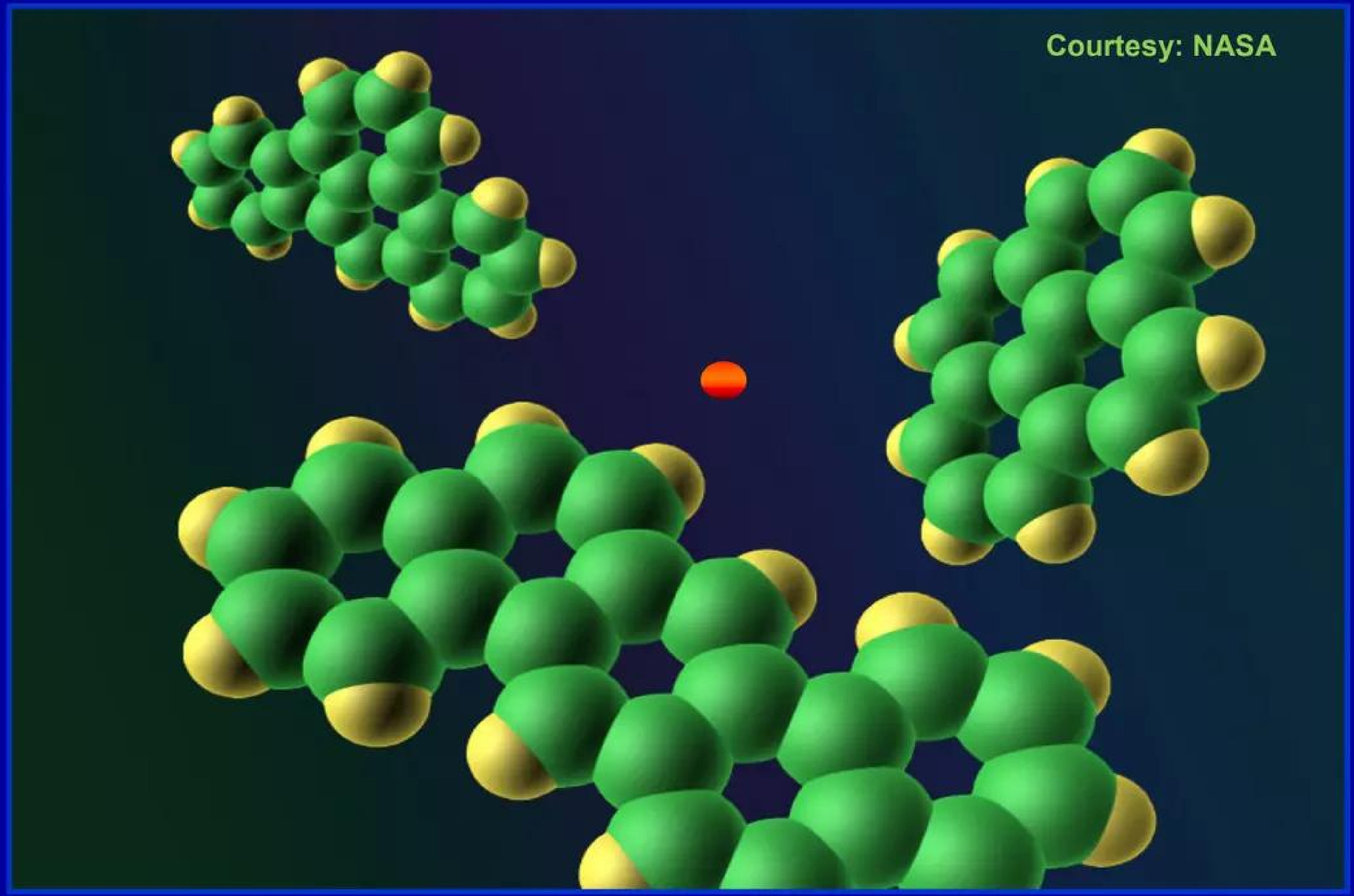
In Section 4 on pp. 20, Mizuno and Sawada report a mass spec analysis on "Solids [residues] found in the cell after the reaction." Whereas at the start of the experiment the carbon [in the Phenanthrene] was 99% ^{12}C, at the end of that experiment more than 50% of the carbon in the residue had been transmuted to ^{13}C. This is strong evidence that ULM neutron-capture reactions are occurring at many locations on the interior surfaces of reaction vessels

It is unclear why an even larger species production peak did not appear at m/e = 30, which could well correspond to $N_2 = {}^{15}N^{15}N^+$; however, irrespective of the particular experiment, a small peak does appear at m/e = 29 (perhaps $N_2 = {}^{14}N^{15}N^+$) in the mass spec data

Unidentified small peak at m/e 22 could represent tiny production of $^{22}Ne^+$, monatomic Neon

Please note that no post-experiment isotopic SIMS analyses were conducted on the interior metallic surfaces of Mizuno and Sawada's reaction vessels

Widom-Larsen theory of LENRs and aromatic rings



"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 …"

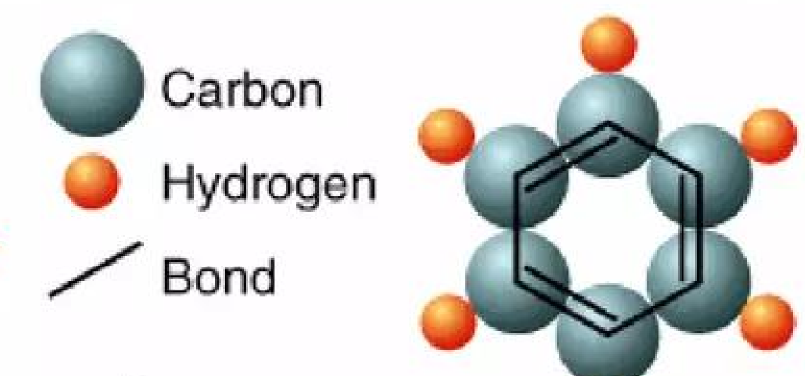
Thomas Kuhn, "The Essential Tension," xvii, 1977

Widom Larsen theory of LENRs applies to aromatic rings

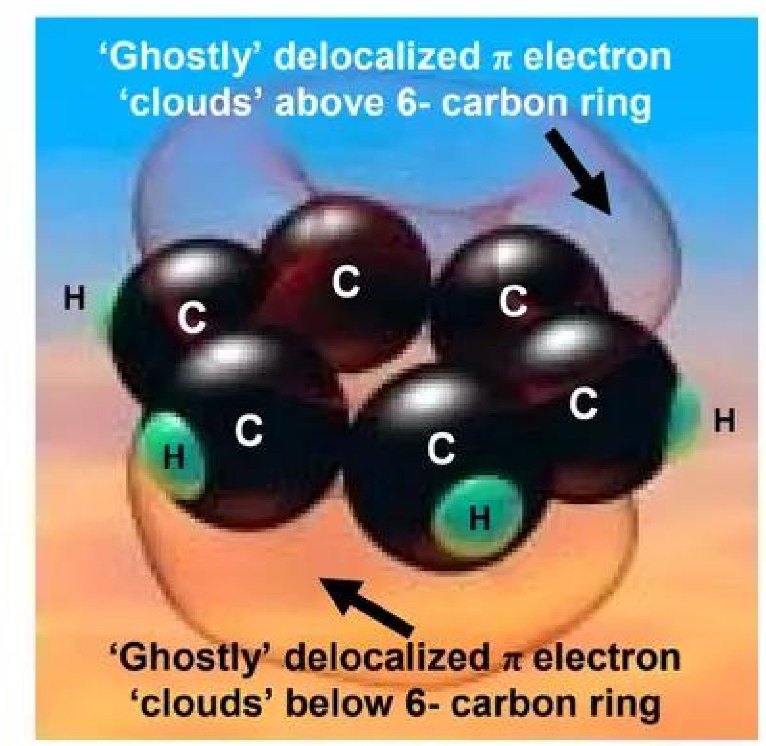
Polycyclic aromatic hydrocarbons (PAHs) adsorbed on metallic surfaces - I

✓ **Hypothesis --- that the W-L theory of LENRs also applies to aromatic rings adsorbed on metallic surfaces --- is as follows:**

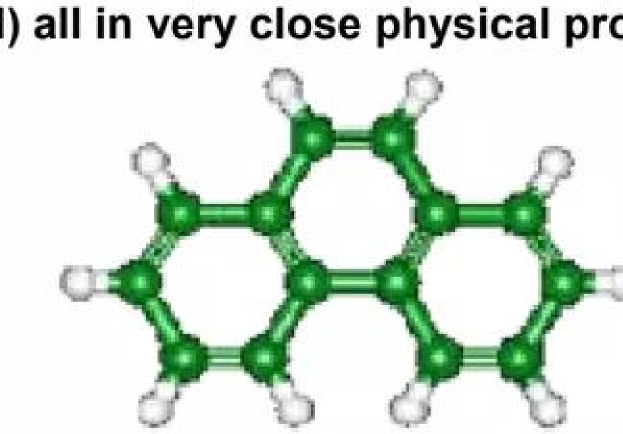
- Delocalized π electrons found above and below 6-carbon benzene (aromatic) ring structures, that also happen to be in very close physical proximity to protons (hydrogen atoms directly attached to the ring's carbon atoms), all oscillate collectively;
- Hydrogen atoms (protons) that are also attached to the ring structure's carbon atoms also oscillate collectively with each other;
- Quantum mechanical wave functions of aromatic ring π electrons and attached ring protons are thus, respectively, effectively entangled;
- There is a local breakdown of the Born-Oppenheimer approximation in and around aromatic ring structures that enables electromagnetic (E-M) coupling and energy transfers between collectively oscillating ring structure π electrons and nearby protons, creating very high nanoscale electric fields;
- When an aromatic structure is adsorbed onto the surface of a metallic catalyst, it spontaneously orients itself as it approaches so that the 'flat surface' of the carbon ring itself is parallel to the catalyst's 'flat' surface. Born-Oppenheimer also breaks down there, enabling further E-M coupling and energy transfers between C-ring π electrons and a 'sea' of surface plasmon polariton (SPP) electrons covering the entire catalyst surface;
- This situation is analogous to what happens when LENRs occur with SPP electrons that are found on loaded metallic hydride surfaces. In this case, the entire carbon ring structure effectively becomes a many-body, LENR active 'patch' in which ULM neutrons can be produced collectively via the weak interaction; ULM neutrons tend to capture on nearby ring Carbons.



Benzene
(C_6H_6)



Benzene showing π electron 'clouds': π electrons, carbon atoms and protons (H) all in very close physical proximity



Unsaturated phenanthrene ($C_{14}H_{10}$)

Widom Larsen theory of LENRs applies to aromatic rings

Polycyclic aromatic hydrocarbons (PAHs) adsorbed on metallic surfaces - II

✓ **Present evidence for the hypothesis is as follows:**

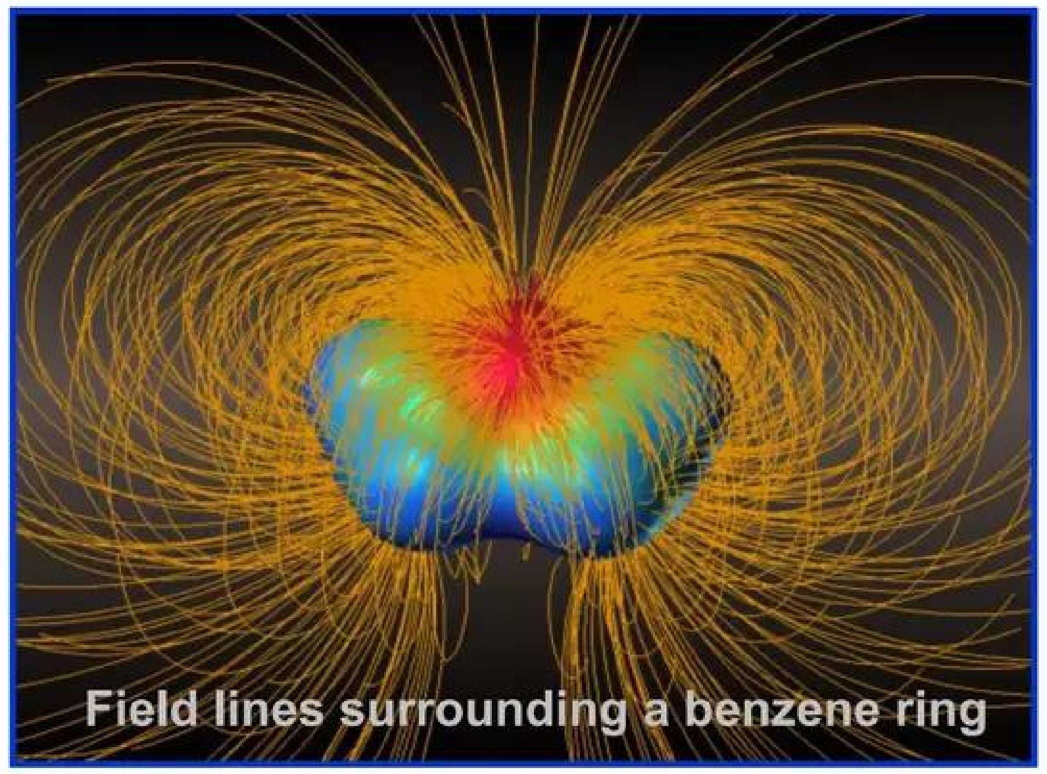
- Born-Oppenheimer approximation is now known to break down on surfaces of carbon fullerene structures and graphene (directly observed by Bushmaker et al, 2009);
- Carbon-arc experiments of Bockris & Sundaresan and Singh et al. provide evidence that that LENRs and the W-L ULM carbon-seed nucleosynthetic network can occur in presence of complex mixtures of fullerenes/graphene (Larsen 9/3/09)
- Born-Oppenheimer is well known to break down on metal surfaces; quoting Yale Prof. John Tully, "Breakdown of the Born-Oppenheimer assumption is the rule rather than the exception in electron transfer reactions, photochemistry, and reactions at metal surfaces." (please see his website at right)
- Born-Oppenheimer is also known to break down in benzene rings in conjunction with quantum entanglement of protons on those rings (see Chatzidimitriou- Dreismann & Mayers, 2002). Quoting from their paper, "… our NCS results …indicate that the physical meaning of … Born-Oppenheimer [approximation] should be critically reconsidered … at least for chemical processes in the …femtosecond time scale … [we also] demonstrate that short-lived protonic quantum entanglement and decoherence are of much broader significance than realized thus far."

→ *Bushmaker et al., "Direct observation of Born-Oppenheimer approximation breakdown in carbon nanotubes" in Nano Letters 9 (2) pp. 607 Feb. 11, 2009*

→ *See Lattice Energy LLC SlideShare presentation dated September 3, 2009, at: http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009*

→ *See Prof. Tully's Yale website at: http://www.chem.yale.edu/~tully/research.html*

→ *Chatzidimitriou- Dreismann & Mayers, "Sub-femtosecond dynamics and dissociation of C-H bonds in solid polystyrene and liquid benzene," Journal of Chemical Physics 116 (4) pp. 1617-1623 2002*



Polycyclic aromatic hydrocarbons (PAHs) adsorbed on metallic surfaces - III

✓ **Present evidence for the hypothesis (continued):**

- Protons found within a wide variety of many-body molecular systems spontaneously oscillate coherently/collectively; their quantum mechanical (QM) wave functions are thus effectively entangled with each other and also with nearby collectively oscillating electrons; amazingly, this behavior occurs even in comparatively "smaller,' 'simpler' molecular systems such as $(NH_4)_2PdCl_6$, ammonium hexaclorometallate (see Krzystyniak et al., 2007 and Abdul-Redah & Dreismann, 2006). Quoting from the paper by Krzystyniak et al., "… different behaviors of the observed anomaly were found for LaH_2 and LaH_3 … As recognized by Chatzidimitriou-Dreismann et al. Coulombic interaction between electrons and protons may build up entanglement between electrons and protons. Such many body entangled states are subject to decoherence mechanisms due to the interaction of the relevant scattering systems with its environment … one can conclude that the vibrational dynamics of NH_4^+ protons as fairly well decoupled from the dynamics of the [attached] heavier nuclei."
- Elaborating further (from Chatzidimitriou-Dreismann , 2005), "Further NCS experiments confirmed the existence of this effect in quite different condensed matter systems, e.g., urea dissolved in D_2O, metallic hydrides, polymers, 'soft' condensed matter, liquid benzene, and even in liquid H_2-D_2 and HD."

→ *Krzystyniak et al., "Anomalous neutron Compton scattering cross sections in ammonium hexachlorometallates," Journal of Chemical Physics 126 pp. 124501 2007*

→ *Abdul-Redah & Chatzidimitriou-Dreismann, "Irreversible hydrogen quantum dynamics and anomalous scattering behavior in liquids and solids," International Journal of Hydrogen Energy 31 pp. 269 - 276 2006*

→ *Chatzidimitriou-Dreismann, "Attosecond protonic quantum entanglement in collision experiments with neutrons and electrons" Laser Physics 15 (6) (4) pp. 780 -788 2005*

→ *Please also see a book chapter by Chatzidimitriou-Dreismann et al., "Attosecond effects in scattering of neutrons and electrons from protons", in Decoherence, Entanglement, and Information Protection in Complex Quantum Systems Akulin et al. eds., NATO Science Series II Vol. 189 Springer Netherlands 2005*

With regard to the dynamics and orientation of benzene molecules and polycyclic aromatic hydrocarbons as they are adsorbed on a metallic catalyst's surface please see:

→ *S. J. Jenkins, "Aromatic adsorption on metals via first-principles density functional theory," Proceedings of the Royal Society 465 pp. 2949 - 2976 2009 – quoting, "[Benzene] adopts a flat-lying … geometry, binding to the surface through donation of electrons through one or both of its degenerate HOMOs and back-donation into one or both of its two degenerate LUMOs."*

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Widom Larsen theory of LENRs applies to aromatic rings

Discussion and Comments

- ✓ Many-body collective oscillations and quantum entanglement of protons (as well as deuterons and tritons) and electrons (e.g., SPPs on metallic surfaces), in conjunction with a breakdown of the Born-Oppenheimer approximation, appear to be relatively common in nature, occurring in many different types of systems
- ✓ While these many-body collective processes chronicled by Chatzidimitriou-Dreismann et al. operate very rapidly and nanoscale coherence can only persist for time spans on the order of femtoseconds (10^{-15} sec) to attoseconds (10^{-18} sec), nuclear processes such as weak interaction ULM neutron production and neutron capture operate on even faster time-scales: 10^{-19} to 10^{-22} sec. Therefore, LENRs as explained by the Widom-Larsen theory can easily take advantage of such many-body collective quantum effects as an integral part of their amazing dynamical repertoire
- ✓ It is well-known that metallic surface nanostructures and SPP electrons can have configurations that are able to effectively absorb E-M energy over a wide area, transfer and concentrate it, and in conjunction with contiguous surface 'patches' of collectively oscillating protons, create extremely high local electric fields. According to W-L theory, ULM neutron production may then follow. If Mizuno is proven correct and aromatic organic molecules can truly support LENRs, it further bridges a long-assumed energetic gulf between chemical and nuclear processes, reuniting chemistry with modern 'alchemy' after 300 years of rancor and estrangement

➡ *C. A. Chatzidimitriou-Dreismann (Technical University of Berlin) and his collaborators have published extensively on collective proton dynamics since 1995. Please also see:*

➡ *"Attosecond quantum entanglement in neutron Compton scattering from water in the keV range" - 2007; can be found at*

http://arxiv.org/PS_cache/cond-mat/pdf/0702/0702180v1.pdf

"Several neutron Compton scattering (NCS) experiments on liquid and solid samples containing protons or deuterons show a striking anomaly, i.e. a shortfall in the intensity of energetic neutrons scattered by the protons; cf. [1, 2, 3, 4]. E.g., neutrons colliding with water for just 100 − 500 attoseconds (1 as = 10^{-18} s) will see a ratio of hydrogen to oxygen of roughly 1.5 to 1, instead of 2 to 1 corresponding to the chemical formula H_2O. … Recently this new effect has been independently confirmed by electron-proton Compton scattering (ECS) from a solid polymer [3, 4, 5]. The similarity of ECS and NCS results is striking because the two projectiles interact with protons via fundamentally different forces, i.e. the electromagnetic and strong forces."

➡ *Also, J. D. Jost et al., "Entangled mechanical oscillators" Nature 459 pp. 683 – 685 4 June 2009, in which "mechanical vibration of two ion pairs separated by a few hundred micrometres is entangled in a quantum way."*

Supporting evidence for Mizuno data and W-L hypothesis - I

Neutron-rich Nitrogen-15 anomalies at a South African steelmaking facility - I

- ✓ **Background**: Talma & Meyer's report concerns the detection, analysis, and environmental 'tracing' of anomalous amounts of the stable, neutron-rich nitrogen isotope (^{15}N) that were found in and around the Iscor Steel Works, an integrated steel making facility located in Vanderbijlpark, South Africa, as well as at a manganese electrolysis plant at another location in that country

- ✓ Polycyclic aromatic hydrocarbons (PAHs, such as Mizuno's phenanthrene which contains three benzene rings in its molecular structure) are often regarded as pollutants, being byproduct s of incomplete combustion of hydrocarbons; i.e., when there is insufficient oxygen present to totally burn-up 'fuel.' Please recall that in the process of producing coke from coal for steelmaking purposes, coal is heated to very high temperatures in an oxygen-free oven. At an earlier stage before volatiles are completely 'burned-off' in a coking oven, large quantities of PAHs are present; ultimately they get 'cracked' into chains or otherwise removed. At that point in the coke making process, Ammonia is produced (note that 1 to 2 wt% Nitrogen is initially present in most input coals). This industrial 'process Ammonia' is then removed by extracting it from a coke oven's gas stream as a "first condensate." It is during this early stage of the coke production process that there can be an opportunity for the occurrence of LENRs a la Mizuno's experiments with phenanthrene

→ *Circa 2002 field report published under the auspices of the International Atomic Energy Agency (IAEA) headquartered in Vienna, Austria:*

A.S. Talma, and R. Meyer, Division of Water, Environment and Forestry, CSIR, Pretoria, South Africa, "Origin and tracing techniques of high 15-N nitrogen compounds in industrial environments"

This 46-page report can be downloaded from:

http://www-pub.iaea.org/MTCD/publications/PDF/te_1298_web/t1298_part3.pdf

→ *IAEA is mainly known for its global investigation and monitoring of nuclear proliferation. Its teams are highly skilled in analytical field work which traces the paths of various isotopes as they move in various molecular forms through the environment; IAEA is thus a recognized authority on such matters*

→ *Quoting from the report, "This factory was established in the early 1950's and has been in operation since then. It houses three batteries of coke ovens and gas handling plants, blast furnaces, steel mills and associated activities. In the course of years the management has had to take increasingly stringent steps to limit the effects of present day pollution and to correct the influences of past water management."*

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Supporting evidence for Mizuno data and W-L hypothesis - II

Neutron-rich Nitrogen-15 anomalies at a South African steelmaking facility - II

- ✓ Quoting from the IAEA report, "Heaton (1987a) found 'condensate' from a coking plant with an anomalously high 15-N values (delta15-N = +21% AIR). In 1995 similar high 15-N values (>30% AIR) were found in ammonia and nitrate in wastewaters of a steel plant in Vanderbijlpark, South Africa. These 15-N values are higher than found in natural compounds. It was deemed useful to investigate the origin and occurrence of such anomalous nitrogen isotope compositions in industrial environments in more detail and explore the possible uses that could be developed from this phenomenon. IAEA supported this project from 1998 to 2000. Additional funding was provided by the CSIR. The report presents the data generated during this project and includes the data prior to 1998."
- ✓ Inside the Vanderbijlpark coking ovens during operation there were present together: high temperatures (heat), PAHs, hydrogen, nitrogen, and metallic nanoparticles comprising various elements that were originally present in input coal streams or produced during mechanical contact of the coal particles with material handling systems and/or hot turbulent gases within oven interiors
- ✓ Al la Mizuno's experiments with phenanthrene, the Widom-Larsen theory of LENRs would suggest that a ULM neutron capture-based LENR carbon-seed nucleosynthetic network (please see Lattice SlideShare presentation dated September 3, 2009) could well be operating somewhere inside the Vanderbijlpark coking ovens

→ ***Note**: the natural isotopic abundance of stable isotopes of Nitrogen (as N_2) found in the earth's air and chemical compounds in the planetary environment is: ^{14}N = 99.634%; ^{15}N = 0.366%*

→ *According to the hypothesized W-L carbon-seed nucleosynthetic network: (1) before Ammonia is extracted from the gas stream, anomalous nitrogen could potentially be produced from capture of ULM neutrons on PAH carbon atoms; (2) such anomalous produced Nitrogen should contain both 14-N and 15-N isotopes; and (3) some of the LENR-produced anomalous Nitrogen should end-up in the plant's process ammonia molecules that will then contain observable anomalous 'excesses' of neutron-rich 15-N versus 14-N compared to natural earthly isotopic abundances*

→ *What Talma and Meyer in fact observed in the mass spectroscopic data of the abundances of Nitrogen isotopes found in process ammonia and nitrate samples from Vanderbijlpark is exactly what the Widom-Larsen theory would predict. An excess of 15-N versus 14-N (compared to earthly and solar system abundances) can occur in LENR systems because W-L ULM neutron capture reactions in condensed matter environments (e.g., LENR ULM neutron capture on PAH carbon atoms) have much higher rates/cross-sections than the charged-particle fusion reactions occurring in super-hot plasmas that produce Nitrogen from Carbon in the inner cores of late-stage red giant stars*

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Supporting evidence for Mizuno data and W-L hypothesis - III

Discussion: ^{15}N anomalies in S. Africa; anomalous Nitrogen production elsewhere

- ✓ In addition to isotopic analyses of samples taken from the Vanderbijlpark steelmaking complex, Talma & Meyer also reported observations of significant ^{15}N anomalies in certain samples of water taken at various points in the process flow through the MMC Nelspruit , SA, manganese electrolysis plant. Examination of the water process flow diagram shown in their Fig. 7 and the isotopic data in Table 9 reveals that the observed ^{15}N anomalies appear to have originated in the plant's electrolysis cells, since no such anomalies were present in either the input municipal water, input NH_3 ammonia, or in the input "electrolysis solution."
- ✓ Interestingly, the situation at Nelspruit has a familiar ring to it: please recall light water Pons-Fleischmann electrolytic LENR cells, which a la Miley (1997) are explained by the W-L theory and are known to produce ULM neutrons and complex transmutations. In this case, one can imagine huge P&F electrolytic cells with NH_4^+ in the electrolyte; W-L would explain ^{15}N anomalies as resulting from ULM neutron capture on ^{14}N in NH_4^+ ions
- ✓ In 1884, W. Foster reported observing much higher Nitrogen content in produced ammonia than could readily be explained by the amount of N present in input coal ("Experiments on the composition and destructive distillation of coal," Proc. Inst. of Civil Engineers, UK). Circa 2000, C. H. Wright of Argonne National Laboratory also noted a similar experimental anomaly ("Coal rank effects in the SRC II process"). Nitrogen anomalies have been reported episodically for 125 years; before, researchers simply assumed that they all resulted from chemical kinetic "fractionation." Per W-L theory, LENR transmutations may better explain some such data

→ ***Special note**: please recall the results reported by Krzystyniak et al. (2007) that were mentioned on Slide #44. In that paper, they state that:*

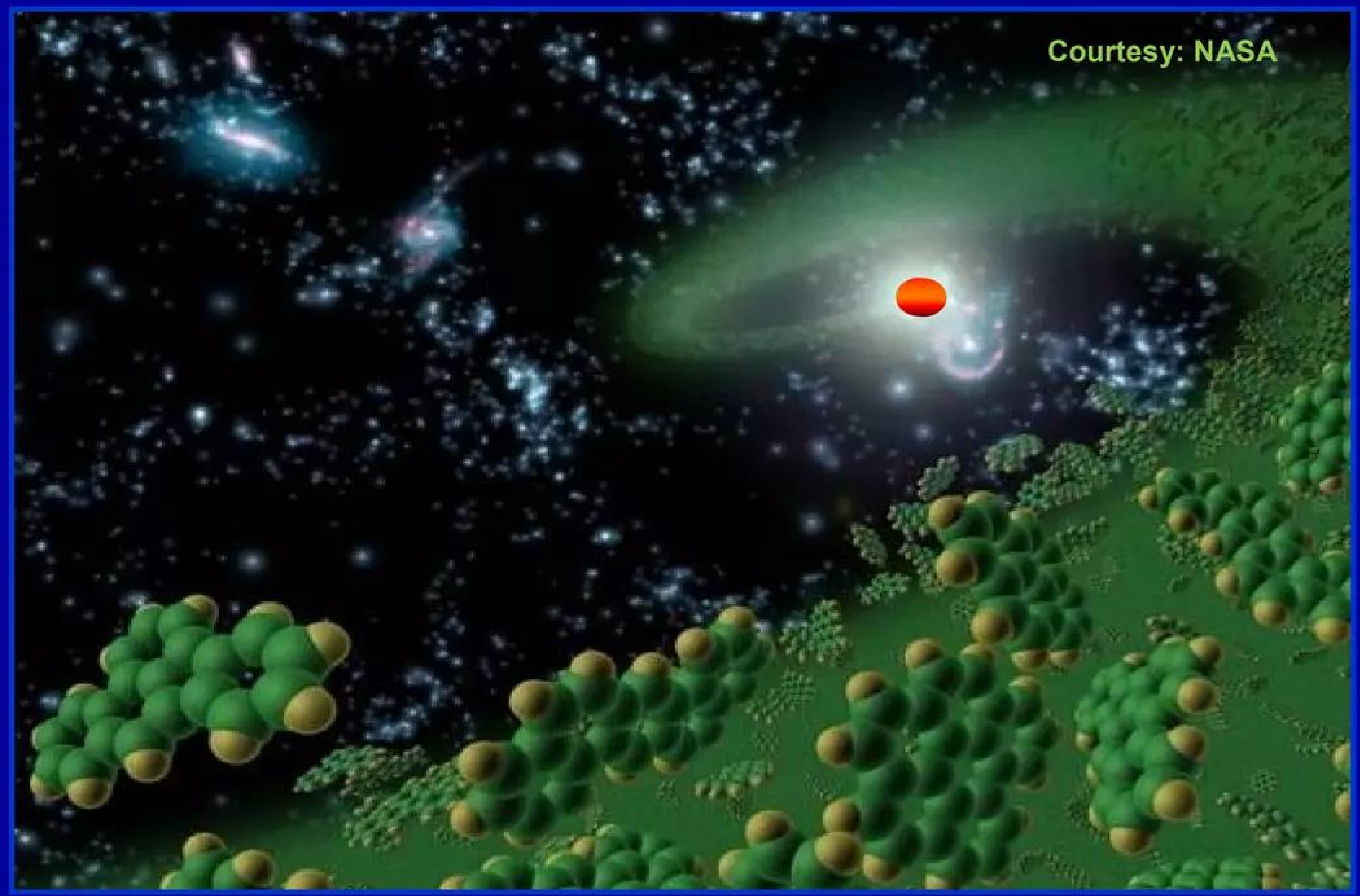
→ *"According to existing theoretical models of quantum entanglement (QE) and decoherence, the relevant quantum system, consisting in this case of ammonium protons and their environment, can be described as quantum entangled particles with finite decoherence time ... The new experimental observation of the onset of the classical neutron cross section presented above places $(NH_4)_2PdCl_6$ and $(NH_4)_2TeCl_6$ in the same group of substances with metal hydrides LiH and LaH_2 as well as YH_3 and YH_2 and some solid polymers formvar, polystyrene, and polyethylene ... Thus, one can consider the vibrational dynamics of NH_4^+ protons as fairly well decoupled from the dynamics of heavier nuclei."*

→ *In other words, protons in NH_4^+ ammonium ions also independently exhibit the <u>same</u> type of anomalous collective oscillations, coherence-decoherence, and QM entanglement that is exhibited by protons found in a variety of other very different molecular systems.*

Lastly, please recall the acid-base pair:

→ $$NH_3(aq) + H_2O(l) \xrightleftharpoons{} NH_4^+(aq) + OH^-(aq)$$

Do PAHs and LENRs extend into the astrophysical realm?



"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

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W-L shows how nucleosynthesis can occur outside of stars

Mixed Regime of High Energy Particle Reactions and LENRs

- Stars – additional nuclear reactions occur in photospheres and out thru coronas
- Dusty, hydrogen-rich nebular ‘clouds’ typically found in star-forming regions
- Magnetars & active galactic nuclei (W-L-S mechanism creates UHE cosmic rays)

- ✓ Very dusty, hydrogen-rich nebular ‘clouds’ found in star-forming regions of galaxies provide a comparatively low-energy, less ionized astrophysical environment in which an array of carbon-based molecules can exist in abundance. Within these comparatively dense, somewhat opaque ‘clouds,’ carbon-based moieties coexist with hydrogen and are intimately associated with dust particles (which themselves contain a very wide variety of elements including many metals). All of this matter is periodically bathed in varying amounts of stellar photon radiation ranging from infrared to ultraviolet wavelengths; in some cases, it is also directly exposed to streams of charged particles such as protons coming from stellar ‘winds.’ Some astrophysicists even believe that gigantic lightning bolts can occur inside such clouds
- ✓ Astronomers have detected large quantities of PAHs, e.g., Phenanthrene, in such star-forming regions; many believe that PAHs are actually synthesized therein through an interaction of energetic photon radiation with simpler carbon structures on dust surfaces
- ✓ While hydrogen gas pressures are vastly lower in such stellar nurseries, physical conditions inside them otherwise resemble Mizuno’s Phenanthrene experiments in many key ways. If that analogy is proper, then W-L theory would predict that LENR nucleosynthesis can occur there

PAHs also thought to be common in the interstellar realm

"The composition, structure, and size distribution of interstellar grains is the result of injection of dust from stellar outflows into the interstellar medium (ISM), followed by destruction, growth, coagulation, and photoprocessing of interstellar grains. The balance among these poorly-understood processes is responsible for the mix of solid material present in the ISM. Most interstellar grain material present in the diffuse ISM must be grown *in* the ISM. The amorphous silicate and carbonaceous materials that form the bulk of interstellar dust must therefore be the result of grain growth in the presence of ultraviolet radiation. Dust in high-z systems such as J1148+5251 is also produced primarily in the ISM, with supernova-produced dust contributing only a small fraction of the total dust mass."

"The wavelength-dependent extinction of starlight – the so-called "extinction curve" – remains the principal source of information about interstellar dust ... The extinction curve contains spectral features that constrain the composition of the dust. The strongest feature by far is a broad "bump" peaking near 2175°A. The strength of this feature requires that it be produced by a substance composed of high-abundance elements, such as C, Mg, Si, or Fe (Draine 1989). The position of the feature, and its width, are strongly suggestive of $\pi \rightarrow \pi^*$ excitations in aromatic carbon, such as graphite or polycyclic aromatic hydrocarbons. Some authors (e.g., Draine & Li 2007) think that the feature is produced by the large population of polycyclic aromatic hydrocarbons that is required to explain a number of infrared emission features."

"Large $a > 0.02\mu m$ grains in the local starlight background will be heated to a more-or-less steady temperature of 15–20K. However, very small grains (1) absorb photons much less frequently, and (2) have very small heat capacities, so that one absorbed photon can raise the grain to a high temperature, followed by very rapid cooling …. Perhaps 2/3 of C is in dust … There is a substantial population of PAHs that contains ~10–20% of the interstellar C in the Milky Way; ~4–5% of the total grain mass is contributed by PAHs in the Milky Way and other star-forming galaxies with ~solar metallicity (Draine et al. 2007) … *Most interstellar dust is not stardust* … Stardust accounts for only ~ 4% of the total mass of interstellar dust … *Most of the material in interstellar grains was formed in the ISM* … . The resulting grain material(s) will undergo heavy UV irradiation … Hydrogenation … This surface site is being bombarded by H atoms at a rate …Observations of quasars and luminous galaxies at high redshift have detected large masses of dust in a number of systems (Wang et al. 2008) …Grain destruction in the ISM is such that ~<10% of the interstellar dust mass consists of "stardust" from stellar sources, including supernovae. *The bulk of interstellar dust has been grown in the ISM*."

B. T. Draine, "Interstellar Dust Models and Evolutionary Implications," arXiv:0903.1658v1 [astro-ph.GA] 9 Mar 2009

See: http://arxiv.org/PS_cache/arxiv/pdf/0903/0903.1658v1.pdf

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PAH/Nitrogen isotope anomalies in meteoritic materials?

Extraordinary Nitrogen isotope anomalies in Isheyevo primordial chondrite - I

- ✓ If the W-L theory-based hypothesis outlined on Slides #42 and in the last bullet on Slide #50 were true, and if LENR-based nucleosynthesis associated with PAHs occurred on surfaces of dust particles in the early solar nebula 4+ billion years ago, what sort of evidence of such earlier nuclear activity might be found today?
  - **Criteria 1:** such isotopic anomalies produced by LENRs should be found in micron-scale 'patches,' probably no larger than 100 – 200 microns in diameter, located on the surfaces of so-called 'primordial grains' of material (xenoliths) embedded in somewhat younger, thermally processed materials comprising meteoritic bodies such as chondrites (for a 'fresh,' unprocessed terrestrial analogue of such LENR surface sites, see the SEM image of such transmutation 'hot spots' in Slide #19)
  - **Criteria 2:** residues of some sort of organic carbon-based molecules (especially PAHs) should also be detected in some fashion at such sites
  - **Criteria 3:** if LENRs took place with ULM neutrons being captured by PAH ring carbon atoms located in PAH 'patches' on nebular dust grain surfaces, Nitrogen should be produced by the W-L Carbon-seed nucleosynthetic network (see Slides #23 and 24). Similar to the coke ovens at the South African steelmaking facility, there should also be significant enrichment of neutron-rich ^{15}N in such locations and accordingly anomalous $^{14}N/^{15}N$ isotopic ratios at those same localized sites
- ✓ Just such local anomalies involving neutron-rich ^{15}N meeting all of these criteria were observed and reported in a paper by Briani et al. that was published in the *PNAS* in May 2009, "Pristine extraterrestrial material with unprecedented nitrogen isotopic variation"

W-L explains ^{15}N isotope anomalies in Isheyevo materials - I

Extraordinary Nitrogen isotope anomalies in Isheyevo primordial chondrite - II

- ✓ 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**: as predicted, 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 "fractionation" processes and 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*

The 6-page article can be purchased from PNAS for $10 and downloaded from the following URL:

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

➡ *A 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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W-L explains ^{15}N isotope anomalies in Isheyevo materials - II

Extraordinary Nitrogen isotope anomalies in Isheyevo primordial chondrite - III

<u>Quoting from their conference presentation</u>: "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."**

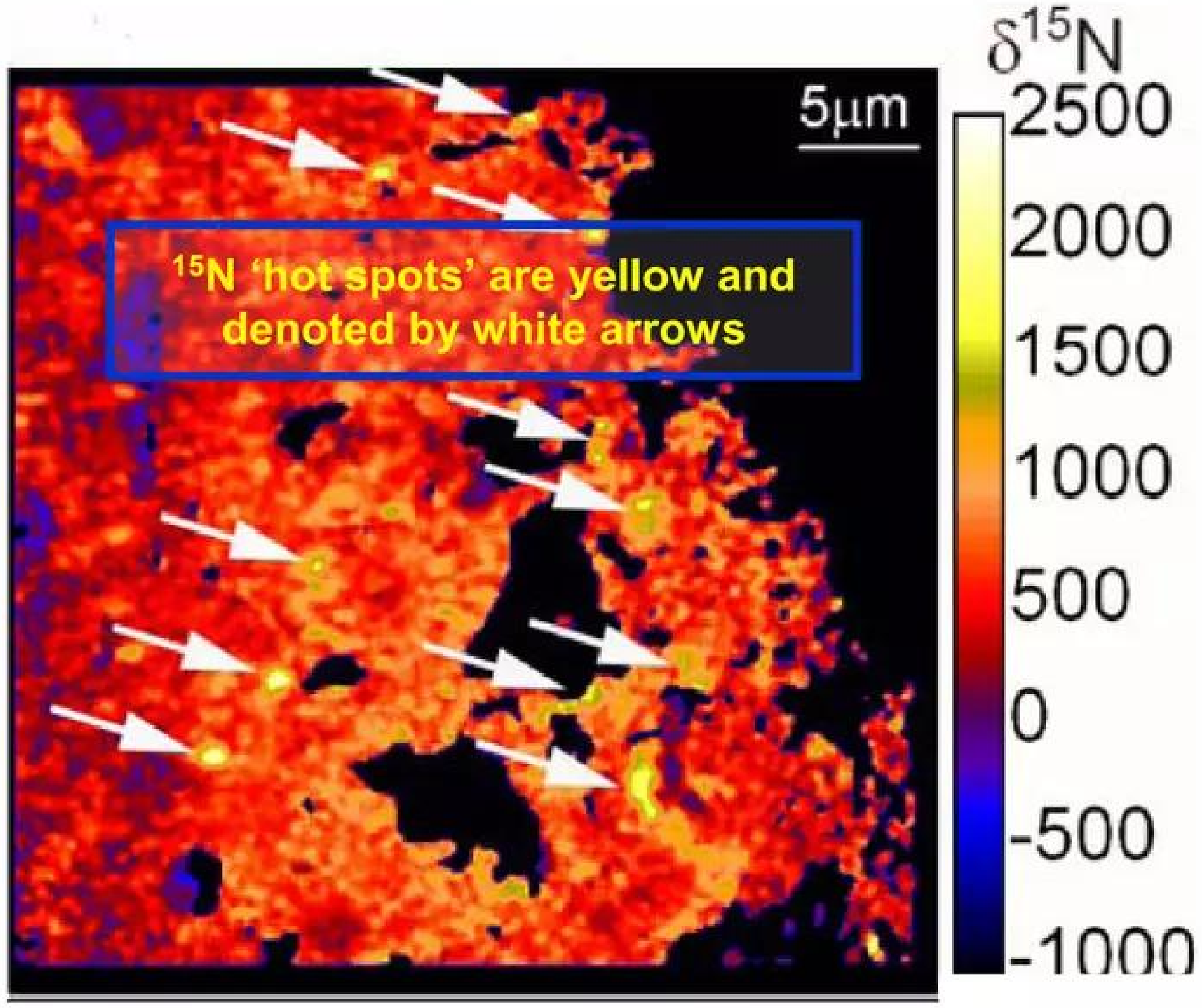


Figure 2. $\delta^{15}N^{AIR}$ distribution of a 40×40 µm^2 region in PX-18, with mean $\delta^{15}N^{AIR}$ = 640 ± 11‰. About 90% of this image is characterized by $\delta^{15}N^{AIR} \geq$ 250‰. Several hotspots are also visible (white arrows).

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

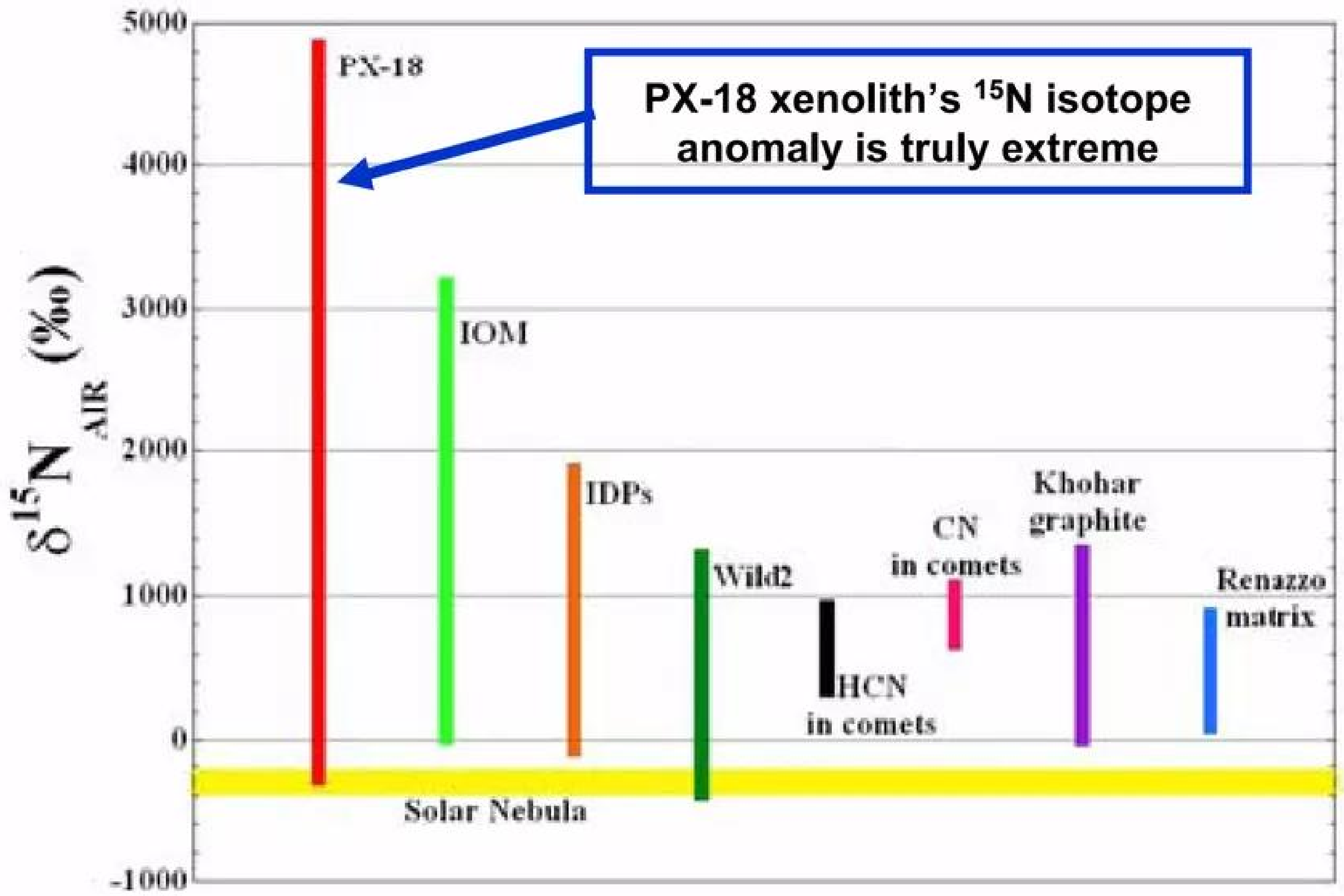
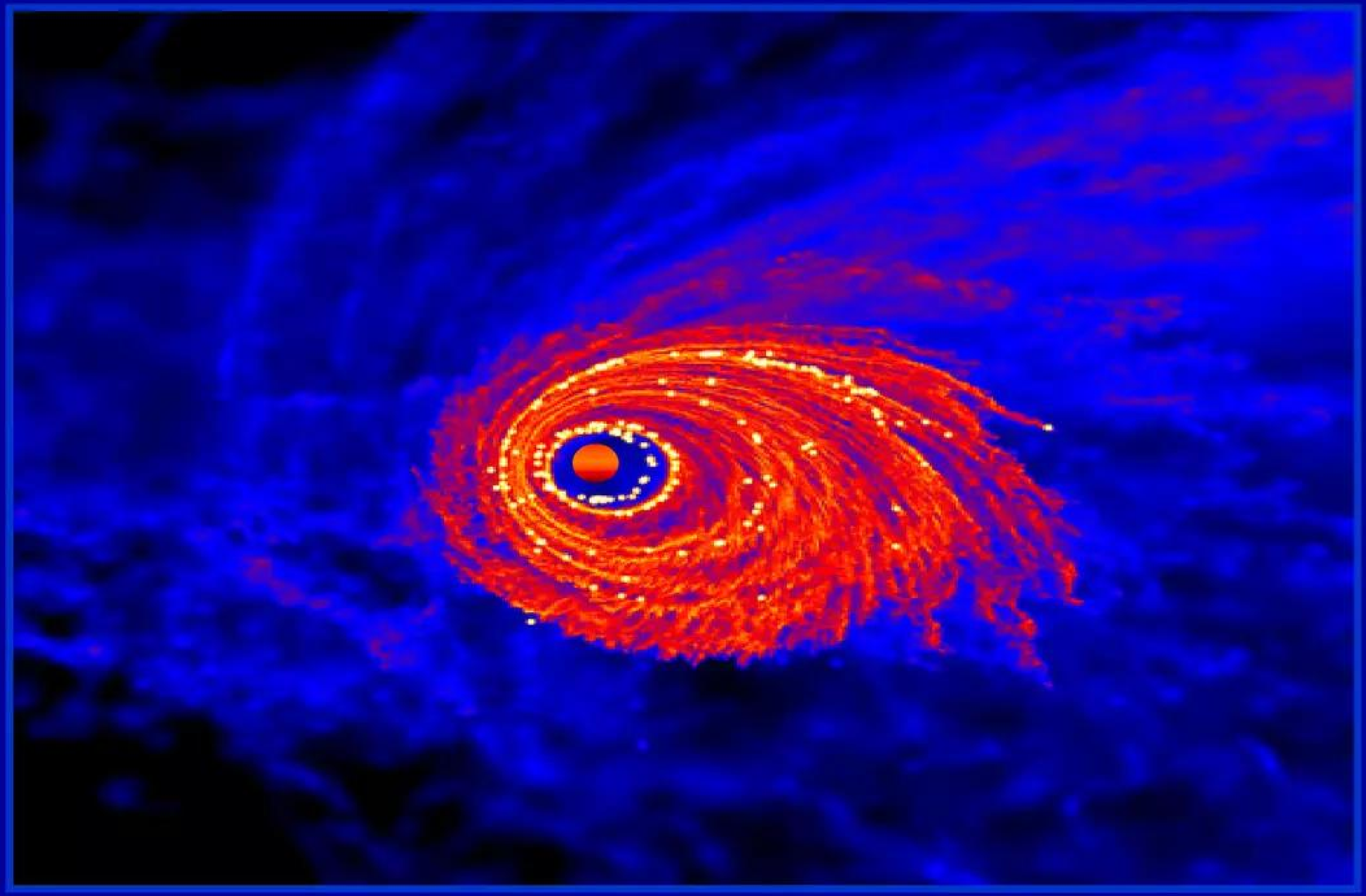


Figure 3. $\delta^{15}N^{AIR}$ values measured in PX-18, compared with previous measurements in other Solar System materials. Ranges reported in the figure comprise results from bulk measures as well as from hotspots (data from literature).

Further thoughts and possibilities for the future



"Tight-lipped, guided by reasons only,
Cautiously let us step into the era of the unchained fire."

Czeslaw Milosz, poem "Child of Europe," New York, 1946

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Technical issues that merit further investigation

Mizuno's innovative phenanthrene experiments suggest additional work

- ✓ Given their potential importance, Mizuno's experiments should be repeated by other groups of skilled experimentalists in Japan and elsewhere to see whether they obtain essentially the same laboratory results
- ✓ In any future such experiments a la Mizuno with phenanthrene and other related aromatic hydrocarbons (PAHs) in metallic reaction vessels, the following would be desirable:
  - **Much better radiation measurements:** in which photon energies and counts are explicitly enumerated for the entire duration of experiments
  - **Much better heat production measurements:** if at all possible, to utilize some sort of Seebeck envelope calorimeter. The goal would be to substantially improve sensitivity, accuracy, and stability, as well as eliminate present "heat location" issues that can produce large, hard to analyze errors
  - **Extensive pre/post experiment SIMS analysis:** at many different locations on surfaces of all materials located inside the reaction vessels; need to know exactly where LENRs are occurring inside
  - **Mizuno and Sawada made an intriguing claim:** "The reaction is reliably triggered by raising temperatures above … threshold temperature of ~600^{o} C and … hydrogen pressures above 70 atm. It can be quenched by lowering the temperature … below ~600^{o} C." If their observation is correct, it suggests that: (a) reaction vessels may be acting as blackbody radiation cavities; and (b) nuclear reactions may turn 'on and off' as LENR-active metal/PAH surface nanostructures move in and out of resonance with the spectral peak of emitted cavity radiation which is temperature-dependent and determined by Planck's, Stefan-Boltzmann's, and Wein's Laws. If this were true, it may open up the technological possibility of controlled positive thermal feedback (see Focardi et al., "Il Nuovo Cimento" 107, pp. 163, 1994)

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Oil industry's new bridge to the future? PAHs as LENR fuel

If Mizuno's results are correct – possible long-term implications for oil industry

- ✓ If the additional investigations outlined in the previous slide were to have successful outcomes, the potential major commercial payoff somewhere down the road would be to be able to 'burn' PAHs as nuclear fuels in unremarkable LENR Pressure/Temperature/Metal catalyst reactors using the W-L carbon-seed ULMN capture nucleosynthetic network
- ✓ At that point, commercial versions of 'green' LENR power generation systems would begin to somewhat resemble present day chemical fuel technologies without having any of their problems, e.g., carbon emissions; unlike existing fission technologies, no hard radiation or radioactive waste issues
- ✓ Interestingly, PAHs could be worth a million times more as nuclear fuels as opposed to their being used in making chemical fuels or used in applications like industrial solvents
- ✓ If this came to pass, the oil industry's new bridge to the future could be extracting and processing hydrocarbons for use as fossil fuels, chemical feedstock, and 'green' LENR fuels

Special note: PAHs are naturally found in significantly higher concentrations in bitumen or "oil sands" of which the largest known deposits are located in Canada and Venezuela. Unlike conventional crude oil, bitumen does not flow freely: it is heavier than water and more viscous than molasses. Today, it has to be heated with steam to liquefy it before it can be pumped out of the ground. Bitumen also contains up to 5% sulfur by weight, and small amounts of oxygen, various heavy metals and other contaminants.

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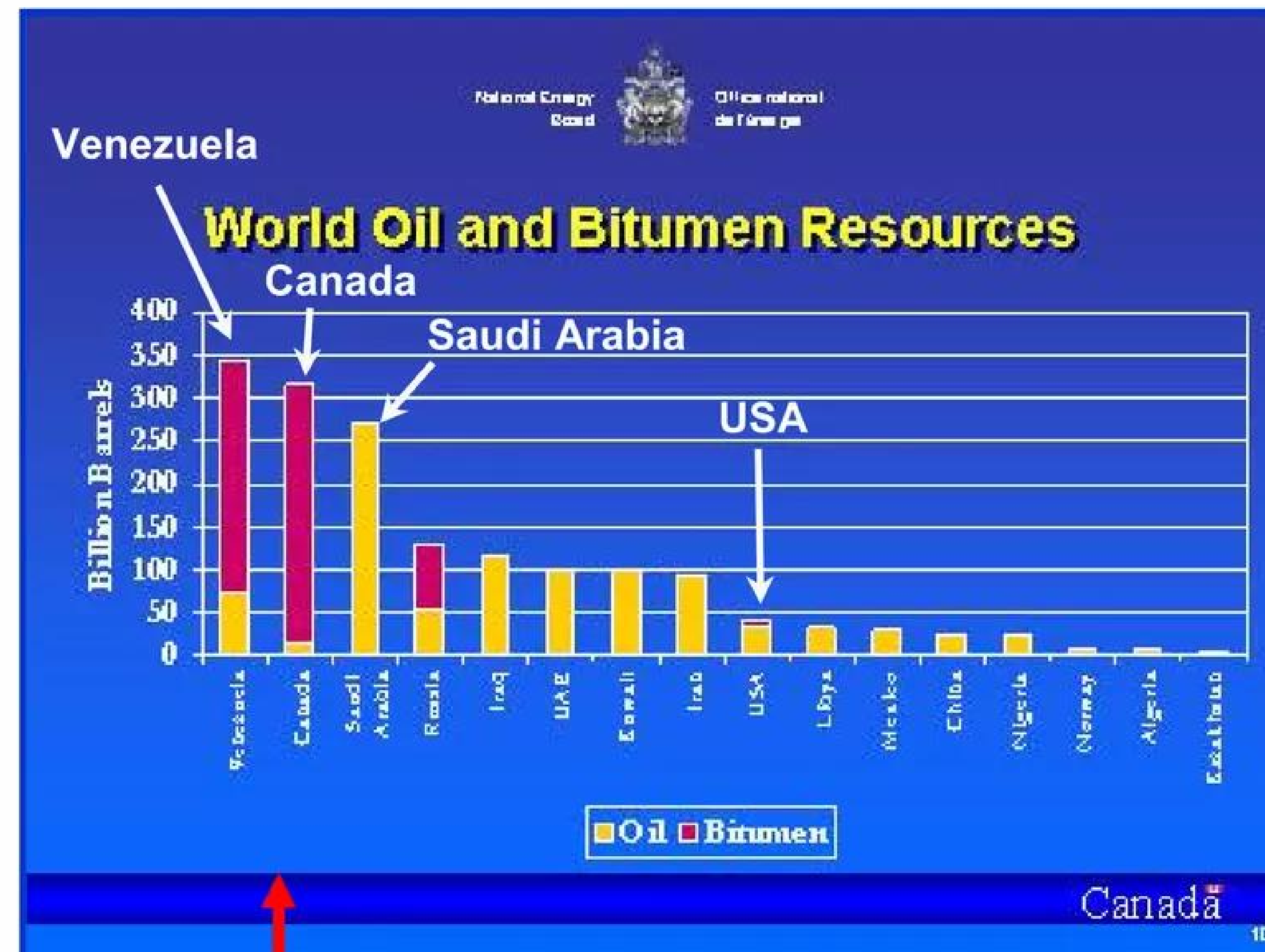
Canada/Venezuela: petronuclear Saudi Arabias of the future?

Commercialization of LENRs/PAHs: redraw geopolitical map of oil and energy?

- ✓ Some oil experts believe that the two largest-known sources of bitumen (found in Alberta, Canada, and in Venezuela) each contain more petroleum than the entire proven conventional oil reserves of the Persian Gulf
- ✓ Today, synthetic crude oil produced from bitumen accounts for ~28% of Canada's total oil production. However, compared to conventional oil (obtained from traditional, easily accessible sources such as Saudi Arabia, Iraq, and Iran), synthetic crude produced from bitumen is now significantly more expensive and complicated to produce using today's best available extraction and processing technologies
- ✓ Whether surface-mined or extracted through well-holes, in Canada natural gas is presently burned to make steam which is used to heat bitumen-containing sands so liquid oil can flow out of pores between rock particles. Surface mining of oil sands and related environmental disturbances may be unnecessary if LENRs can be commercialized. To eliminate burning of natural gas for heat, high performance, cost-effective LENR-based 'green' nuclear heaters with duty cycles of 5,000 - 10,000 hours between scheduled refueling/maintenance breaks could potentially be developed and mass produced. In-situ LENR heat sources would be small enough to be lowered down existing well-holes to reach desired locations in oil-bearing formations where long-lived, controllable production of intense heat is required for recovery. LENRs could thus reduce extraction and production costs, as well as reduce the total 'carbon footprint' vs. today
- ✓ On top of that, as we have shown herein, it is possible that PAH aromatic fractions in bitumen could someday be 'burned' directly as 'green' LENR nuclear fuels. Thus, PAHs could potentially be worth a million times more $ as nuclear fuel rather than being burned chemically or used in feedstock



Legend in graph above:

= conventional oil

= bitumen in oil sands (not shale)

Main Canadian bitumen deposits are located in the province of Alberta. Please see orange-colored areas in the map to the right

As of today, Venezuelan bitumen deposits are not as well-developed as Canada's

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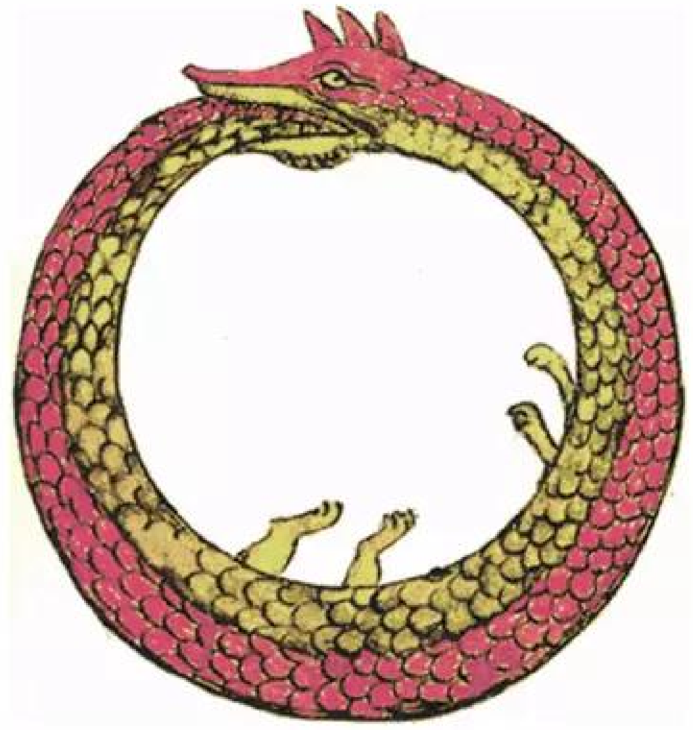
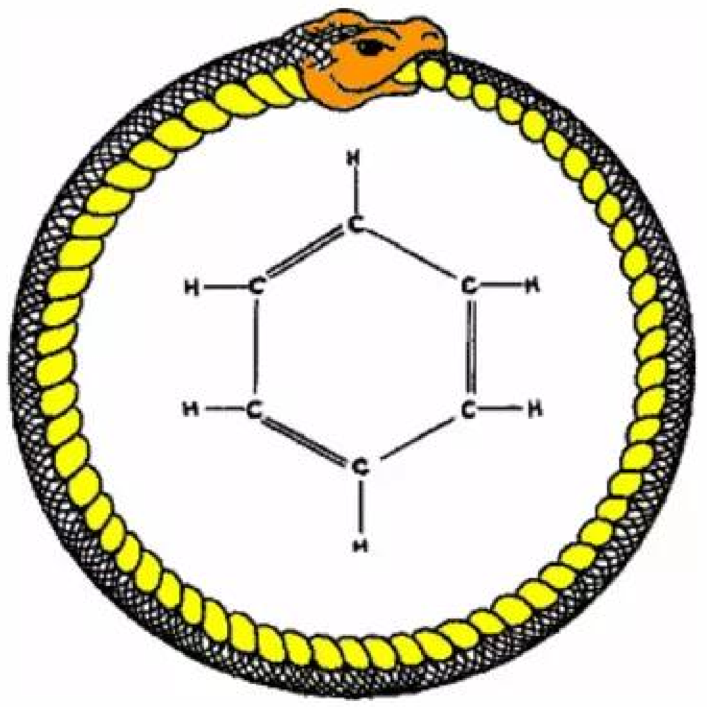
Final remarks on alchemy, LENRs, and chemistry

Chemistry and alchemy (nuclear transmutations) have finally come full-circle

- ✓ LENR transmutations are not a fevered alchemical delusion. As we have shown herein, they are widespread in Nature, allowing nucleosynthetic processes to take place in many different types of 'milder' environments besides the hot plasma cores of stars, nuclear weapons, and fission reactors
- ✓ Unlike fission and fusion reactions, naturally occurring LENR processes are innately benign because they are enabled by and rely on many-body collective effects, quantum phenomena, and the weak interaction. As a result, they typically do not emit dangerous 'hard' photon/neutron radiation, nor do they produce large amounts of long-lived radioactive isotopes. LENRs are clean, 'green,' ubiquitous, and can potentially release just as much energy as fusion
- ✓ If LENRs can be successfully commercialized at some point in the future, they have the potential to help solve many of the world's long term energy problems. If PAHs can someday be used as LENR fuel, it would allow humanity to release more than a million times more energy from Carbon molecules without injecting any more Carbon atoms into the earth's environment
- ✓ If a medieval alchemist were magically transported from the past into Mizuno's lab, after a discussion he would readily recognize metal reaction vessels as athanors. That begs a question: were alchemists wrong about everything? Were 17 centuries of effort, including work by Newton and Bacon, all for naught? Or just once in a very great while, did someone, somewhere, see something real? We may never know



Ouroboros by Theodoros Pelecanos, in alchemical tract titled, "Synosius" (1478).



Modern interpretation of the Ouroboros; did August Kekule dream about it when he hypothesized that benzene was a cyclic compound?

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Collective LENR effects appear to be widespread in Nature

Welcome to the New World

"I am increasingly persuaded that all physical law we know about has collective origins, not just some of it."

"… I think a good case can be made that science has now moved from an Age of Reductionism to an Age of Emergence, a time when the search for ultimate causes of things shifts from the behavior of parts to the behavior of the collective ….. Over time, careful quantitative study of microscopic parts has revealed that at the primitive level at least, collective principles of organization are not just a quaint sideshow but everything ---- the true essence of physical law, including perhaps the most fundamental laws we know … nature is now revealed to be an enormous tower of truths, each descending from its parent, and then transcending that parent, as the scale of measurement increases."

"Like Columbus or Marco Polo, we set out to explore a new country but instead discovered a new world."

Robert Laughlin, "*A Different Universe - Reinventing Physics from the Bottom Down,*" Basic Books, 2005, pp. xv and 208

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In Memoriam

This presentation is dedicated to the memory and work of Prof. Andrei Lipson

до свидания мой друг

Vechnaya Pamyat

Andrei Grigorevich Lipson at ICCF15, October 2009
(Photo by David Nagel)

Only 52 years old, Andrei died unexpectedly of cardiac problems in Moscow on November 1, 2009. He was a fine scientist, friend, and dedicated family man. Andrei and Alexei Roussetski did excellent work for Lattice on LENR charged particle measurements back in 2001 – 2002. Everyone who knew Andrei will miss him. May he rest in peace.