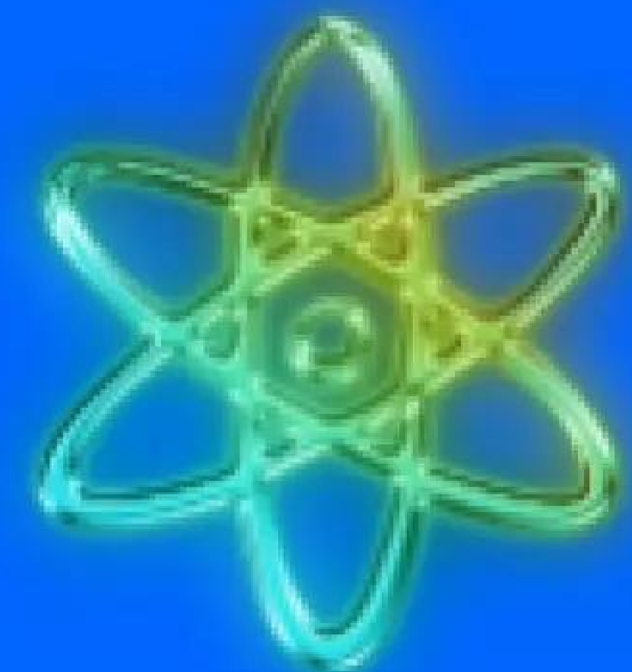
# Ultralow energy neutron reactions (LENRs)

## Disruptive new source of safe, radiation-free nuclear energy

**Experiments reported in 2017 by Prof. Gong-xuan Lu et al. at Lanzhou Institute of Chemical Physics, in Lanzhou, China showed photocatalytic triggering of LENRs at NTP with visible light**

Lanzhou Institute of Chemical Physics,
Chinese Academy of Sciences

**Very significant discovery if experimental claims can be independently confirmed by other researchers using same methods**

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June 30, 2018

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# Lu et al.: Photocatalytic triggering of LENR transmutations

## Claims: production of Deuterium and Helium & transmutation of K → Ca

### Experimental results reported in *Journal of Molecular Catalysis* (China) in 2017

- Published three closely-related experimental papers in same Chinese journal
- April 2017: photocatalytic production of Deuterium ($^{2}H$) and Helium (He)
- August 2017: photocatalytic production of Helium-3 ($^{3}He$) and Helium-4 ($^{4}He$)
- October 2017: photocatalytic transmutation of Potassium (K) to Calcium (Ca)
- Their reported results, if correct, can be readily explained by operation of ultralow energy neutron capture and nuclear decay processes as posited by Widom-Larsen many-body collective theory of LENRs in condensed matter
- Lu et al.'s results are potentially quite significant and consequently should be independently repeated by other experimentalists using same methods
- If Lu et al.'s claims are confirmed, their work has important implications. For chemical catalysis, it suggests that LENR transmutations can occur at very low rates in parallel with ordinary chemical reactions; LENRs can coexist and interoperate at NTP. Also implies total mass-balances for chemical elements comprising reactants and products might not necessarily be conserved. For astrophysics and cosmochemistry, it means that nucleosynthesis can occur on surfaces of Hydrogen- and metal-rich dust grains irradiated by starlight

# Contents

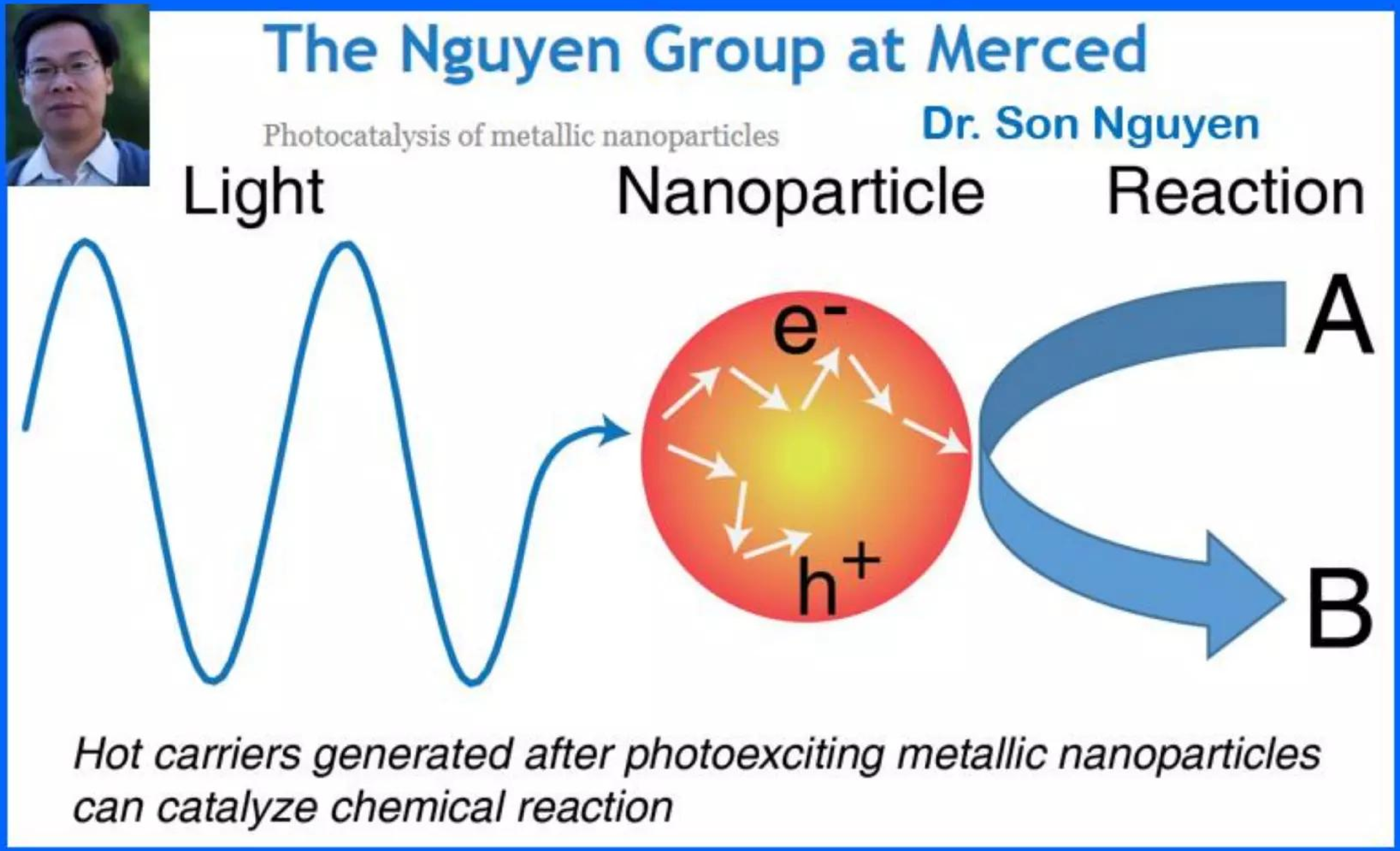


# Energy from light captured by various types of nanoparticles

## Metallic NPs next to metal-oxide nanoparticles share surface plasmons

### Very high electric fields are created at 'hotspots' on surfaces of nanoparticles




http://faculty.ucmerced.edu/son/

# Photocatalysis uses energy in light to split $H_2O$ into $H_2$ & $O_2$

## Catalyst ($TiO_2$) enables reaction @ NTP to produce Hydrogen ($H_2$) gas

### Anatase (Titania, $TiO_2$) photocatalyst produces Hydrogen in aqueous cell

$$H_2O\ \text{(liquid)} \xrightarrow[\text{light } E = nh\nu \text{ (energy)}]{\text{catalyst } TiO_2 \text{ (surface)}} H_2\text{(gas)} + O_2\text{(gas)}$$

**Image of experiment is at right:**

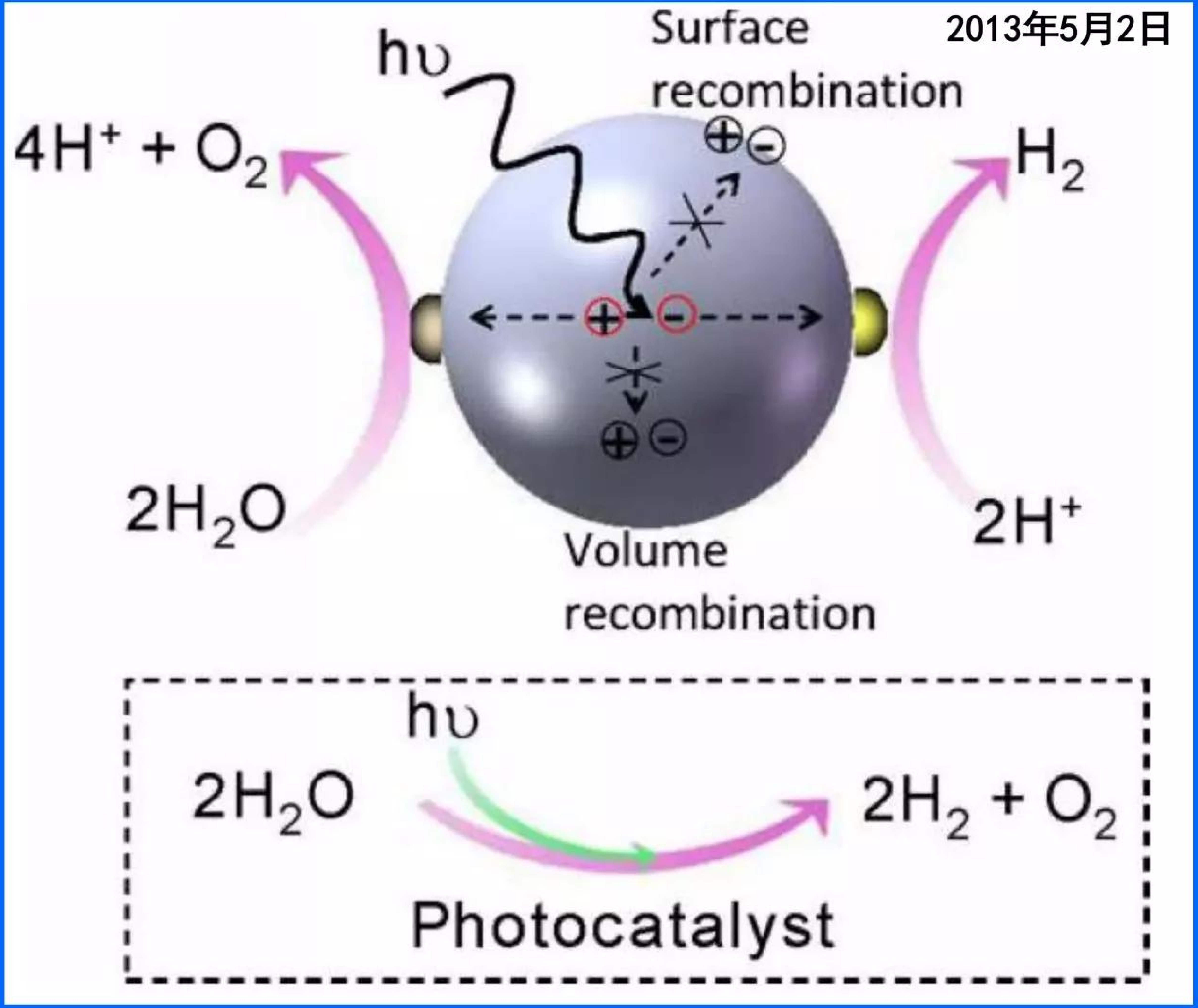
"Photons from a light source (out of image frame further to right) are absorbed by the surface of the Titanium dioxide [$TiO_2$] disc, exciting electrons within the material. These then react with the water [$H_2O$] molecules [adsorbed onto $TiO_2$ disc], splitting it [$H_2O$] into its constituents of Hydrogen and Oxygen. In this experiment, chemicals dissolved in the water prevent the formation of [free] Oxygen, which would otherwise recombine with the Hydrogen."

Wikipedia & University College London


http://www.ucl.ac.uk/mathematical-physical-sciences/potw/potw/potw1315

# Overview: photocatalysis of water to produce Hydrogen ($H_2$)

## "Roles of cocatalysts in photocatalysis and photoelectrocatalysis"





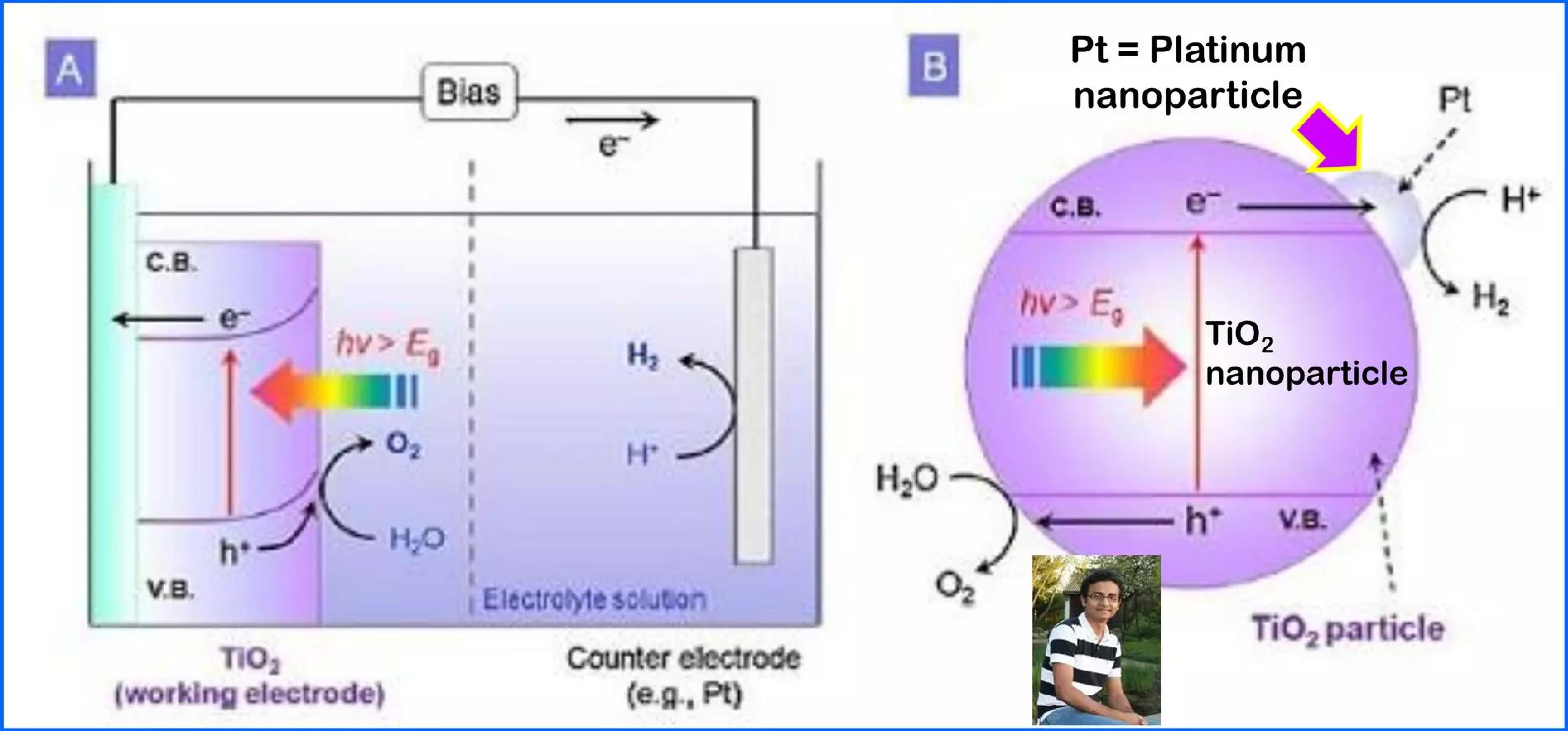

http://www.canli.dicp.ac.cn/article%20highlight/130502article_en.html

# Photocatalysis uses energy in light to split $H_2O$ into $H_2$ & $O_2$

## Catalyst ($Pt/TiO_2$)enables reaction @NTP to produce Hydrogen ($H_2$) gas

Figure 1: (A) Photoelectrochemical water splitting on $TiO_2$ photoanode
(B) Photocatalytic water splitting on hybrid $Pt/TiO_2$ nanoparticles




From: "Solar water splitting: a step towards Carbon-free energy and environment"
Md. Golam Kibria (McGill Univ.) *Chemical Engineering & Science* magazine (2012)
https://chethoughts.com/solar-water-splitting-a-step-towards-carbon-free-energy-and-environment/

# LENRs are a conceptual paradigm shift in nuclear science

## Radiation-free transmutation of chemical elements under mild conditions

**NTP (per NIST) = normal temperature and pressure: about 20 ºC and 1 atmosphere**

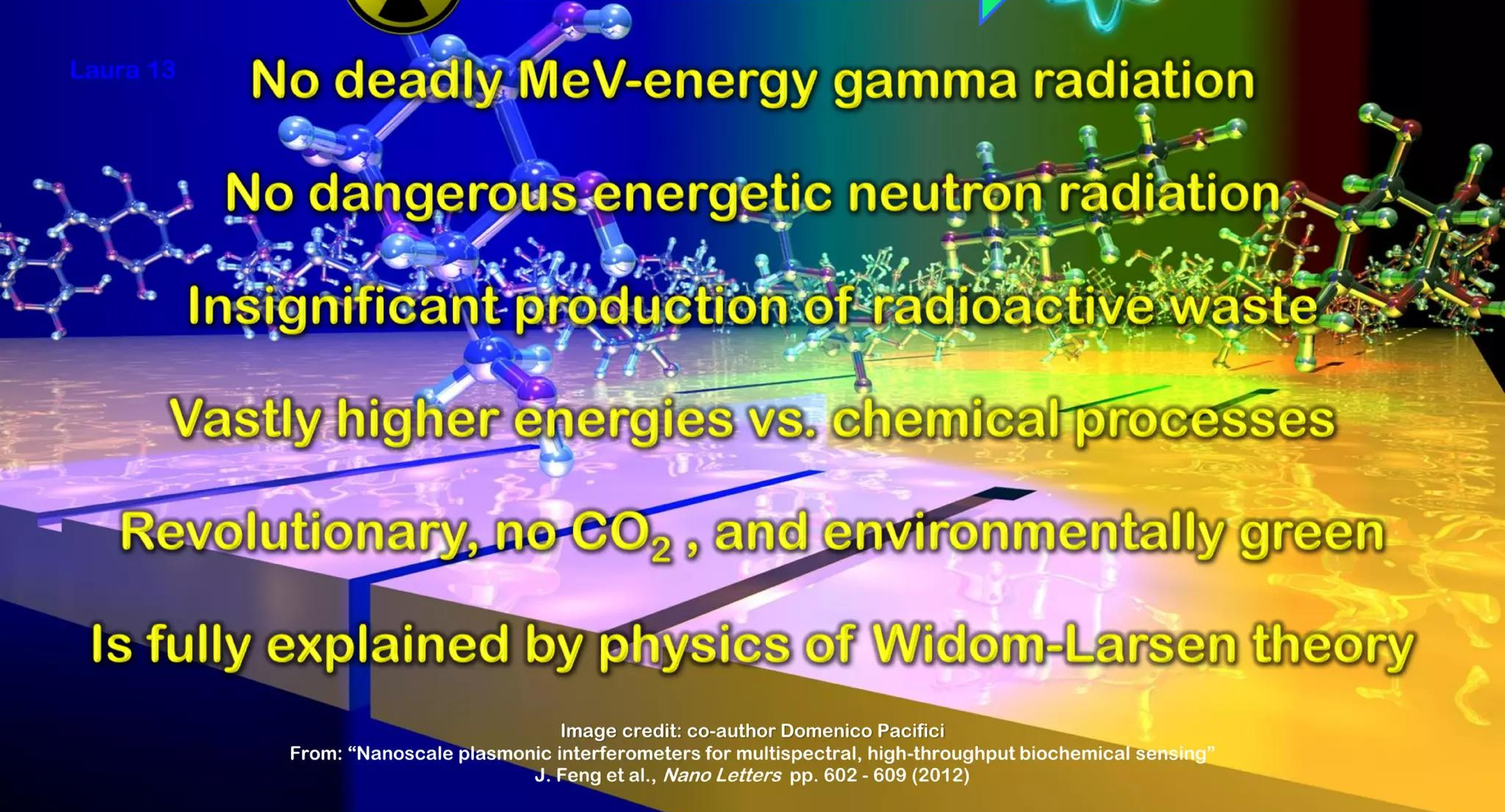
At the heart of multi-decadal controversy and tension surrounding ultralow energy neutron reactions (LENRs) is a revolutionary, still ongoing paradigm shift in nuclear science *a la* Thomas Kuhn. As a result, LENRs have caused great controversy and consternation in the global nuclear community because many scientists' old sacred cows are being gored. In LENRs, radiation-free nucleosynthesis and transmutation of elements can occur in condensed matter systems under comparatively mild, NTP-like macroscopic temperatures and pressures. Idea of LENRs is heretical and anathema to many nuclear scientists still mired in the tight grip of today's dominant, 70-year-old conceptual paradigm. This widely accepted scientific worldview posits that nucleosynthetic processes can only occur in super-hot stellar plasmas, manmade or natural fission reactors, manmade 150 million ºC fusion reactors like the ITER D+T Tokamak, explosions of nuclear weapons, and/or particle accelerators --- all of which emit deadly, readily detected energetic gamma and/or neutron radiation.

# Revolutionary ultralow energy neutron reactions (LENRs)

## Radiation-free LENRs transmute stable elements to other stable elements

Fission and fusion → Evolution of nuclear technology → Safe green LENRs

Laura 13



**No deadly MeV-energy gamma radiation**

**No dangerous energetic neutron radiation**

**Insignificant production of radioactive waste**

**Vastly higher energies vs. chemical processes**

**Revolutionary, no $CO_2$ , and environmentally green**

**Is fully explained by physics of Widom-Larsen theory**

Image credit: co-author Domenico Pacifici
From: "Nanoscale plasmonic interferometers for multispectral, high-throughput biochemical sensing"
J. Feng et al., *Nano Letters* pp. 602 - 609 (2012)

# LENRs are an incredibly interdisciplinary area of science

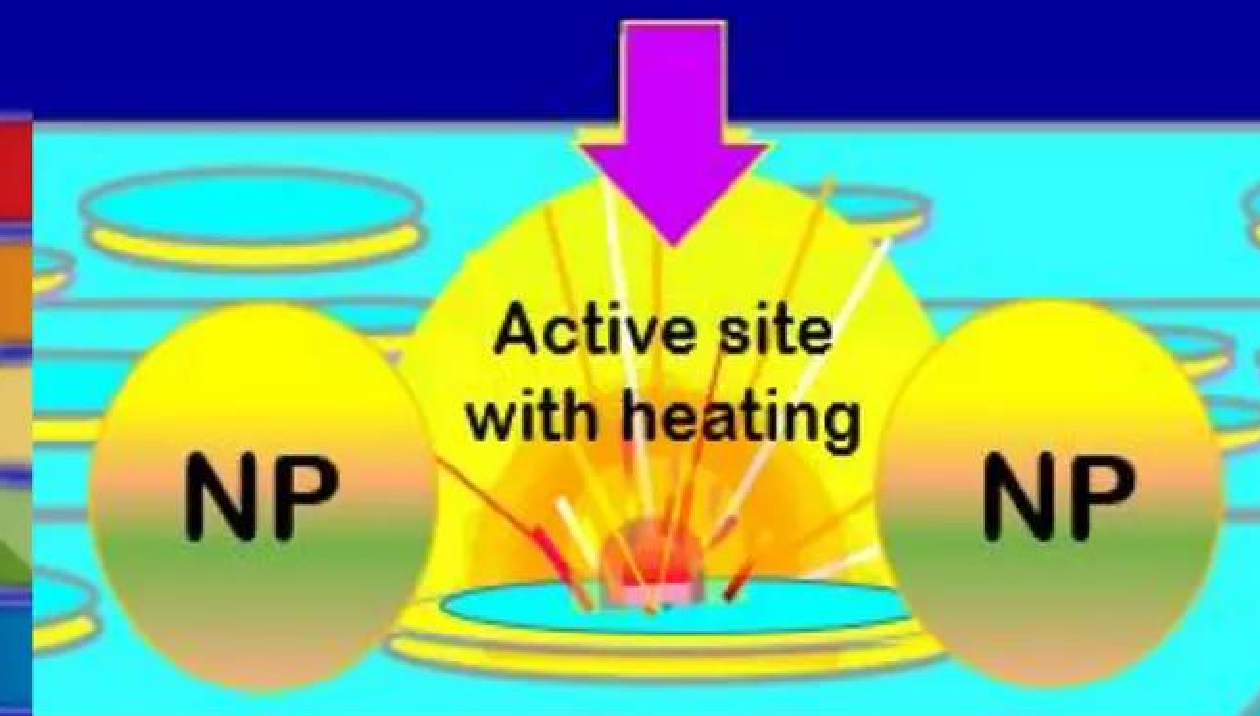
## Resisted understanding until Widom-Larsen put all the pieces together

## Many-body collective quantum effects in LENR active sites enable the 'impossible'

**Scientists observed LENRs for 100 years but didn't connect anomalies to nuclear processes**

- Many-body collective Q-M effects
- Quantum electrodynamics (QED)
- Chemical/enzymatic catalysis
- Modern quantum mechanics
- Condensed matter physics
- Classical electrodynamics
- Plasmonics & photonics
- Modern nuclear physics
- Select nanotechnology
- Surface physics (H,D)
- Dusty plasma physics

Many disciplines are needed to fully understand key physics and operation of microscopic LENR active sites



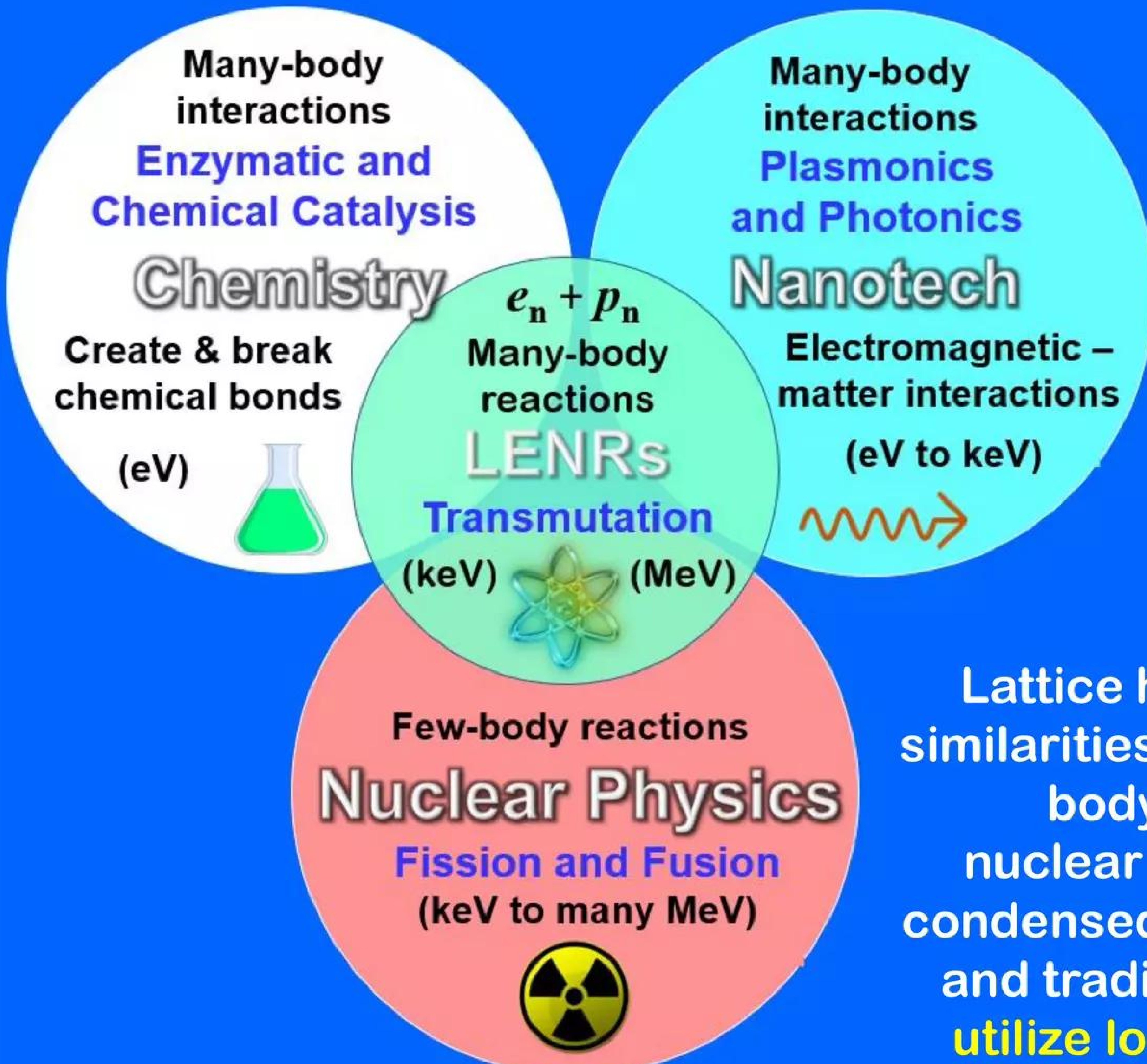

NP = nanoparticle
Micron ($\mu$m) to nanometer (nm) length-scales

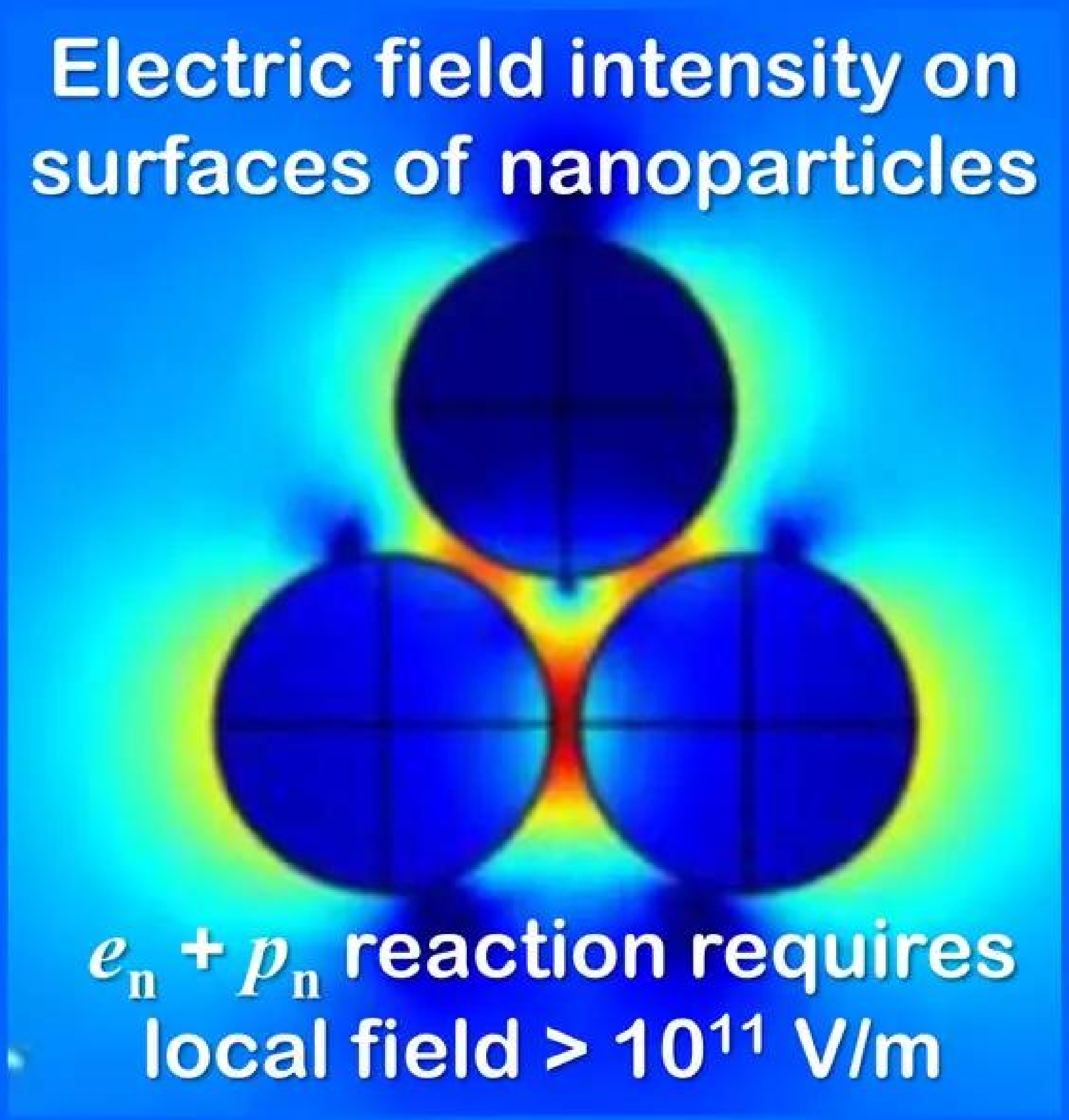
LENR active sites, as a key functional unit, are analogous to transistors in microchips

# LENRs are not as exotic a technology as many might assume

## Widom-Larsen theory: LENR physics, nanotech & chemistry interrelated

### Leverage W-L theory & nanotech know-how to accelerate LENR development




Lattice has discovered deep causal similarities between what enables many-body collective electroweak nuclear catalysis ($e_n + p_n$ reaction in condensed matter), enzymatic catalysis, and traditional chemical catalysis: all utilize local electric fields ≥ $10^{10}$ V/m

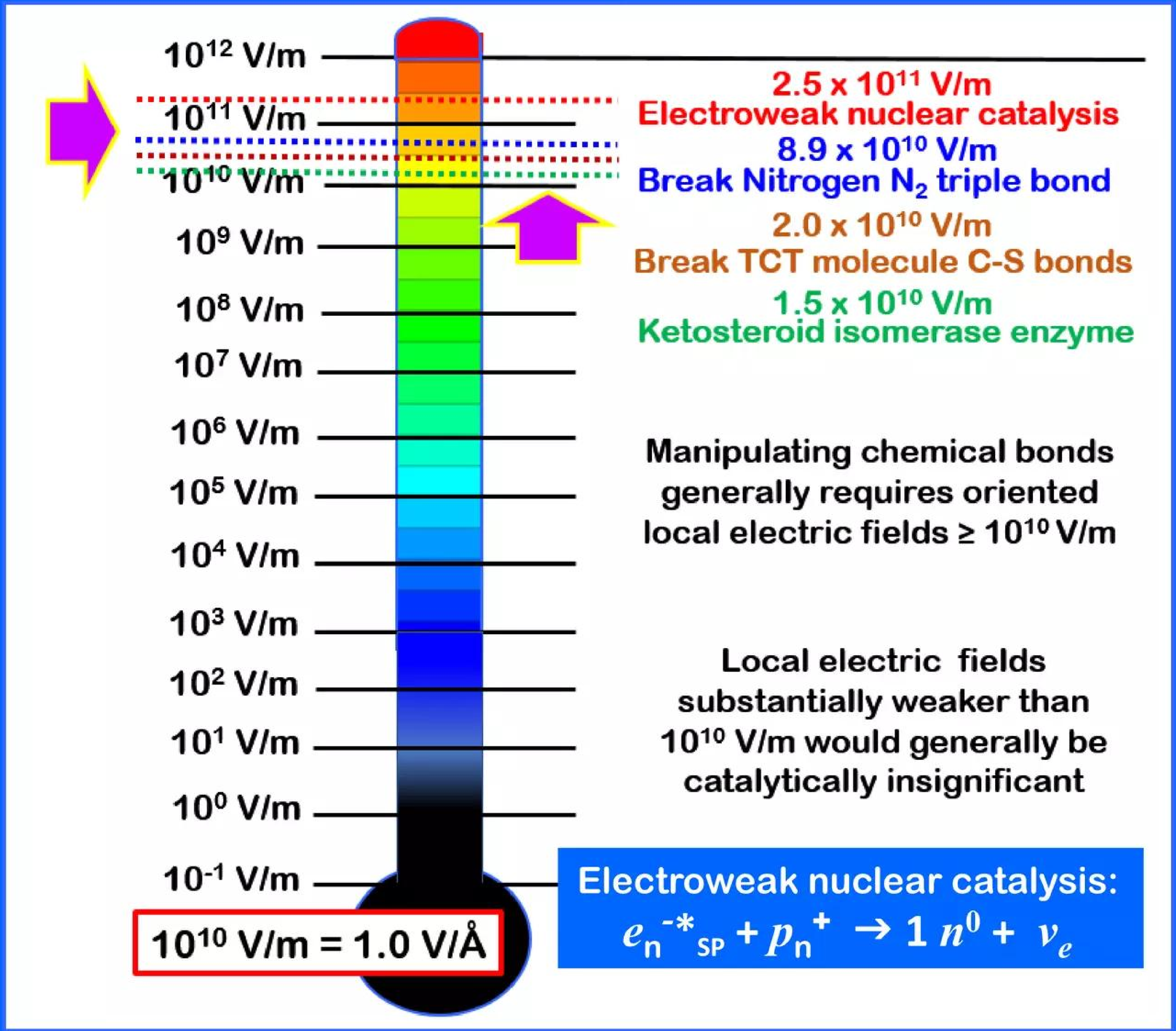
https://www.slideshare.net/lewisglarsen/lattice-energy-llc-japanese-confirm-lattice-hypotheses-re-importance-of-adsorbed-protons-and-high-local-electric-fields-in-chemical-catalysis-june-27-2017

# Chemical & nuclear catalysis involve electric fields ≥ $10^{10}$ V/m

## Electroweak nuclear catalysis threshold < 10x value for breaking $N_2$ bond

Strength of local electric fields on small length-scales measured in Volts/meter (V/m)



# Electroweak ULE neutron production in Widom-Larsen theory

## Protons or deuterons can react directly with electrons to make neutrons

### Input energy required to trigger many-body $e_n + p_n$ reactions in LENR active sites

Input energy boosts electric fields >$10^{11}$ V/m

Heavy-mass $e^{-*}$ electrons react directly with protons

**Collective many-body quantum effects:** many SP electrons each transfer little bits of energy to a much smaller number of *sp* electrons also bathed in same nuclear-strength local electric field > $10^{11}$ V/m

**Quantum electrodynamics (QED):** smaller number of electrons that absorb energy directly from local electric field will increase their effective masses ($m = E/c^2$) above key thresholds $\beta_0$ where they can react directly with a proton (or deuteron) ⟶ neutron and neutrino

Input energy

$$\text{Energy}_{\text{E-field}} + e^-_{n\ SP} \rightarrow e^{-*}_{n\ SP} + p^+_n \rightarrow n^0_{ule} + \nu_e$$

$\nu_e$ neutrinos: ghostly unreactive particles that fly-off into space; $n^0$ neutrons capture on nearby atoms

Induces safe hard-radiation-free nuclear transmutation processes

**Neutrons + atomic nuclei ⟶ heavier elements + decay products**

Neutron capture: $$n + (Z, A) \rightarrow (Z, A+1)$$

Beta decay: $$(Z, A+1) \rightarrow (Z+1, A+1) + e^-_\beta + \bar{\nu}_e$$

Neutron capture-driven transmutation of isotopes and elements

# Widom-Larsen theory posits that LENRs are 5-step process

## Summary of key steps that occur in electroweak Q-M nuclear catalysis

### Hard-radiation-free process: duration of Steps 3 - 4 < 200 - 400 nanoseconds

1. Collectively oscillating, quantum mechanically entangled, many-body active sites of Hydrogen ions ($p^+$, $d^+$, or $t^+$) form spontaneously on substrate surfaces

2. Born-Oppenheimer approximation spontaneously breaks down, allows E-M coupling between local surface plasmon electrons and protons in active sites; application of input energy then creates nuclear-strength local electric fields > 2 x $10^{11}$ V/m: increases effective masses of surface plasmon electrons in sites

3. Heavy-mass SP electrons created in many-body active sites can then react directly with electromagnetically interacting protons: reaction creates neutrons and benign neutrinos via many-body collective electroweak $e + p$ reaction:

   $e_n^- + p_n^+ \rightarrow 1\, n_{ule} + \nu_e$ $\quad$ $e_n^- + d_n^+ \rightarrow 2\, n_{ule} + \nu_e$ $\quad$ $e_n^- + t_n^+ \rightarrow 3\, n_{ule} + \nu_e$

4. Neutrons created in active sites have ultra-low kinetic energies (ULE); virtually all are absorbed by nearby atoms – no dangerous energetic neutron emissions; locally produced or ambient gammas converted directly into infrared photons by unreacted heavy electrons (US# 7,893,414 B2) - no deadly gamma emissions:

   $n_{ule} + (Z, A) \rightarrow (Z, A+1)$ neutrons capture on nearby atoms of elements

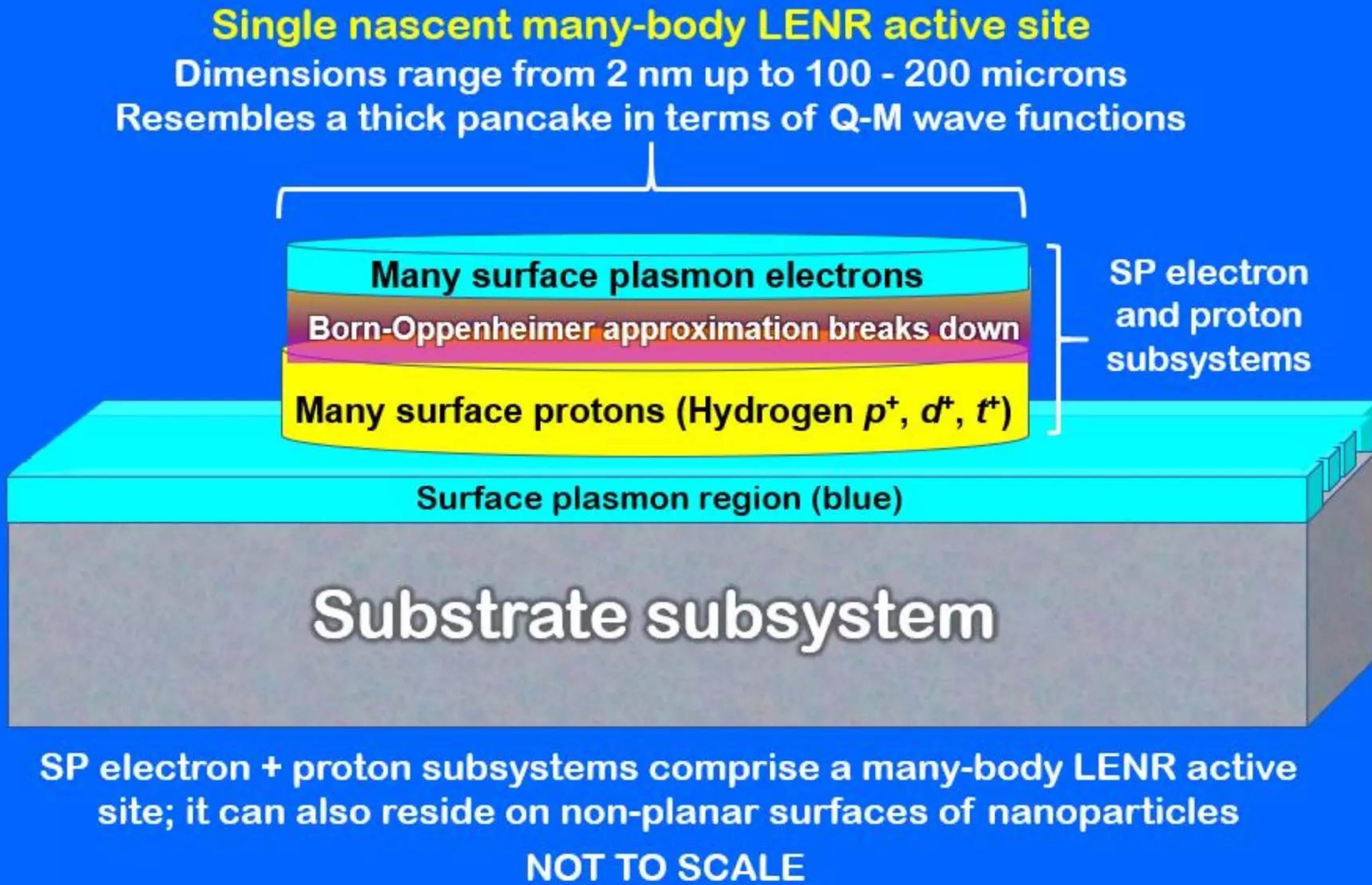
5. Transmutation of locally present elements occurs in and around active sites:

   $(Z, A+1) \rightarrow (Z + 1, A+1) + e_\beta^- + \overline{\nu}_e$ mainly transmutation via beta$^-$ decay

# Widom-Larsen theory provides model for LENR active sites

## Born-Oppenheimer approximation breaks down; enables huge E-fields

### Active site is many-body collection of Q-M entangled protons and SP electrons

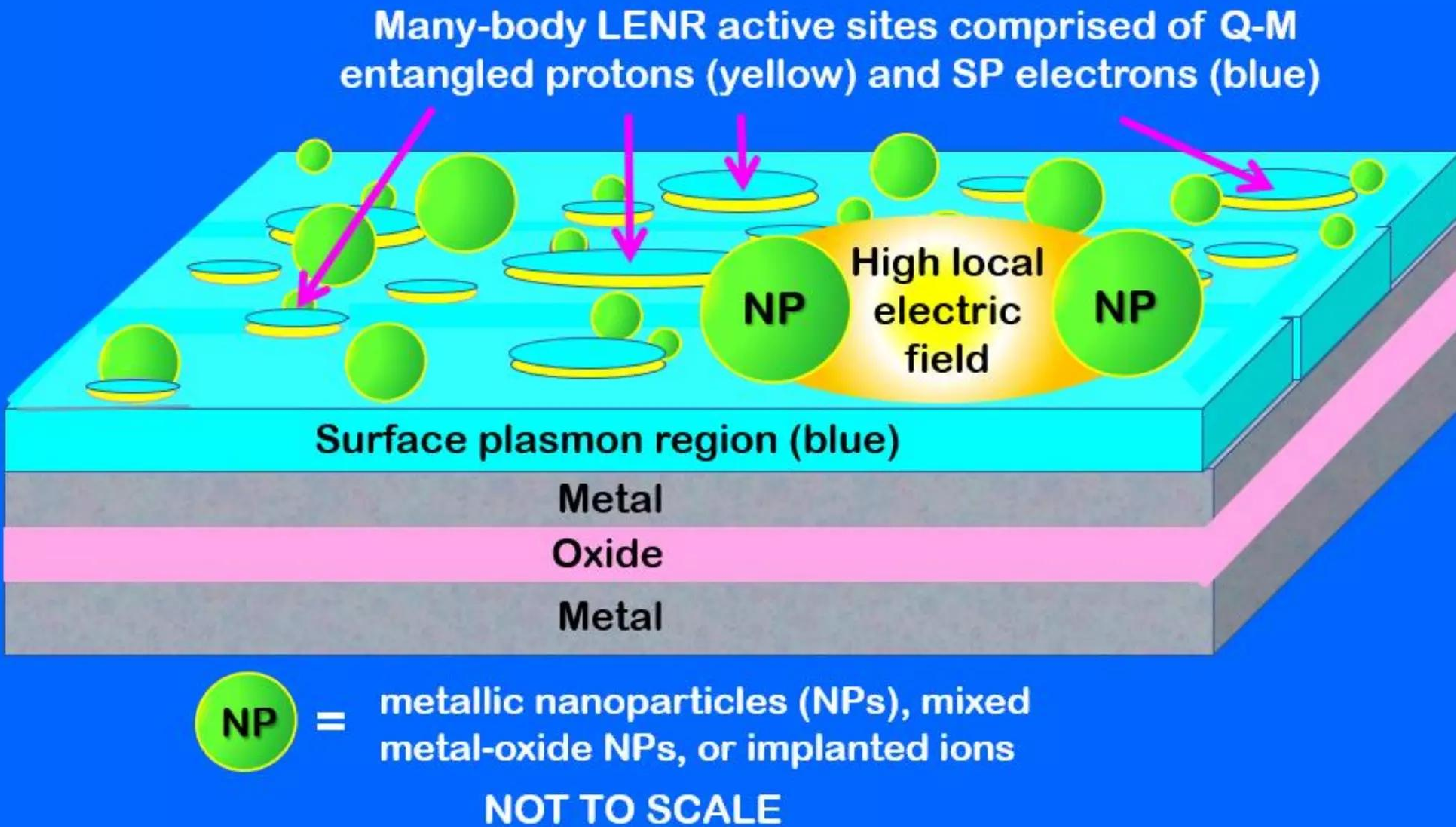


# Widom-Larsen theory provides model for LENR active sites

**Input energy from charged particle currents or electromagnetic photons**

**Injection of input energy can create electric fields > $10^{10}$ V/m in localized regions**



# Nanoparticle shapes/positioning can vastly increase E-fields

## Fang & Huang's Figs.: input energy is concentrated in high electric fields

### Properties can be predicted, modeled, and used to design active site precursors

Figure 1.

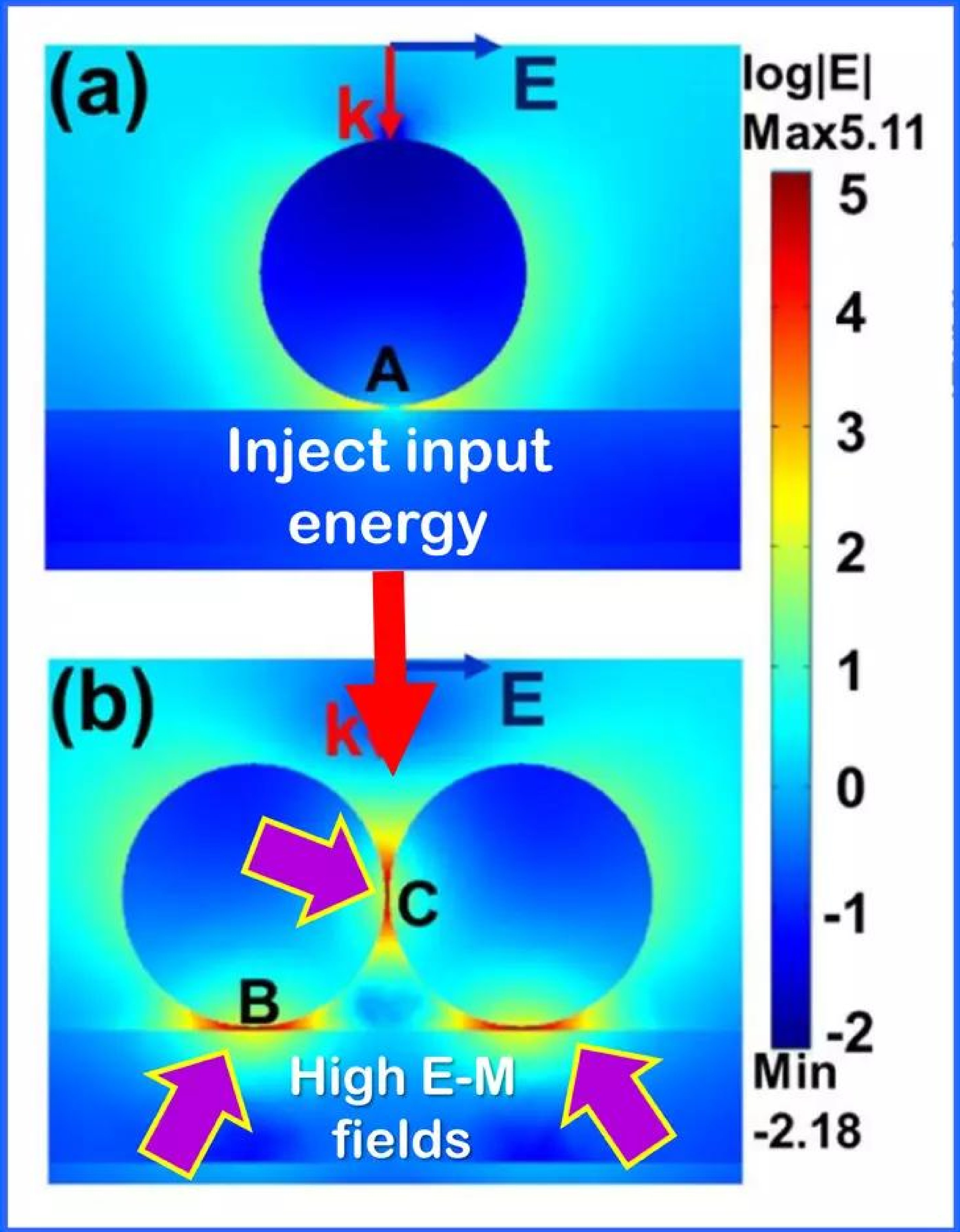
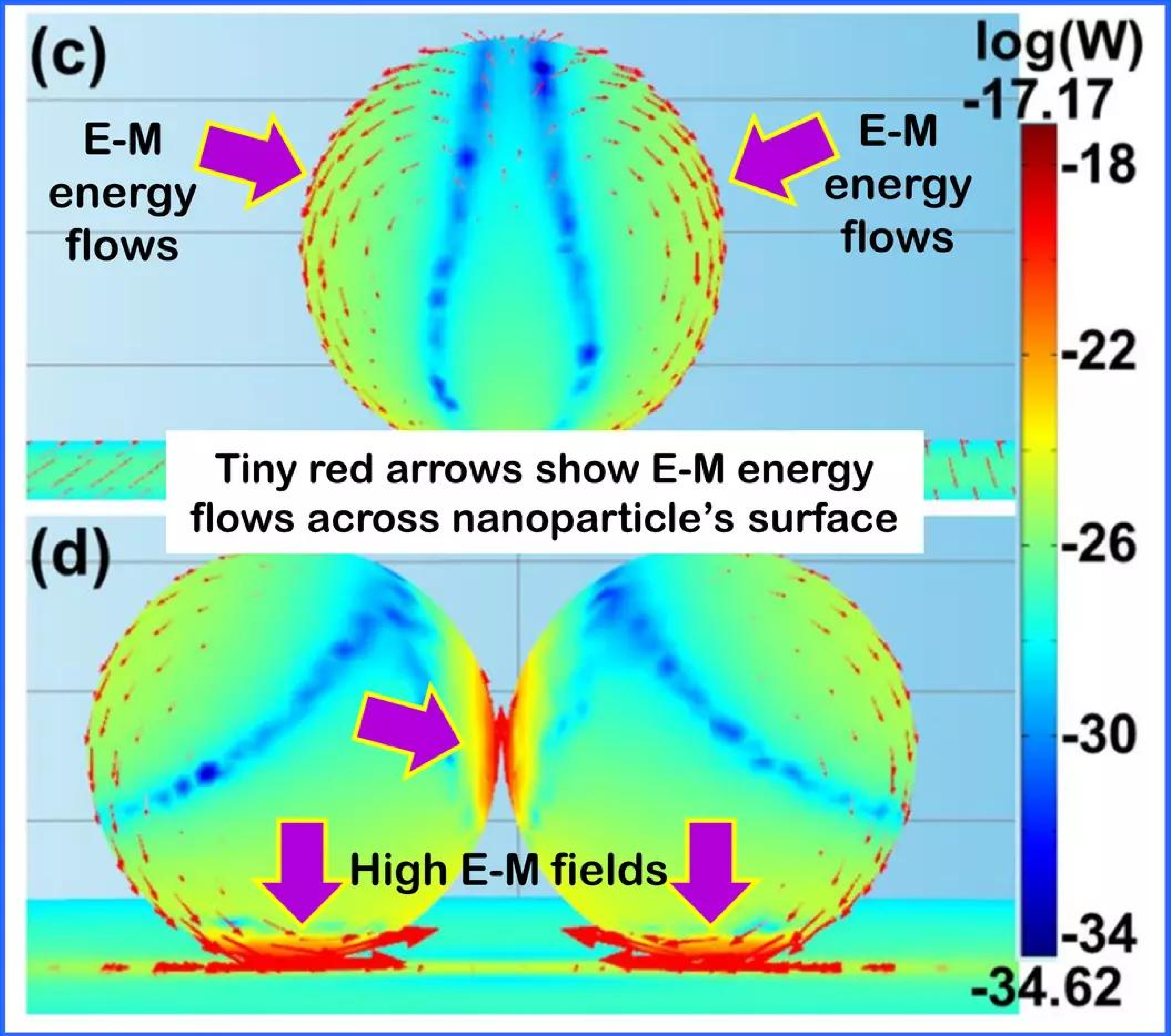



Figure 3.



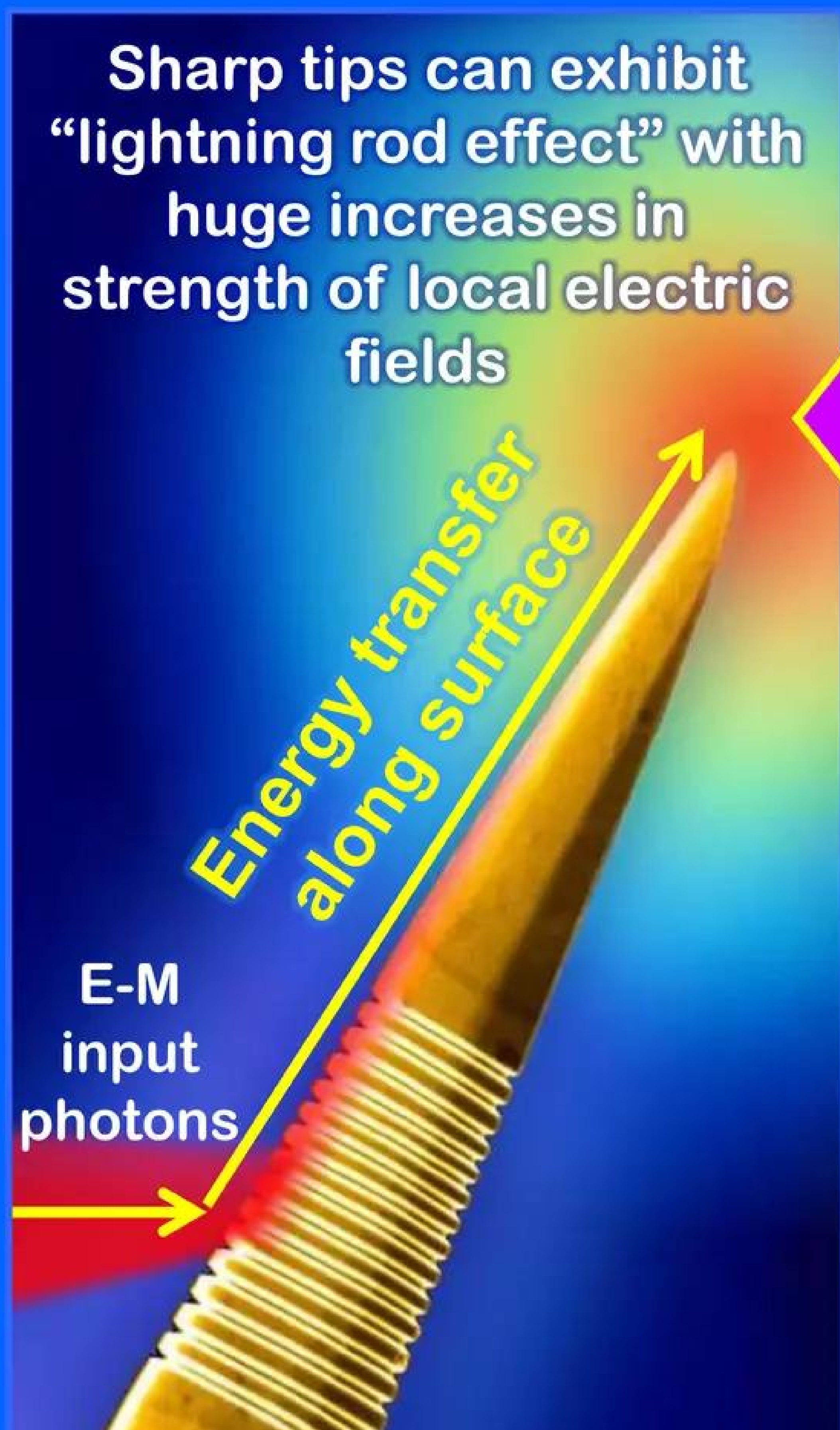

http://publications.lib.chalmers.se/records/fulltext/178593/local_178593.pdf

# Nanostructures can act as antennae that absorb E-M energy

## Surface plasmons (SP) intensify local electric fields on nanoparticles

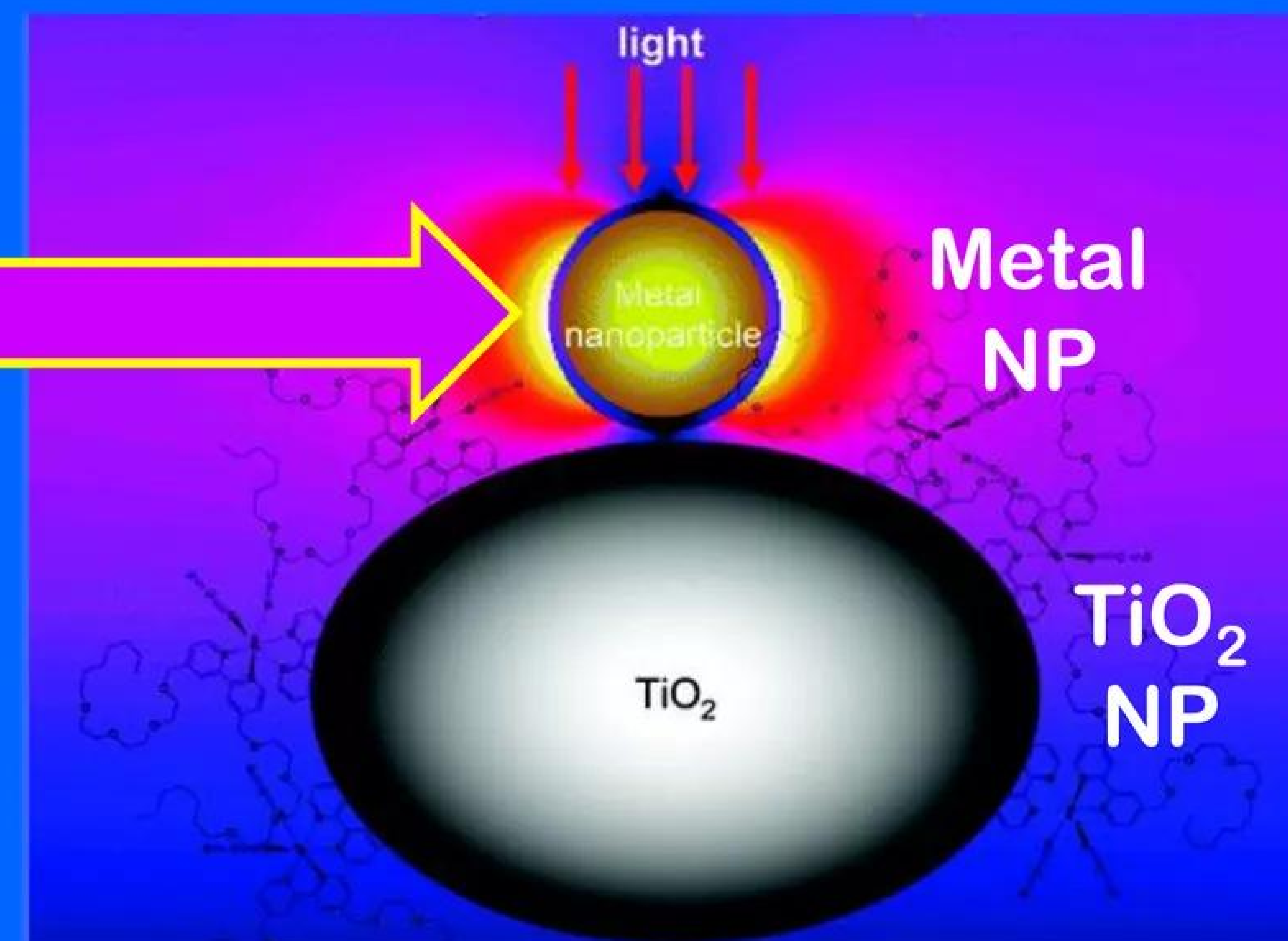
### Nanostructures can be designed to create pulsed E-fields > $2.5 \times 10^{11}$ V/m

**Shows capture of input E-M photons and energy transfer via SP electrons**




Regions of increased electric fields

Plasmonic light harvesting antennae




Metal NP

$TiO_2$ NP

http://people.ccmr.cornell.edu/~uli/res_optics.htm

Source of above image is Wiesner Group at Cornell University: "Plasmonic dye-sensitized solar cells using core-shell metal-insulator nanoparticles" M. Brown et al., *Nano Letters* 11 pp. 438 - 445 (2011)

http://pubs.acs.org/doi/abs/10.1021/nl1031106

# LENR active sites require input energy to produce neutrons

## Charged-particle currents and/or E-M photons can provide input energy

### Widom-Larsen theory of LENRs specifies suitable types of external input energy

- To produce neutrons, LENR active sites require external non-equilibrium fluxes of charged particles or electromagnetic (E-M) photons that can transfer input energy directly to many-body surface plasmon (SP) or $\pi$ electron surface 'films'. Possible external input energy sources include (can be used in combination): DC electric currents and/or oscillating electric currents; E-M photons emitted from coherent lasers, or from incoherent IR resonant E-M cavity walls and other types of light sources (e.g., visible, IR, UV); pressure gradients of $p^+$, $d^+$, and/or $t^+$ ions imposed across nearby surfaces; and/or charged currents of other ions traversing SP electron 'films' in either direction (i.e., two-way ionic fluxes)
- External sources must provide adequate amounts of input energy required to surpass certain minimum Hydrogen-isotope-specific increased electron-mass thresholds that enable production of ultralow energy (ULE) neutrons via Widom-Larsen many-body collective electroweak $e^*_n + p^+_n$ ; $e^*_n + d^+_n$ ; $e^*_n + t^+_n$ reactions
- Note that surface plasmons (SPs) are many-body, collective electromagnetic (E-M) excitations that are: (1) created by electrons or photons; (2) tightly coupled with surfaces and interfaces. SPs occur at gas/metal interfaces or metal/oxide interfaces. They can therefore be present at or near contact points between metallic surfaces and adjacent layers and/or discrete individual nanoparticles comprising various oxides, e.g., PdO, Graphene oxide, $TiO_2$, $PtO_2$; or vice-versa

# LENR theory extends to aromatics, graphene, and fullerenes

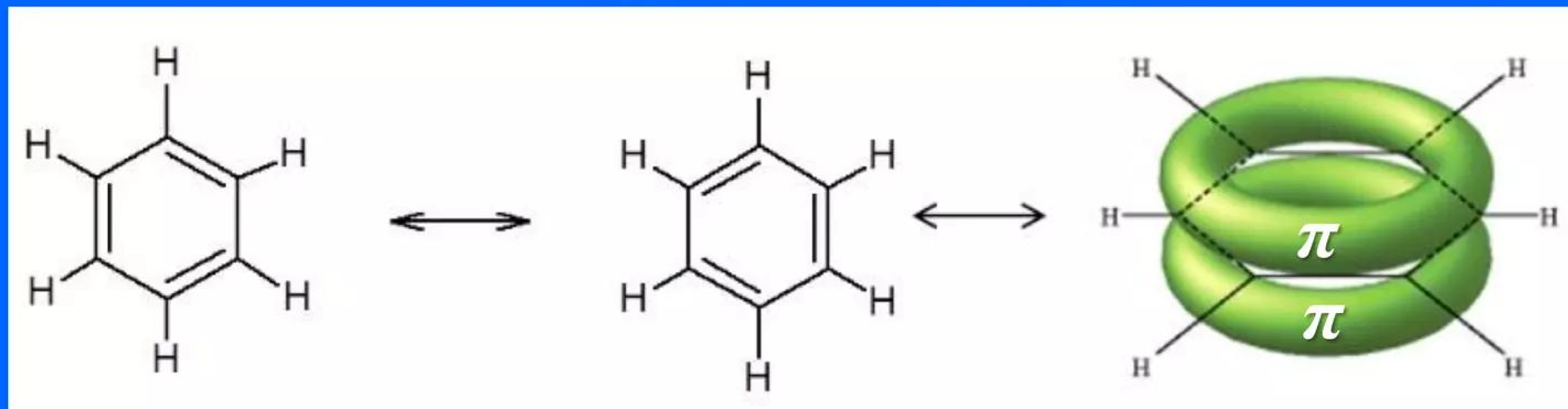
Just like surface plasmon electrons on metals, $\pi$ electrons found above and below rings of aromatic Carbon molecules, on surfaces of planar graphene, and on some fullerene structures, are delocalized, oscillate collectively, and are Q-M entangled. Hydrogen atoms (protons or deuterons) bonded to aromatic molecules or adsorbed on surfaces of graphene (or bonded to Graphane) and some fullerenes can also oscillate collectively and are entangled. Consequently, under proper conditions these molecular systems can form many-body collections of Q-M entangled protons and electrons that are functionally equivalent to nm- to multi-micron-sized LENR active sites that form spontaneously on surfaces of Hydrogen-loaded metals. As with metal-hydrides, Born-Oppenheimer approximation can also break down on graphene and fullerene molecular surfaces.

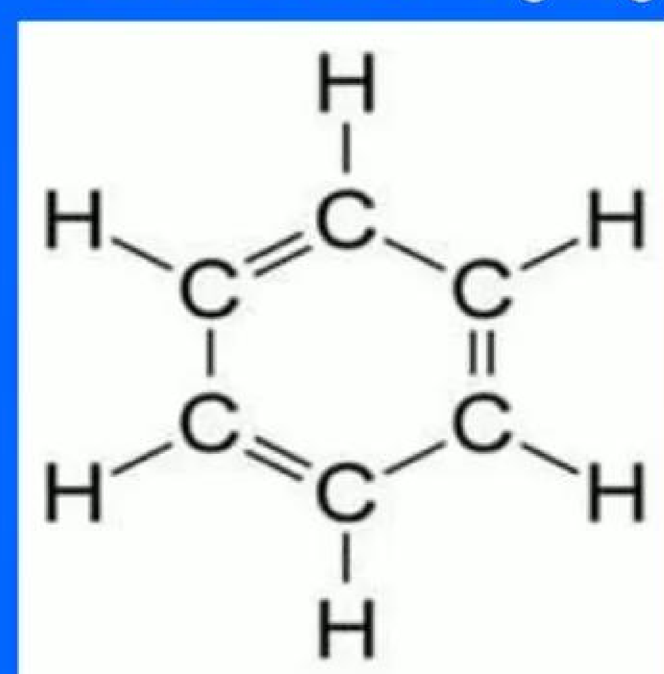
# LENR theory extends to aromatics, graphene, and fullerenes

## $\pi$ electrons on aromatics & Graphene can behave like surface plasmons

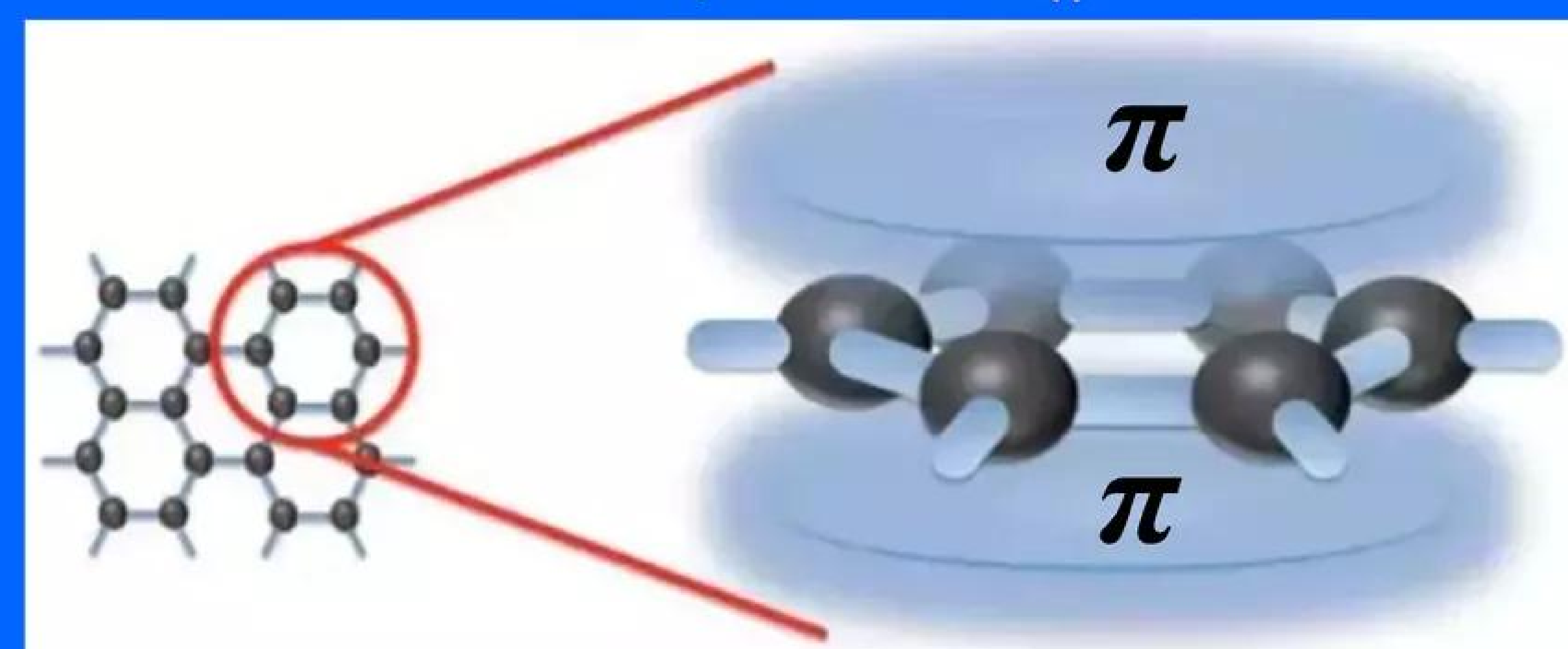
**Aromatic Carbon ring molecules (simplest is Benzene)**




**Benzene $C_6H_6$**




**Graphene $C_n$**




"Damping pathways of mid-infrared plasmons in Graphene nanostructures" H. Yan et al. *Nature Photonics* 7 pp. 394 - 399 (2013)

https://www.nature.com/articles/nphoton.2013.57

"Graphene-plasmon polaritons: From fundamental properties to potential applications" S. Xiao et al. *Frontiers of Physics* 11 pp. 117801 - 117814 (2016)

https://link.springer.com/article/10.1007/s11467-016-0551-z

# Widom-Larsen theory shows how to increase reaction rates

## Maximize density of $e^{-}*p^{+}$ or $e^{-}*d^{+}$ reactants and quantity of input energy

"Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces" A. Widom and L. Larsen Cornell physics preprint arXiv:nucl-th/0608059v2 12 pages (2007)

http://arxiv.org/pdf/nucl-th/0608059v2.pdf

- Term $(\beta - \beta_0)^2$ in our published rate equation reflects the degree to which heavy-mass (renormalized) $e^{-}*$ electrons in LENR-active surface sites exceed minimum W-L threshold ratio for electroweak neutron production, $\beta_0$
- We predict that, all other things being equal, the higher the surface area-density of $e^{-}*p^{+}$ or $e^{-}*d^{+}$ reactants and greater the rate and total quantity of appropriate forms of nonequilibrium energy inputs, the higher the rate of ULE neutron production in nm- to $\mu$m-scale LENR-active sites in properly engineered, nanotech-based, LENR thermal power generation devices
- LENR transmutation network pathways comprising series of picosecond-duration neutron captures interspersed with serial beta-decay cascades can release substantial amounts of nuclear binding energy, much of it in form of usable process heat, over periods ranging from hours to weeks --- depends on target fuels, pathways used, and total quantity of input energy

# Many-body collective quantum effects are crucial for LENRs

## Enable LENR transmutation reactions at moderate temps & pressures

Many-body collective quantum $e^{*}{}_{n}^{-} + p_{n}^{+} \rightarrow 1\ n_{ule} + \nu_{e}$ effects

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

$$(Z, A+1) \rightarrow (Z+1, A+1) + e_{\beta}^{-} + \overline{\nu}_{e}$$

**LENRs do not involve any fission or 2-body hot fusion reactions --- key step that produces neutrons is many-body collective $e_n + p_n$ reaction between quantum mechanically entangled electrons and protons on top solid surfaces or at interfaces**

**"Quantum entanglement in physics - What it means when two particles are entangled" Andrew Z. Jones for *ThoughtCo* July 10, 2017**
https://www.thoughtco.com/what-is-quantum-entanglement-2699355

Credit: MARK GARLICK/SCIENCE PHOTO LIBRARY/Getty Images

# Many-body collective quantum effects are crucial for LENRs

## Surface plasmons in LENR active sites quantum mechanically entangled

### SPs comprise up to ~$10^{10}$ electrons and 'macroscopic' but are still Q-M entangled

"Plasmon-assisted transmission of entangled photons"
E. Altewischer *et al.*, *Nature* 418 pp. 304 - 306 (2002)

http://home.physics.leidenuniv.nl/~exter/articles/nature.pdf

- "Here we investigate the effects of nanostructured metal optical elements on the properties of entangled photons. To this end, we place optically thick metal films perforated with a periodic array of subwavelength holes in the paths of the two entangled photons. Such arrays convert photons into surface-plasmon waves --- optically excited compressive charge density waves --- which tunnel through the holes before reradiating as photons at the far side. We address the question of whether the entanglement survives such a conversion process. Our coincidence counting measurements show that it does, so demonstrating that the surface plasmons have a true quantum nature."
- "From a general perspective, the observed conservation of quantum entanglement for the conversion from photon → surface plasmon → photon is a demonstration of the true quantum nature of SPs."
- " … a simple estimate shows that SPs are very macroscopic, in the sense that they involve some $10^{10}$ electrons. Our experiment proves that this macroscopic nature does not impede the quantum behaviour of SPs …"

# Many-body collective quantum effects are crucial for LENRs

## Protons in LENR active sites are also quantum mechanically entangled

### Quantum entanglement of protons is relatively widespread throughout Nature

- Protons found within a wide variety of many-body condensed matter molecular systems spontaneously oscillate coherently and collectively: their quantum mechanical (Q-M) wave functions are thus effectively entangled with each other and also with nearby collectively oscillating electrons. Amazingly, this behavior occurs even in comparatively smaller, much simpler molecular systems such as $(NH_4)_2PdCl_6$, ammonium hexaclorometallate; see Krzystyniak *et al*. (2007) and Abdul-Redah & Dreismann (2006)
- Quoting from Krzystyniak et al.(2007): "… 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."
- Quoting 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."

# Many-body collective quantum effects are crucial for LENRs

## Protons go in-and-out of entanglement in 100 - 500 x $10^{-18}$ s time-frames

### LENRs can take advantage of this because they work on even faster time-scales

"Attosecond quantum entanglement in neutron Compton scattering from water in the keV range" C.A. Chatzidimitriou-Dreismann
*Physica B: Condensed Matter* 385 - 386 pp. 1 - 6 (2006)
https://arxiv.org/abs/cond-mat/0702180

- Quoting: "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: "Entangled mechanical oscillators" J. Jost et al., *Nature* 459 pp. 683 - 685 (2009) where they state "… mechanical vibration of two ion pairs separated by a few hundred micrometres is entangled in a quantum way."

# Many-body collective quantum effects are crucial for LENRs

## Protons in LENR active sites are also quantum mechanically entangled

### "No other nucleus can manifest such an increase of its coherent cross-section"

"Evidence of macroscopically entangled protons in a mixed isotope crystal of $KH_pD_{1-p}CO_3$" F. Fillaux, A. Cousson, and M. Gutmann
*Journal of Physics: Condensed Matter* 22 pp. 045402 (2010)
http://iopscience.iop.org/0953-8984/22/4/045402/pdf/0953-8984_22_4_045402.pdf

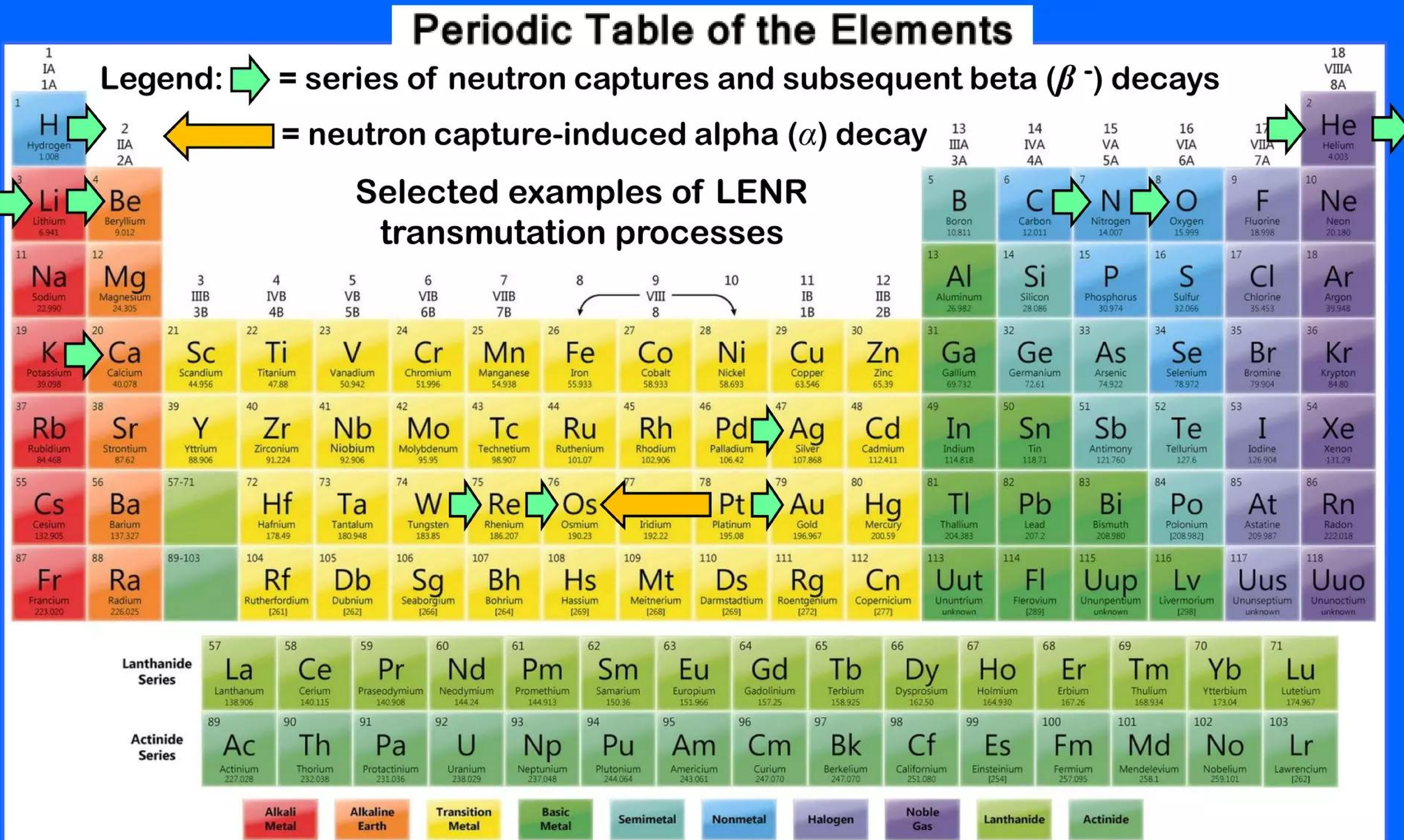
- Quoting: "Proposed theory is based on fundamental laws of quantum mechanics applied to crystal in question … It leads to macroscopically entangled states … This theory is consistent with a large set of experimental data (neutron diffraction, QENS, INS, infrared and Raman) and, to the best of our knowledge, there is no conflict with any observation. There is … every reason to conclude that the crystal is a macroscopic quantum system for which only nonlocal observables are relevant."
- "Protons are unique to demonstrating quantum entanglement, because they are fermions and because the very large incoherent cross-section can merge into the total coherent cross-section. No other nucleus can manifest such an increase of its coherent cross-section … They are evidences of macroscopic quantum correlations which have no counterpart in classical physics … This work presents one … case of macroscopically entangled states on the scale of Avogadro's constant in a mixed isotope crystal at room temperature … quantum theory suggests that macroscopic quantum effects should be of significance for many hydrogen bonded crystals."

# Neutron captures & $\beta^-$ decays go from left-to-right along rows

## Alpha decays induced by neutron capture go from right-to-left along rows

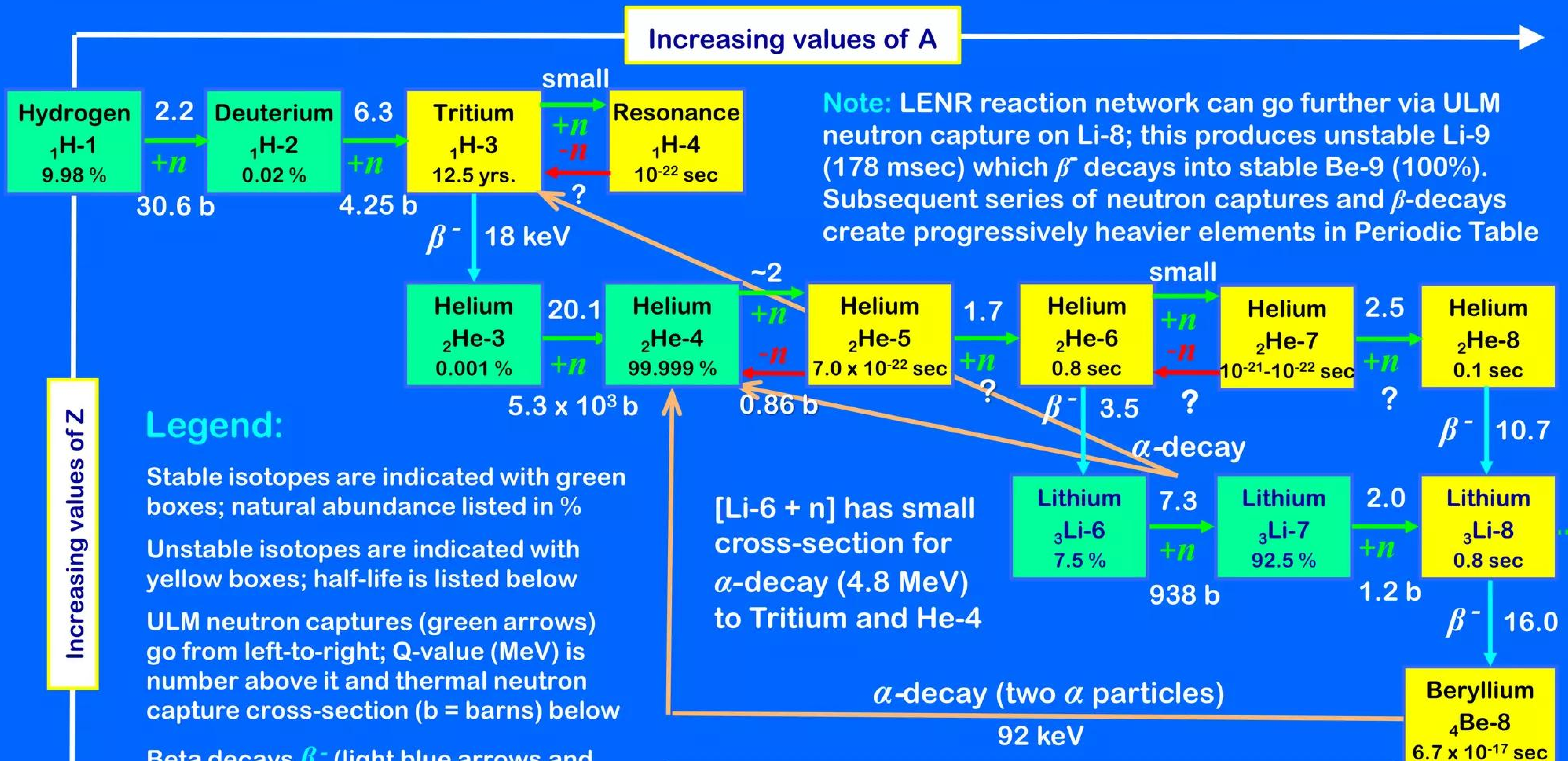
## Alpha-decay process produces Helium-4 ($^4He$) which comprises a monatomic gas



# LENR transmutation reactions from Hydrogen thru Beryllium

## Combination of neutron captures and $\beta^-$ decays create D, T, He, Li & Be

### Big Bang elements produced in lab experiments under moderate conditions




**Note:** LENR reaction network can go further via ULM neutron capture on Li-8; this produces unstable Li-9 (178 msec) which $\beta^-$ decays into stable Be-9 (100%). Subsequent series of neutron captures and $\beta$-decays create progressively heavier elements in Periodic Table

## Legend:

Stable isotopes are indicated with green boxes; natural abundance listed in %

Unstable isotopes are indicated with yellow boxes; half-life is listed below

ULM neutron captures (green arrows) go from left-to-right; Q-value (MeV) is number above it and thermal neutron capture cross-section (b = barns) below

Beta decays $\beta^-$ (light blue arrows and numbers) go top-to-bottom; isotope's decay energy (MeV unless otherwise noted) listed to right of the arrow

Alpha decay of Be-8 is in dark orange

Gamma emissions are not shown on chart because they are automatically converted directly into infrared photons (heat) by unreacted heavy-mass SP electrons per Widom-Larsen theory: see Lattice issued patent US #7,893,414 B2

# Helium is produced via neutron capture on some Pt isotopes

## Many elements have tiny cross-sections for $\alpha$-decay with neutron capture

### Permitted if *Q*-value for n-capture + $\alpha$-decay > *Q*-value for n-capture + $\gamma$ emission

"On the reaction Pt(n, $\alpha$)Os" M. Cresswell & R. Roy
*Proceedings of the Physical Society* 78 pp.1297 - 1300 (1961)

http://iopscience.iop.org/article/10.1088/0370-1328/78/6/331

Abstract: "The reaction Pt(n,$\alpha$)Os has been investigated by a nuclear emulsion technique, using the thermal neutron flux of the Pennsylvania State University reactor. A semi-empirical range-energy relationship has been developed for $\alpha$-particles in Platinum and has been used for the evaluation of data. Two groups of alpha particles have been observed with certainty, corresponding to *Q*-values 6.9±0.3 MeV, and 8.5±0.3 MeV and have been identified with reactions $^{194}$Pt(n,$\alpha$)$^{191}$Os and $^{195}$Pt(n,$\alpha$)$^{192}$Os respectively. A probable group of alpha particles corresponding to *Q*-value 12.1±0.3 has been associated with the reaction $^{193}$Pt(n,$\alpha$)$^{190}$Os."

# Helium is produced with neutron captures on many elements

## Many isotopes have small $\alpha$-decay cross-sections upon neutron capture

### Allowed if Q-value for n-capture + $\alpha$-decay > Q-value for n-capture + $\gamma$ emission

"Search for gas producing reactions in thermal reactors"
P. D'hondt et al.'s conference paper: pp. 147 - 149 in book
"Nuclear Data for Science and Technology" K. Böckhoff ed.
Proceedings of the International Conference Antwerp (Sept. 6 - 10, 1982)

https://link.springer.com/chapter/10.1007/978-94-009-7099-1_29

Abstract: "Four types of gas producing reactions induced by thermal neutrons have been studied at an intense thermal neutron beam of the Grenoble High Flux Reactor: (i) Hydrogen, Tritium and Helium production during the ternary fission process for several actinides; (ii) Hydrogen and Helium production via ($n_{th}$, $p$) and ($n_{th}$,$\alpha$) reactions on structural materials like V, Zn and Mo; (iii) Helium production via ($n_{th}$,$\alpha$) reactions on fission products like Ru, Pd, Cd and Sn; (iv) Helium production via ($n_{th}$,$\alpha$) reactions on Actinides from $^{232}$Th to $^{239}$Pu. Gas producing cross-sections ranging from a few barn to smaller than one microbarn have been observed."

Nuclear reactions: " $^{233}$U(n,f); $^{235}$U(n,f); $^{237}$Nn(n,f); $^{239}$Pu(n,f); $^{51}$V(n,$p$); $^{65}$Zn(n,$\alpha$); $^{95}$Mo(n,$\alpha$); $^{97}$Mo(n,$\alpha$); $^{101}$Ru(n,$\alpha$); $^{105}$Pd(n,$\alpha$); $^{113}$Cd(n,$\alpha$); $^{115}$Sn(n,$\alpha$); $^{232}$Th(n,$\alpha$); $^{233}$U(n,$\alpha$); $^{235}$U(n,$\alpha$); $^{238}$U(n,$\alpha$); $^{239}$Pu(n,$\alpha$)"

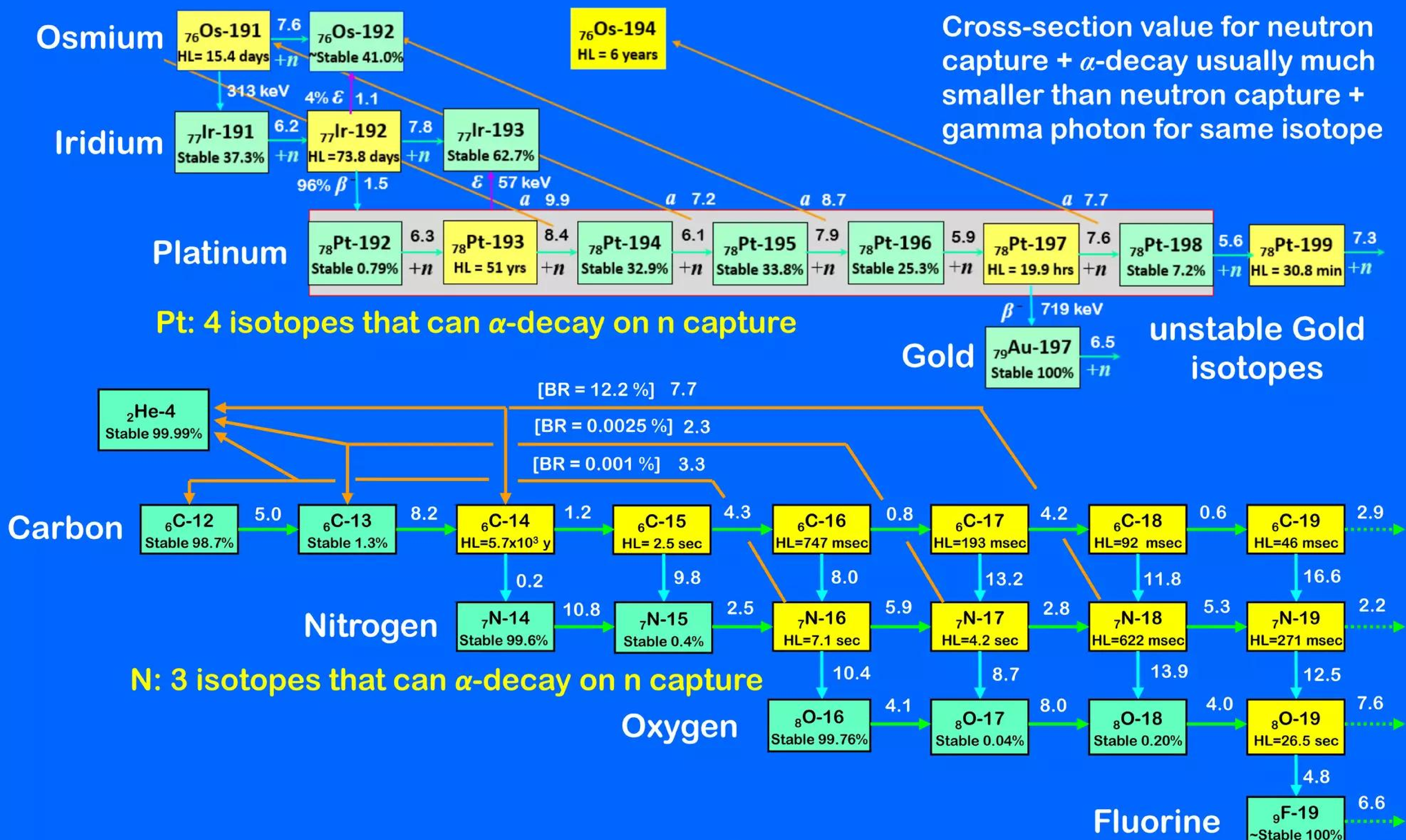
E [neutrons] = thermal; yield of ternary particles, $\sigma$(n,$\alpha$)."

# Helium (He) can be produced via multiple pathways in LENRs

## Certain Platinum isotopes can undergo an $\alpha$-decay after neutron captures

## Very neutron-rich Nitrogen isotopes have significant alpha-decay cross-sections



# Neutron captures cause significant changes in isotope ratios

## LENR transmutations alter Carbon, Nitrogen, and Oxygen isotope ratios

$$\delta^{15}N(‰) = \left( \frac{\left({}^{15}N/{}^{14}N\right)_{sample} - \left({}^{15}N/{}^{14}N\right)_{standard}}{\left({}^{15}N/{}^{14}N\right)_{standard}} \right) \times 1000$$

**Natural abundances (two stable isotopes):**
**$^{14}N$ = ~99.636%; $^{15}N$ = ~0.364%**
**Thermal neutron capture cross-section (barns):**
**$^{14}N$ = 0.080 ; $^{15}N$ = 0.04 mb**

- If $^{14}N$ were exposed to ULE neutron fluxes, it would be transmuted to $^{15}N$ with the capture of one neutron. Thus, abundance of $^{15}N$ can be enriched by neutron-catalyzed LENR processes; i.e., $\delta^{15}N$ would *increase* vs. the Standard, which happens to be the isotopic ratio of Nitrogen found in Earth's atmosphere
- When stable Carbon-13 ($^{13}C$ natural abundance = ~1.3%) captures one neutron, it creates unstable Carbon-14 ($^{14}C$ half-life = 5,730 years; varying trace amounts are always present in living matter), which then beta decays to Nitrogen-14 ($^{14}N$) thus *decreasing* $\delta^{15}N$ (because it increases value of $^{14}N_{sample}$ in the denominator)
- If $^{15}N$ captures one neutron, it would be transmuted to $^{16}N$, which is unstable (half-life = 7.1 seconds); $^{16}N$ beta decays to stable Oxygen ($^{16}O$ natural abundance = 99.76%). In this case, $^{15}N$ will be depleted and $^{16}O$ enriched; thus mass-balance of Nitrogen could show a deficit; there may be "missing Nitrogen" that 'disappeared'
- Depending on initial conditions, exposing C, N, or O to ULE neutron fluxes would detectably alter whatever isotopic ratios that had existed prior to being exposed

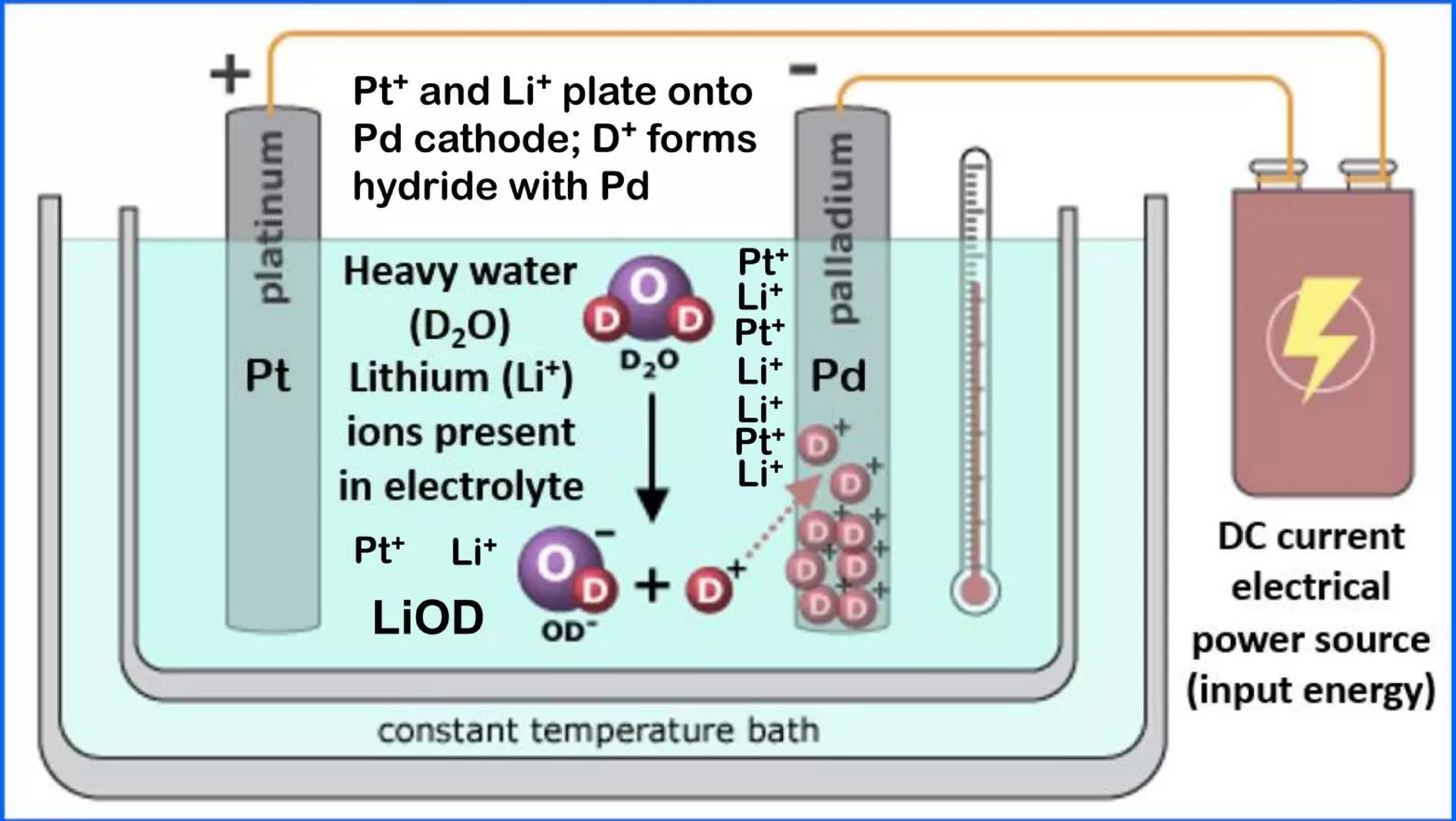
# LENRs are well-documented to occur in electrochemical cells

## Example below: Pt anode, Pd cathode, $D_2O$, Lithium salts in electrolyte

## DC current provides input energy to split water $D_2O$ ($d^+$) and create neutrons

Experimental apparatus in example closely resembles battery being charged

$$\text{Input energy}_{\text{DC electric current}} + e^-_n \rightarrow e_n^{-*} + d_n^+ \rightarrow 2n + \nu_e$$




Adapted from source: http://undsci.berkeley.edu/article/0_0_0/cold_fusion_03

# Li-7/Li-6 isotopic shifts are observed in Lithium-ion batteries

## Reported by K. Okano *et al*. (2015) during charging of a LiMnO cell

### Mass spectroscopy used to measure changes in Li-7/Li-6 isotope ratios

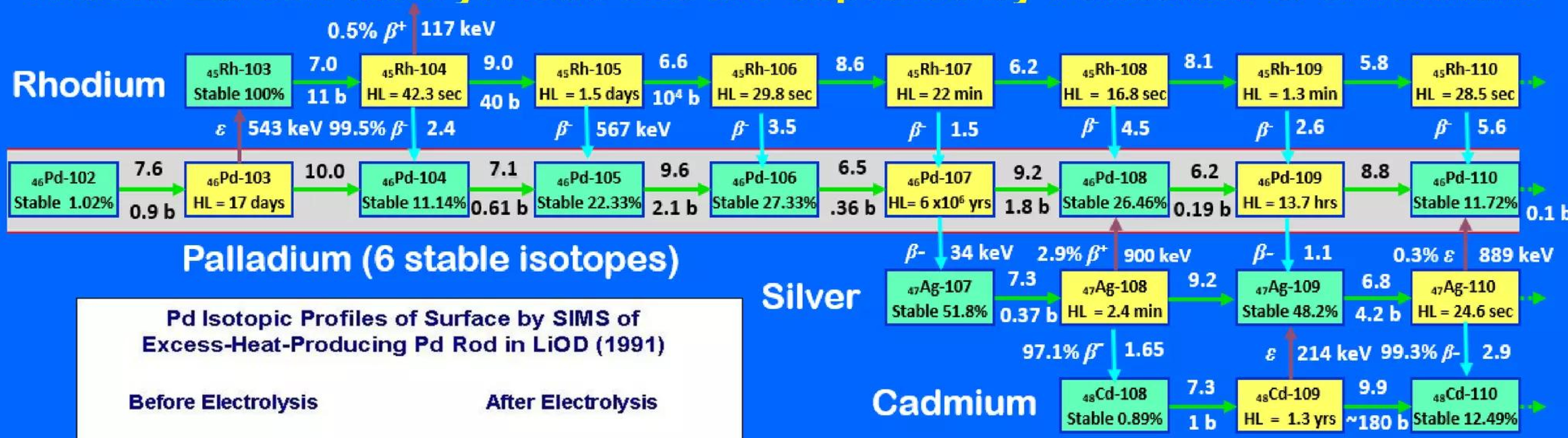
"Lithium isotope effects upon electrochemical release from Lithium manganese oxide" K. Okano *et al*. *Energy Procedia* 71 pp. 140 - 148 (2015)

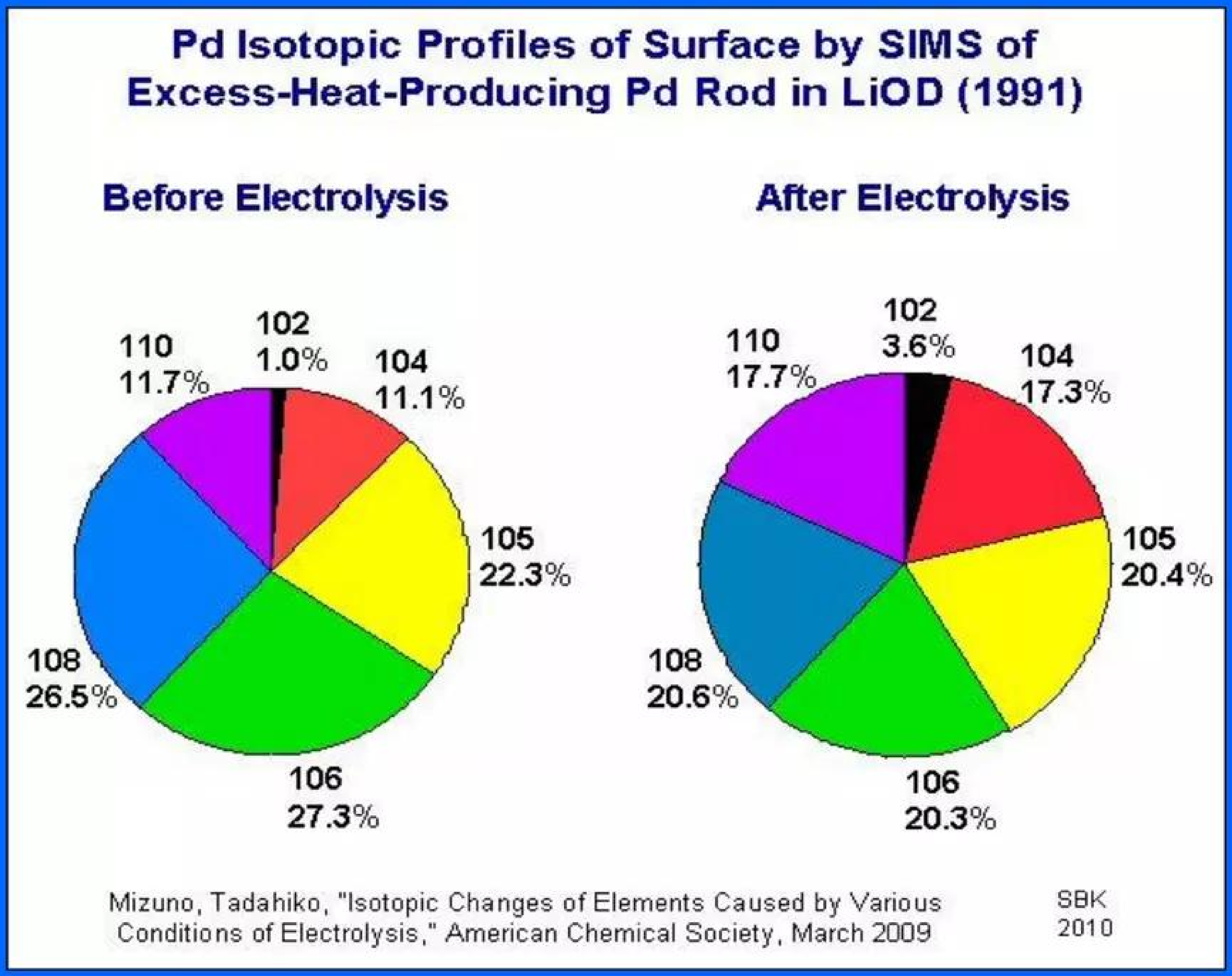
http://www.sciencedirect.com/science/article/pii/S1876610214026939

- 3. Results and discussion: " … the cathode is enriched in the heavier isotope, $^{7}Li$, after the Lithium release in every experiment." Authors attempted to explain $^{7}Li/^{6}Li$ isotopic shifts with "equilibrium or kinetic isotope effects or their combination"
- Depletion of Lithium-6 and enrichment of Lithium-7 is exactly the same as what has been reported for many LENR cathodes on which Lithium isotope ratios were measured. While Okano et al.'s $^{7}Li/^{6}Li$ shift is consistent with neutron captures on Lithium-6, it is not yet conclusively proven that LENRs are occurring in Lithium-ion batteries because chemical fractionation processes and LENRs can mimic each other. For LENRs in Palladium cathodes, reported shifts in Pd isotope ratios were very large (% vs. ‰ for fractionation processes) and accompanied $^{7}Li$ enrichment
- LENR experiments typically employed much longer electrolysis times ranging from days to 1 - 2 weeks vs. just 1.3 to ~7.0 hours for Okano et al.; operating voltages for electrochemical cells in LENR experiments were 5 V or higher vs. 4.2 or 4.4 V for Okano et al. LENR experiments used greater input energy for much longer periods

# Isotopic shifts in Palladium and Chromium after electrolysis

## Widom-Larsen theory: neutrons are captured by Palladium & Chromium

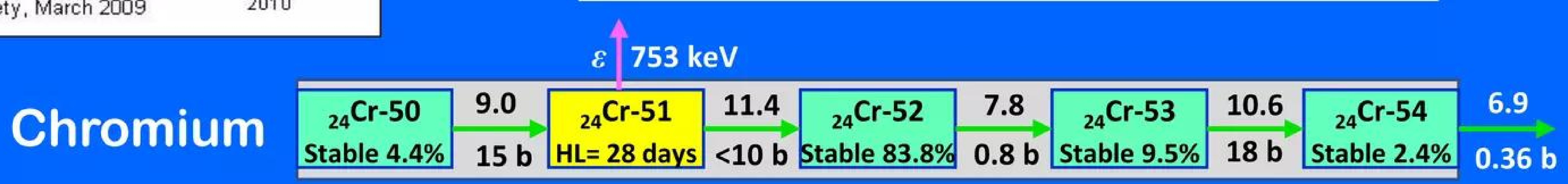



Mizuno & Kozima's Chromium (Cr) SIMS isotopic measurements

| Isotope | Before | After | Result |
|---|---|---|---|
| Cr-50 | 4.3 % | 14.3 % | + 10 % |
| Cr-52 | 83.8 % | 50.9 % | - 32.9 % |
| Cr-53 | 9.5 % | 23.8 % | + 14.3 % |
| Cr-54 | 2.4 % | 10.9% | + 8.5% |

SIMS = secondary ion mass spectrometry




http://newenergytimes.com/v2/news/2010/35/SR35906insights.shtml

# Chemical fractionation creates ‰ shifts in isotope abundance

## LENRs create ‰ to large % shifts in isotopes and transmute elements

1‰ = 0.1%  10‰ = 1.0%  100‰ = 10.0%  500‰ = 50%  1,000‰ = 100%

- At low rates of neutron production for short periods, LENRs may only shift relative isotope abundance values on order of ‰ and will mimic ‰ values for isotopic shifts created by various types of chemical fractionation processes
- At higher rates of ULE neutron production for longer periods, LENRs can: (1) create very large % shifts in relative isotopic abundances; (2) also produce *other* chemical elements that were not a result of any external contamination and not initially present in local domains where LENRs have occurred. For example, Mizuno & Kozima (1991) experimentally produced a 7% (70‰) shift in $^{106}$Pd plus *simultaneous* comparable % shifts in other stable isotopes of Palladium; for Chromium they reported a ~33% (330‰) shift in $^{52}$Cr. Shifts of such magnitudes are unprecedented for Pd and Cr in terrestrial materials and unlikely to have been caused by any type of chemical fractionation process
- Compelling evidence for presence of LENR transmutation processes is clear-cut observations of elements that: (1) appear to be 'new', i.e. were not initially present in domains where LENRs are thought to have occurred; or (2) exhibit anomalous local increases in abundance. If external contamination is totally excluded, no chemical process can explain such data. If Lu et al. (2017) really produced Deuterium, Helium, and Calcium, their data would strongly confirm that nuclear transmutations can occur inside photocatalytic systems at NTP

# Two-body stellar fusion reactions require extreme conditions

## ${}_1H^1$-fusion reactions that power Sun occur at millions of degrees and atm.

**Hydrogen fusion produces Sun's nuclear heat and elemental Helium (${}_2He^4$)**

Proton - proton chain reaction:

$${}_1H^1 + {}_1H^1 \xrightarrow{\text{fusion}} {}_1H^2 + {}_{+1}e^0 + \text{energy}$$

positron

$${}_1H^2 + {}_1H^1 \xrightarrow{\text{fusion}} {}_2He^3 + \text{energy}$$

$${}_2He^3 + {}_1H^1 \xrightarrow{\text{fusion}} {}_2He^4 + {}_{+1}e^0 + \text{energy}$$

The overall reaction, therefore, may be written as:

$$4\ {}_1H^1 \xrightarrow{\text{fusion}} {}_2He^4 + 2\ {}_{+1}e^0 + \text{energy}$$

**All fusion reactions measured to date have at least one branch with non-negligible cross-section for emission of dangerous energetic, penetrating gamma photon radiation**

Credit: NASA/Corbis

# Stellar supernovas are not required to produce Gold & Silver

## Widom-Larsen theory explains how this occurs in electrochemical cells

### $e + p$ is 2-body reaction in supernovas; $e_n + p_n$ is many-body collective in LENRs

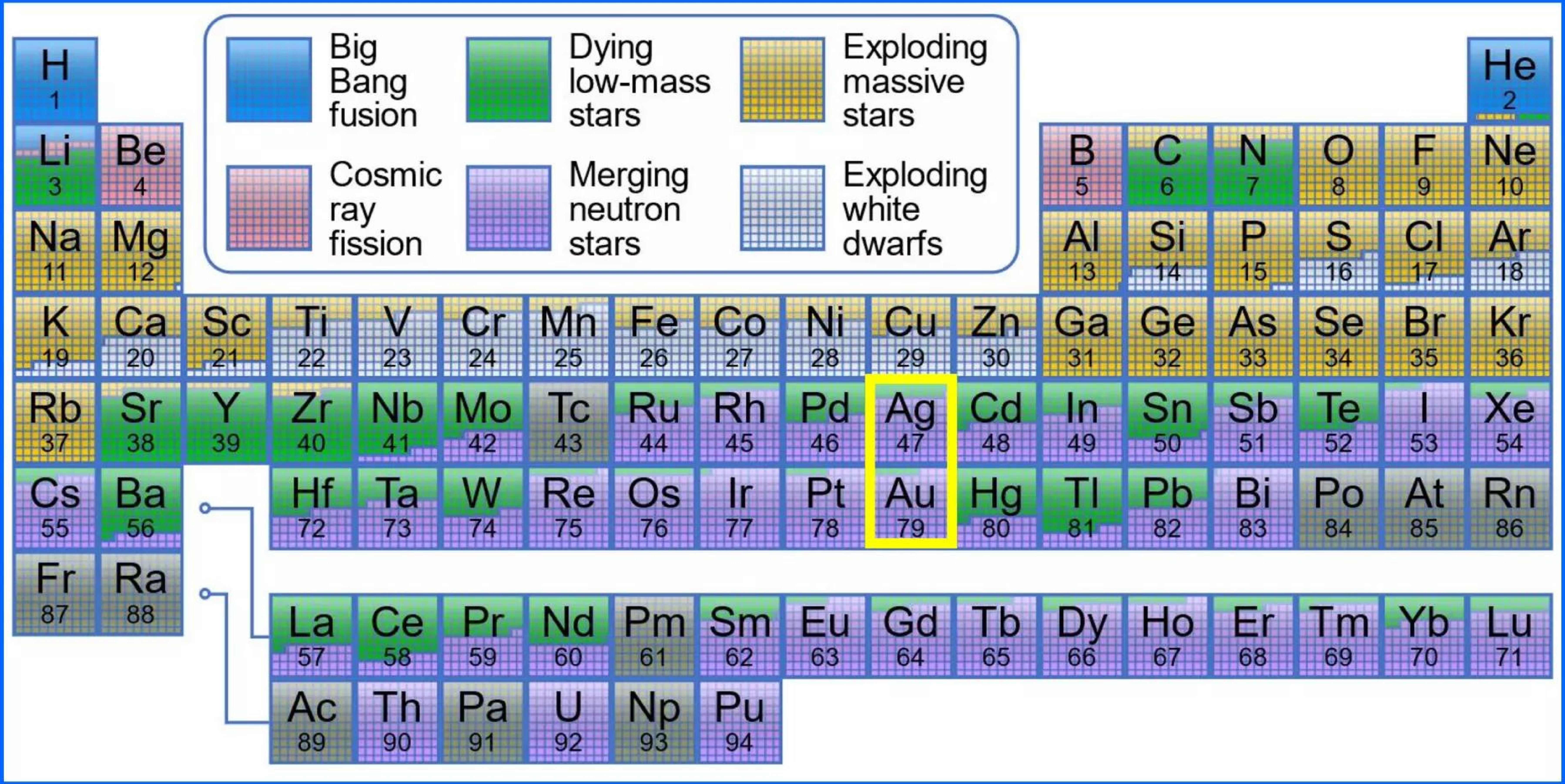
- For past 60 years, most astrophysicists believed that Gold and Silver could only be produced in stars, fission reactors, and large particle accelerators
- Today, Widom-Larsen theory (WLT) of LENRs explains how such elements can be produced --- albeit in nanogram quantities detected with sensitive mass spectroscopy -- with modest DC electric currents running through battery-like, aqueous electrochemical cells operated at NTP, unlike many millions of degrees required by nucleosynthetic processes found in stars
- WLT's integration of condensed matter quantum effects with many-body collective physics can explain very large, diverse collection of anomalous experimental results that has accumulated in publications over 100 years, including data reported by Dash et al. (1993). Viewed through lens of this theoretical breakthrough, old long-inexplicable observations as well as Mitsubishi Heavy Industries' new data can finally be rigorously understood
- Proprietary extensions of WLT as-published provide a powerful conceptual framework that can help guide thermal device nanoengineering programs aimed at commercializing LENRs for green radiation-free power generation

Artists impression of shock breakout during initial phase of stellar supernova - credit: Kavli IPMU

# Present paradigm as to where elements are created in Nature

## Silver & Gold created in dying low-mass stars and merging neutron stars

### Many-body collective Q-M effects enable production in electrochemical cells



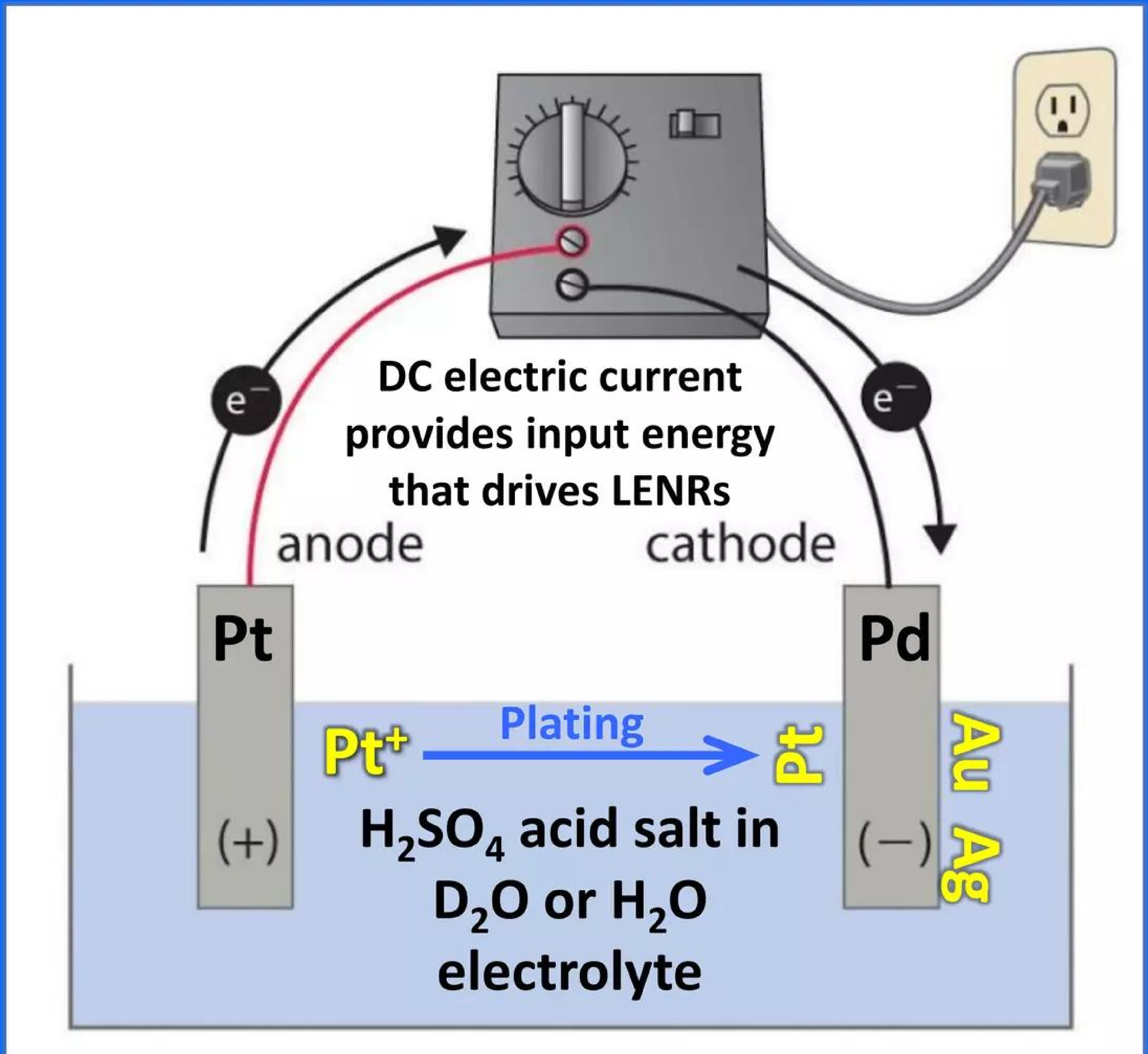

Credit: Cmglee - based on data by Jennifer Johnson (Ohio State Univ.)

# Electrochemical cells demonstrate transmutation of elements

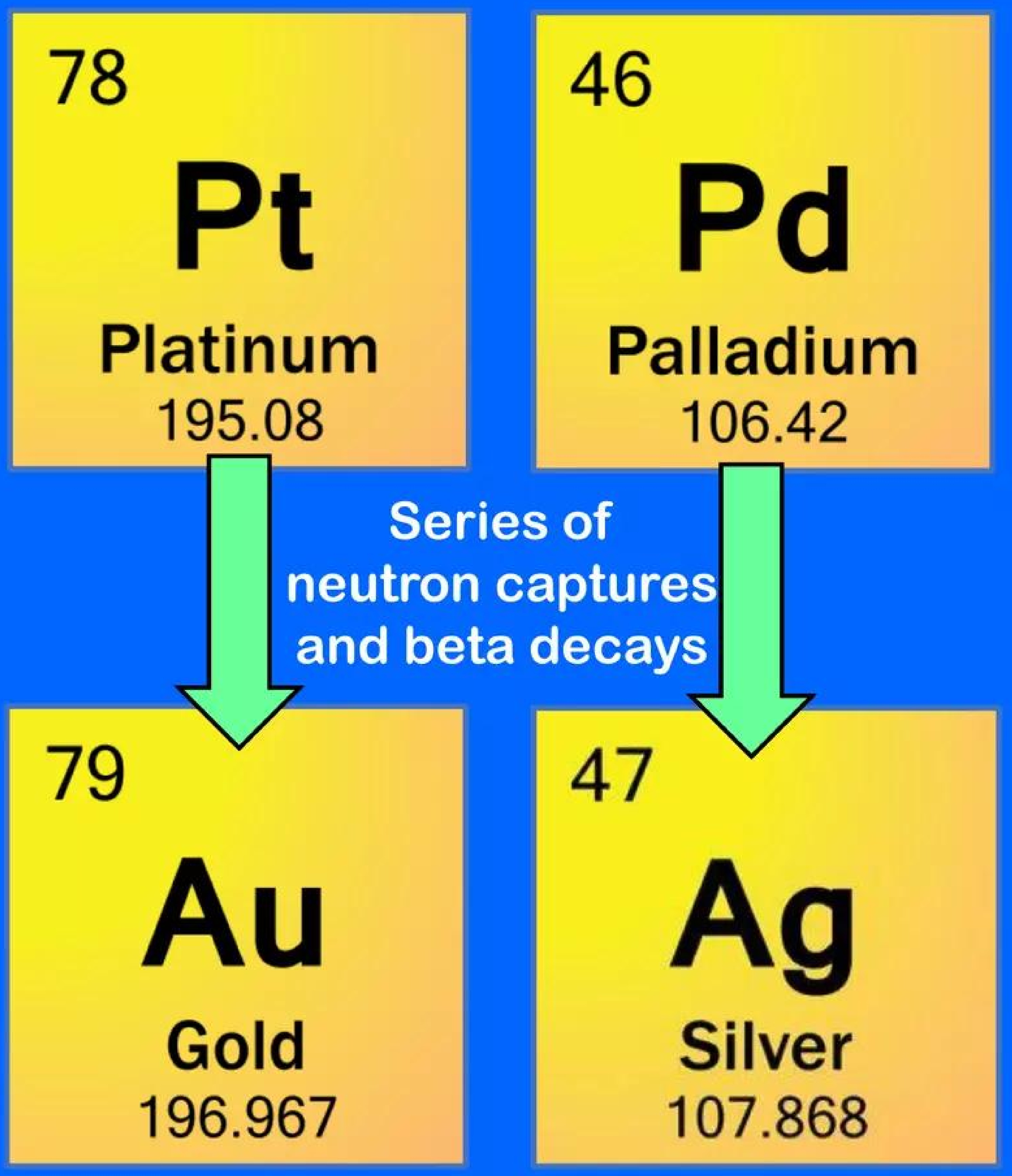
## Dash et al. (1993): Platinum (Pt) → Gold (Au); Palladium (Pd) → Silver (Ag)

### Stars and fission reactors are not required for LENR transmutation of elements



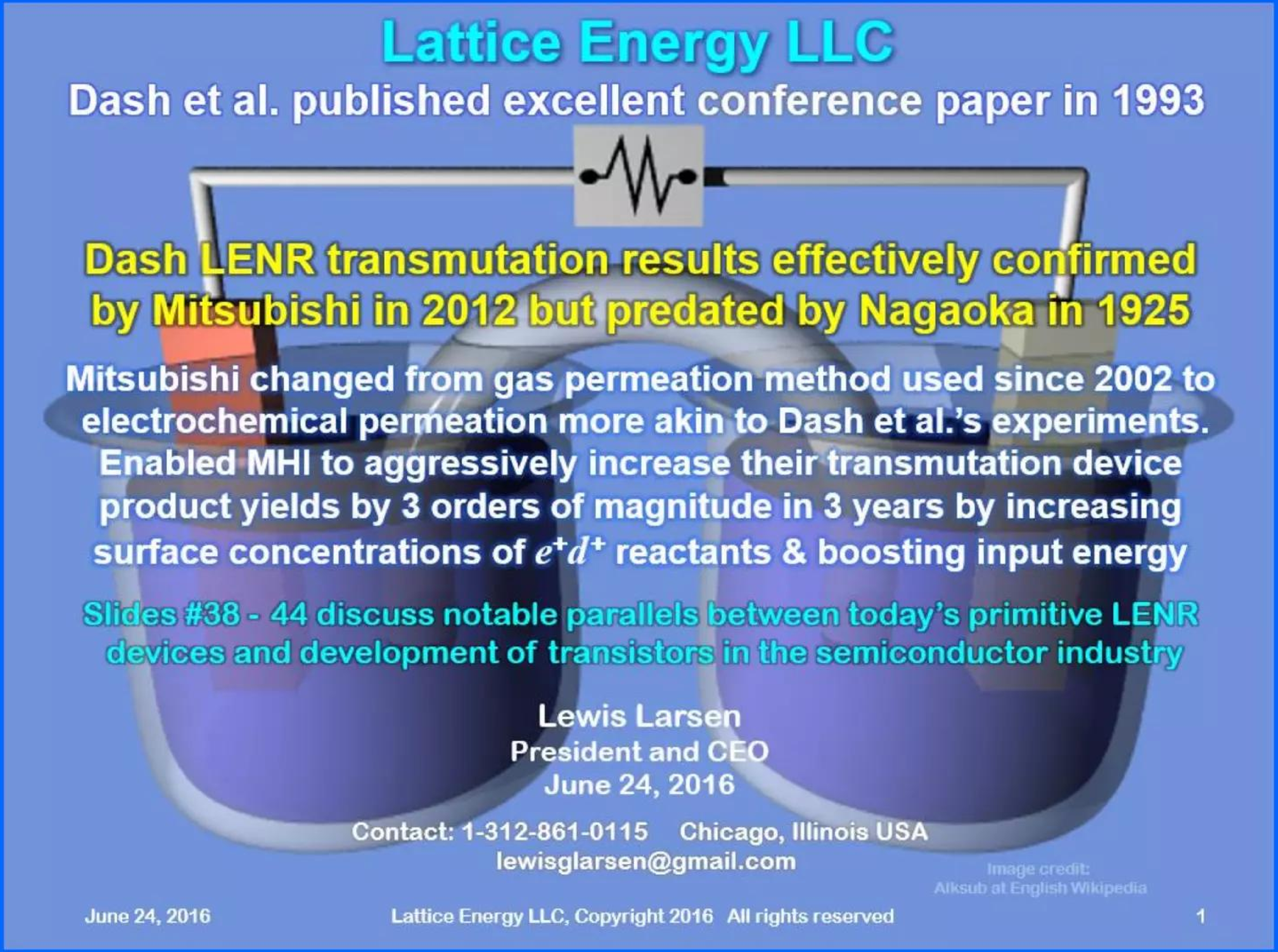

Electrochemical cell

Electricity provides input energy needed to produce neutrons



# Dash et al. reported transmutations in electrochemical cells

## Tungsten (W) & Platinum (Pt) → Gold (Au); Palladium (Pd) → Silver (Ag)




http://www.slideshare.net/lewisglarsen/lattice-energy-llc-1994-conference-paper-prof-john-dash-reported-production-of-gold-and-silver-in-electrochemical-cell-experiment-june-24-2016

# Lu et al. observed nuclear effects in $H_2O$ photochemical cells

## Claimed production of Deuterium and Helium & transmutation of K to Ca

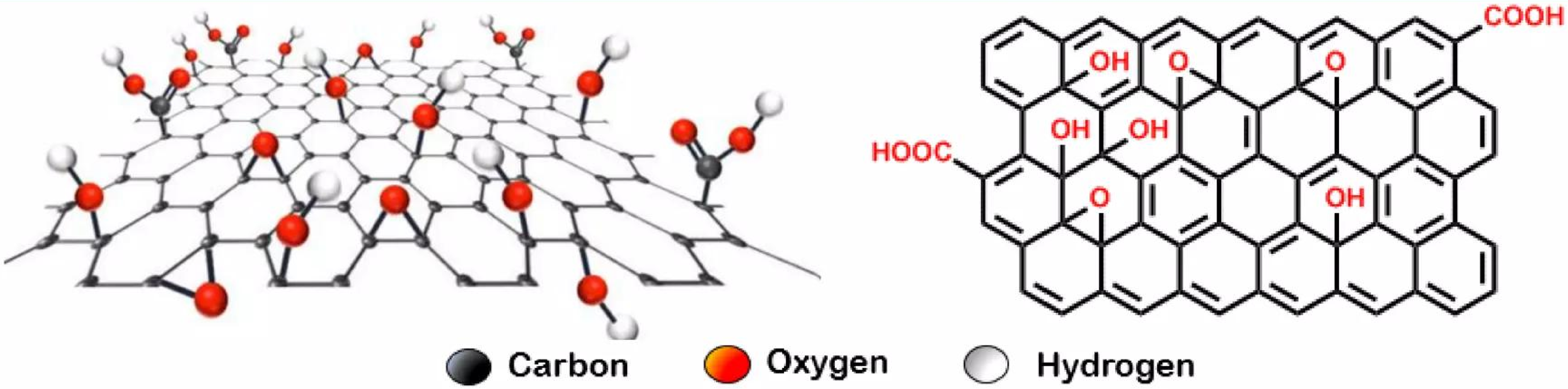
### Experimental results reported in *Journal of Molecular Catalysis* (China) in 2017

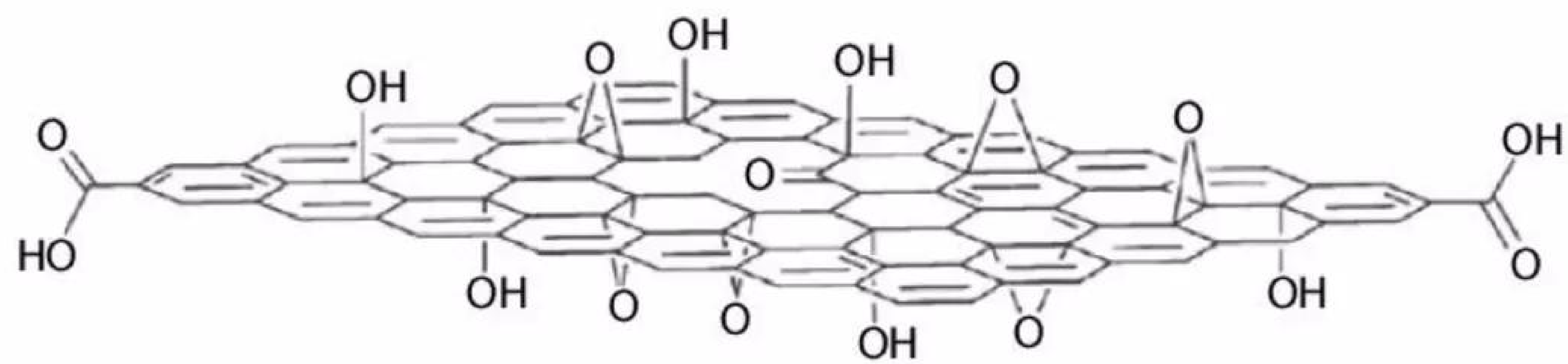
- Published three closely-related experimental papers in same Chinese journal:
  - April 2017: photocatalytic production of Deuterium ($^2H$) and Helium (He)
  - August 2017: photocatalytic production of Helium-3 ($^3He$) and Helium-4 ($^4He$)
  - October 2017: photocatalytic transmutation of Potassium (K) to Calcium (Ca)
- If Lu et al. (2017) produced Deuterium, Helium, and Calcium, their results provide provocative experimental data that nuclear transmutation reactions can occur in photocatalytic systems at NTP; supports idea of paradigm shift in nuclear science
- Prof. Gong-Xuan Lu, lead author and researcher on these papers, was trained as a physical chemist and is internationally recognized as an expert in photocatalysis. His two coauthors are a chemist and a nanotechnologist. Work reported in these three papers was supported by grants from National Natural Science Foundation of China and the 973 Program of Dept. of Sciences and Technology China
- Lu et al. appear to have been surprised and intrigued by their initial discovery of Deuterium and Helium production during routine photocatalytic research. They astutely recognized there was a significant observational anomaly and conducted further experiments; chemistry cannot create Big Bang elements. Lu et al. have since struggled to articulate a process that can explain their data. Untrained in nuclear science, they have proffered mechanisms that invoke implausible physics

# Graphene oxide $C_{140}H_{42}O_{20}$ is often used in photocatalysis

## Readily dispersed in $H_2O$; substrate for cocatalysts like Pt nanoparticles



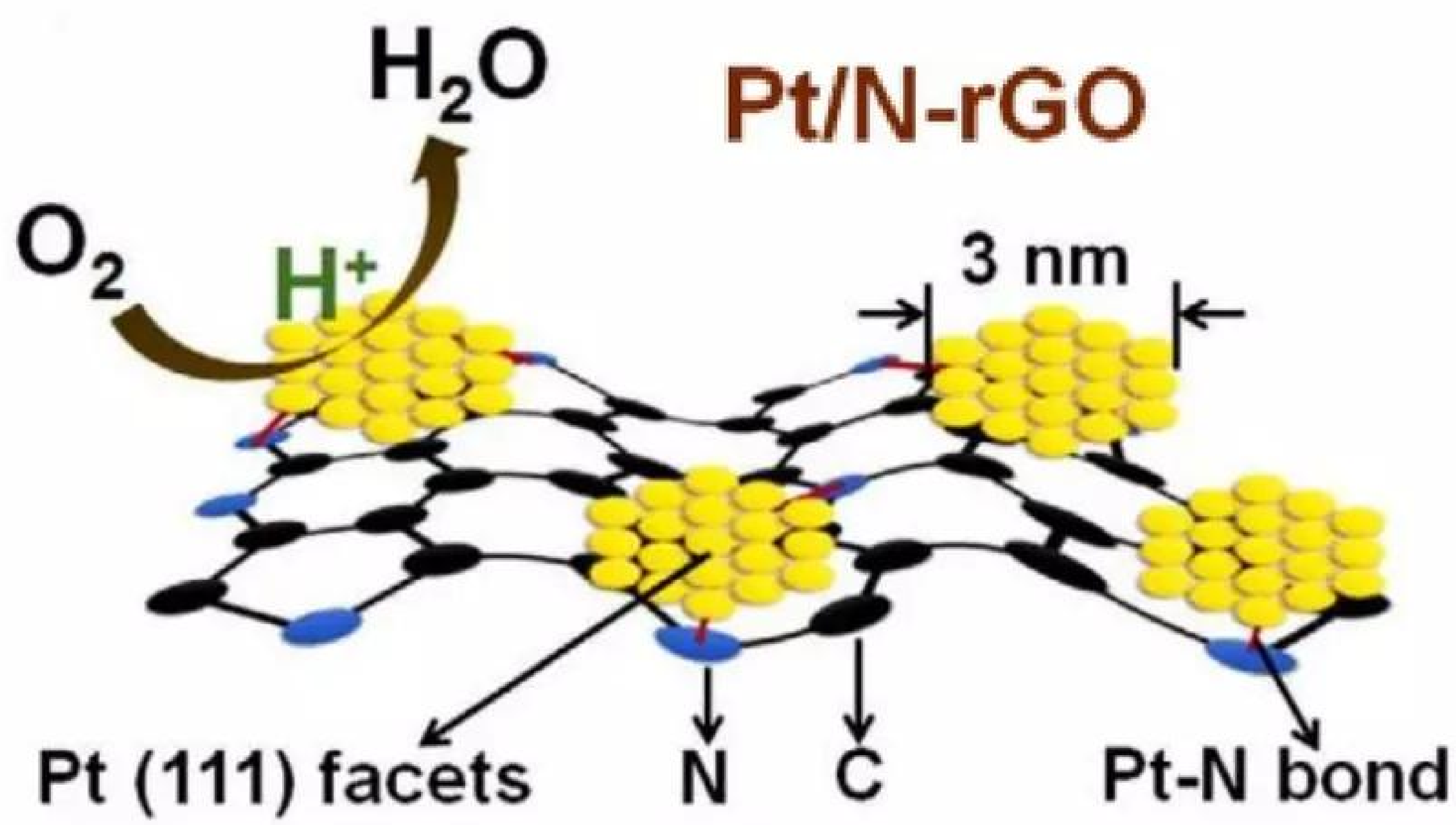




**Fig. 1** in "Low content Pt nanoparticles anchored on N-doped reduced Graphene oxide with high and stable electrocatalytic activity for oxygen reduction reaction" Z. Li et al. *Scientific Reports* 7, article #43352 (2017).
**Caption:** "Synthesis and configuration of Pt/N- rGO performed as the catalyst of ORR. Pt particles with uniformed 2.8nm diameter and exposed (111) crystal planes anchored on the surface of N-r GO evenly. And N works as the bridge between Pt and rGO with Pt-N and N-C chemical bonds in Pt/N-rGO."

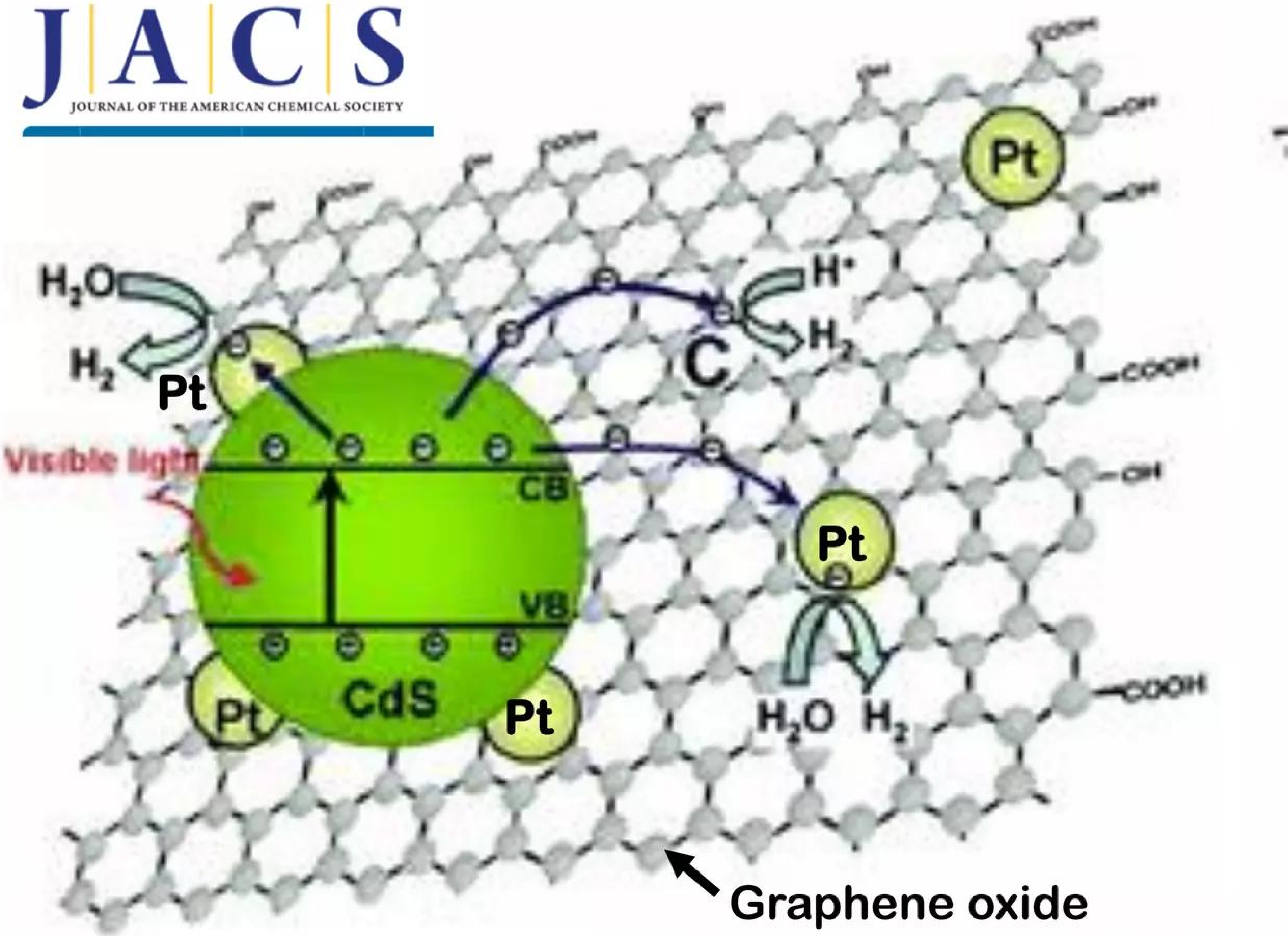
https://www.nature.com/articles/srep43352.pdf

# Graphene oxide $C_{140}H_{42}O_{20}$ is often used in photocatalysis

## Li et al.: GO used in conjunction with CdS and Pt to produce Hydrogen

**Abstract:** "Graphene oxide (GO) served as the support and Cadmium acetate ($Cd(Ac)_2$) as the CdS precursor. These nanosized composites reach a high $H_2$-production rate of 1.12 mmol $h^{-1}$ (about 4.87 times higher than that of pure CdS nanoparticles) at graphene content of 1.0 wt % and Pt 0.5 wt % under visible-light irradiation and an apparent quantum efficiency (QE) of 22.5% at wavelength of 420 nm. This high photocatalytic $H_2$-production activity is attributed predominantly to presence of graphene ..."

JACS
JOURNAL OF THE AMERICAN CHEMICAL SOCIETY

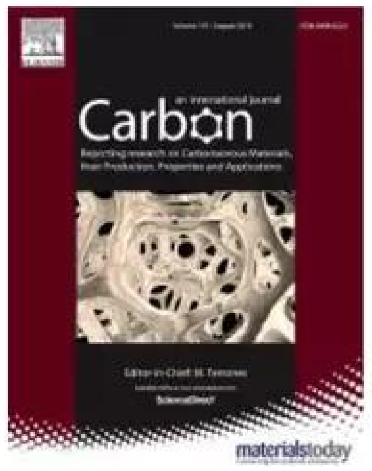



"Highly efficient visible-light-driven photocatalytic Hydrogen production of CdS-cluster-decorated Graphene nanosheets"
Q. Li et al. *JACS* 133 pp. 10878 - 10884 (2011)
https://pubs.acs.org/doi/abs/10.1021/ja2025454

# Graphene oxide $C_{140}H_{42}O_{20}$ is often used in photocatalysis

## Electron transfers between Gold NPs and 2-D sheet of Graphene oxide




**"Graphene oxide coupled with Gold nanoparticles for localized surface plasmon resonance based gas sensor"**
**M. Cittadini et al. *Carbon* 69 pp. 452 - 459 (2014)**

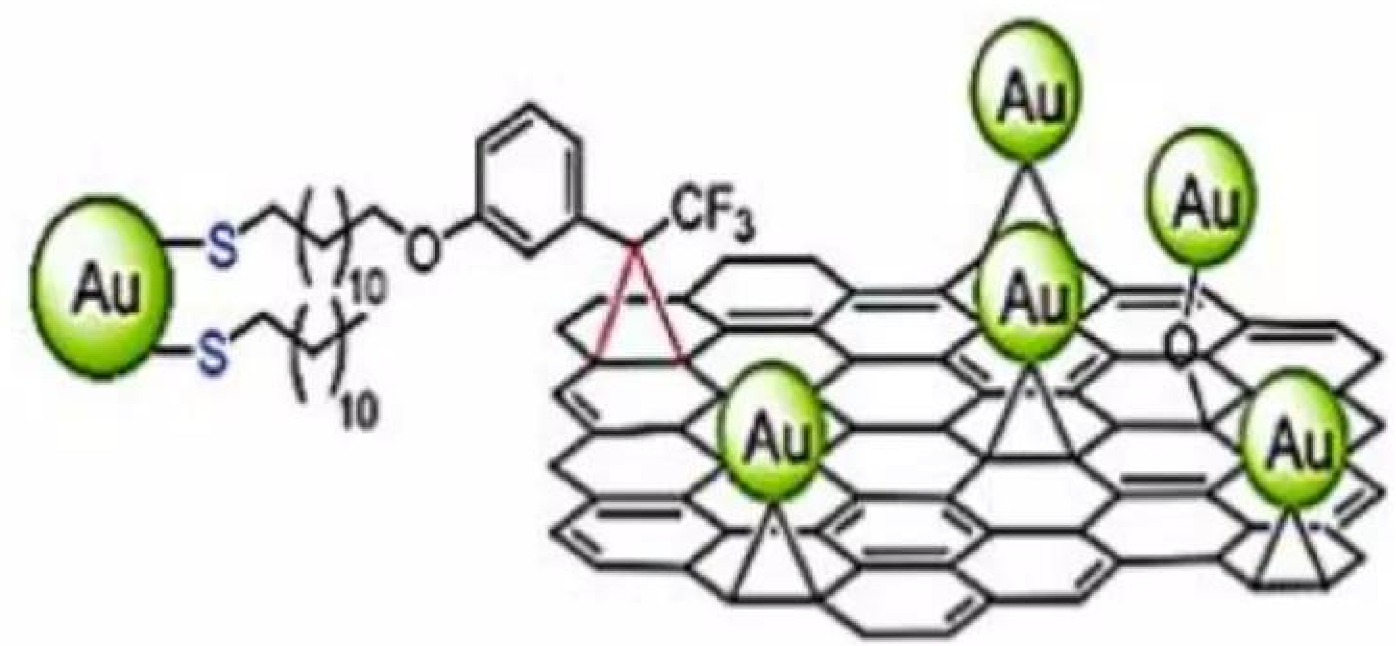
https://www.sciencedirect.com/science/article/pii/S0008622313012037

ELSEVIER

Carbon an international journal

**Abstract:** "An optical gas sensor was prepared by depositing Graphene oxide flakes over a monolayer of Gold nanoparticles, chemically attached to a functionalized fused silica substrate. The coupling between flakes and nanoparticles lead to optical changes upon exposure to different gases: in particular, we observed a shift of … surface plasmon resonance band in presence of both reducing and oxidizing gases. This effect can be explained in terms of a strong Gold-Graphene interaction and specifically of electron transfer between the Gold nanoparticles and the two-dimensional sheet of $sp^2$-hybridized Carbons of Graphene oxide."

**Gold (Au) NPs/Graphene**



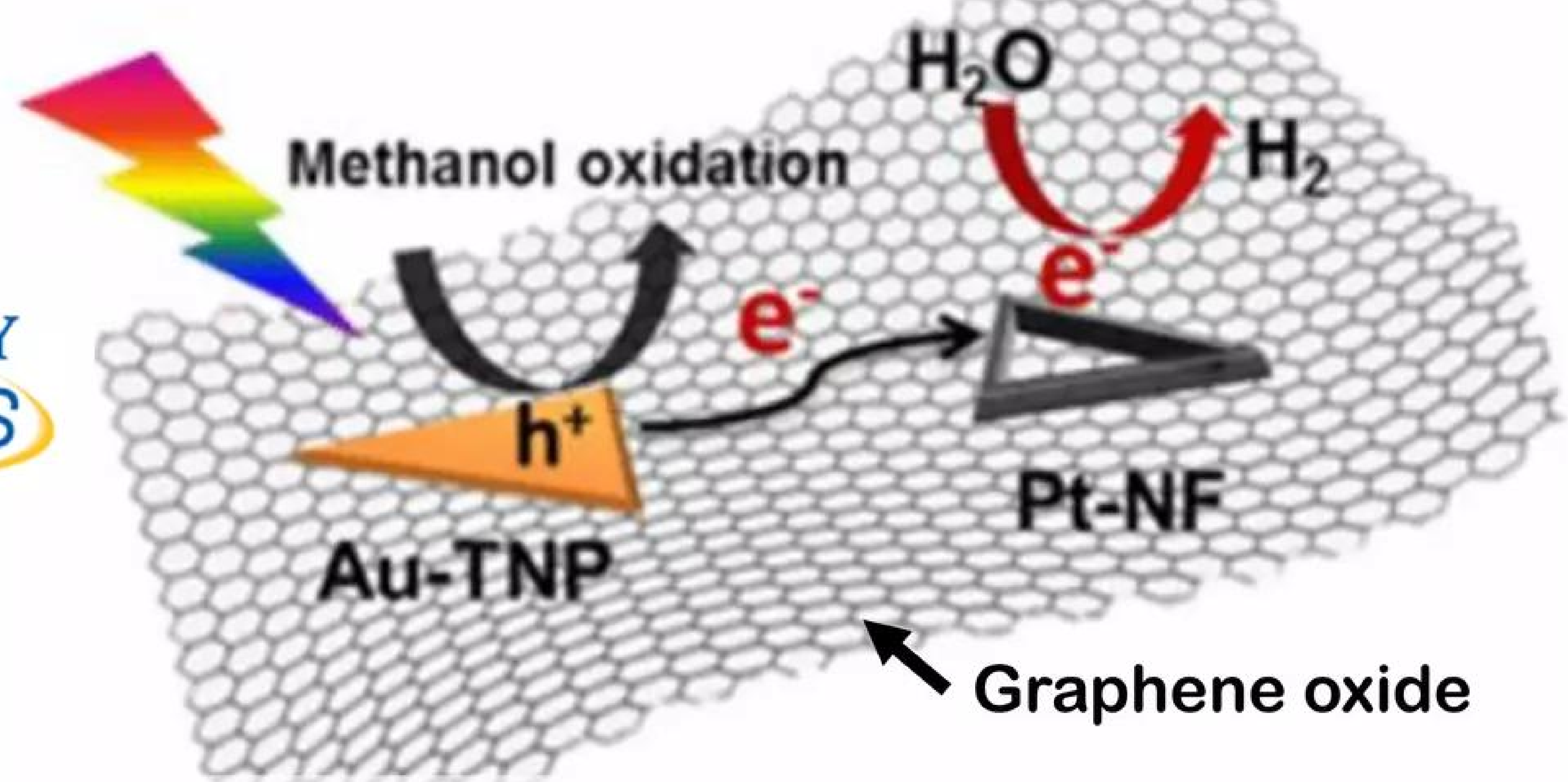

©2011 American Chemical Society

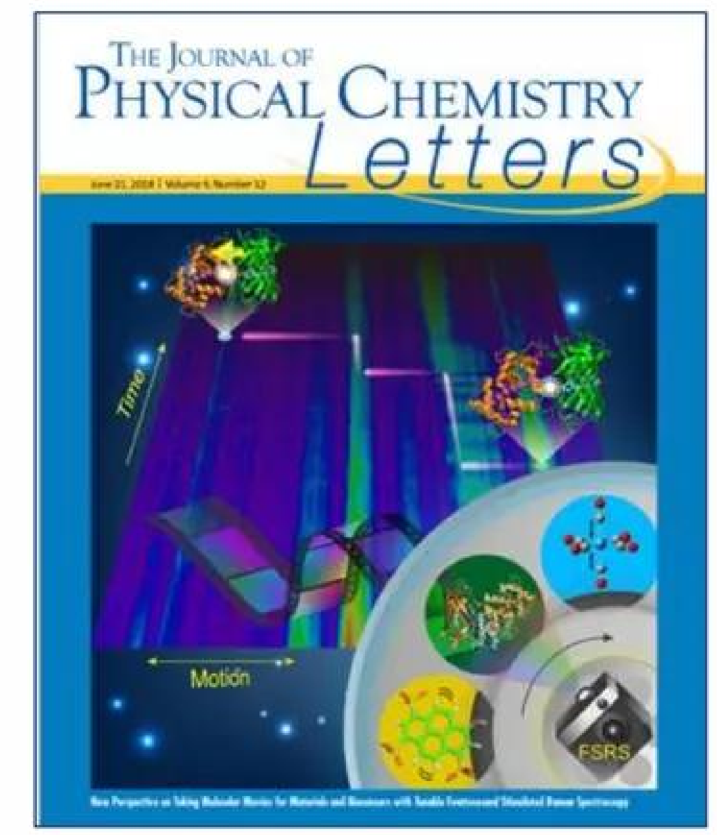
# Graphene oxide $C_{140}H_{42}O_{20}$ is often used in photocatalysis

## Surface plasmon electrons intimately involved in photocatalytic activity

**"Two-dimensional Au-nanoprism/reduced Graphene oxide/Pt-nanoframe as plasmonic photocatalysts with multiplasmon modes boosting hot electron transfer for Hydrogen generation" Z. Lou et al. *J. Phys. Chem. Lett.* 8 pp 844 - 849 (2017)**

THE JOURNAL OF PHYSICAL CHEMISTRY Letters




**Abstract:** "Two-dimensional Au-nanoprism/reduced graphene oxide (rGO)/Pt-nanoframe was synthesized as plasmonic photocatalyst, exhibiting activity of photocatalytic hydrogen generation greater than those of Au-nanorod/rGO/Pt-nanoframe and metallic plasmonic photocatalyst Pt–Au. The single-particle plasmonic photoluminescence study demonstrated that Au-nanorod has only a longitudinal plasmon resonance mode for hot electron transfer to rGO, while Au-nanoprism has in-plane dipole and multipole surface plasmon resonance modes for hot electron transfer, leading to highly efficient charge separation for hydrogen generation."

https://pubs.acs.org/doi/abs/10.1021/acs.jpclett.6b03045?journalCode=jpclcd

# Professor Gong-xuan Lu

## Lanzhou Institute of Chemical Physics

### Keynote speaker: Session 1 - Solar water splitting and $CO_2$ conversion at 22nd Int'l. Conf. on Photochemical Conversion and Storage of Solar Energy, Hefei, China July 29 to August 3, 2018

"Professor Lu obtained his PhD in Physical Chemistry in 1993 from the Chinese Academy of Sciences. He became a member of State Key Laboratory for Oxo Synthesis and Selective Oxidation (OSSO) in 1986. His research interests includes environment-friendly catalysis, catalytic hydrogen production, reusable energy sources conversion, solar energy conversion and storage via photocatalysis. He has published more than 250 papers in those fields. Currently, he is the Director of the National Engineering Research Center of Fine Petrochemical Intermediates (ERC) and Vice-Director of the OSSO Laboratory in Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences. He is also the deputy Chief Editor of the *Journal of Molecular Catalysis* (China), fellow of Chinese Renewable Energy Society (Photochemistry Committee), Chinese Chemical Society, China Physical & Vacuum Society, and Chinese Catalysis Society. More than 10 students have obtained their Master and Doctor Degree in his group."

http://english.licp.cas.cn/pe/js/lgx/

E-mail: gxlu@lzb.ac.cn

# Lu et al. published three very closely related papers in 2017

**Experiments in all three papers below involve photoelectrochemical cells**

**"Photocatalytic Hydrogen evolution and induced transmutation of Potassium to Calcium via low-energy nuclear reaction (LENR) driven by visible light"**
**G. Lu & W. Zhang *Journal of Molecular Catalysis* (China) 31 pp. 401 - 410 (2017)**

**Open source pdf copy created in English on-demand is available at URL:**

http://www.jmcchina.org/html/2017/5/20170501.htm

**"Formation of Helium-3 and Helium-4 during photocatalytic Hydrogen generation over Cadmium Sulfide under visible light irradiation"**
**G. Lu & W. Zhang *Journal of Molecular Catalysis* (China) 31 pp. 299 - 410 (2017)**

**Open source pdf copy created in English on-demand is available at URL:**
http://www.jmcchina.org/html/2017/4/20170401.htm

**"Formation of Deuterium and Helium during photocatalytic Hydrogen generation from water catalyzed by Pt-Graphene sensitized with Br-dye under visible light irradiation"**
**G. Lu & B. Tian *Journal of Molecular Catalysis* (China) 31 pp. 101 - 104 (2017)**

**Open source pdf copy created in English on-demand is available at URL:**
http://www.jmcchina.org/html/2017/2/20170201.htm

# Peer-reviewed Journal of Molecular Catalysis (China)



Bimonthly in Chinese with English abstracts

Supervised by: Chinese Academy of Sciences

Website: http://www.jmcchina.org/

Editor-in-Chief: LI Shuben

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# Peer-reviewed Journal of Molecular Catalysis (China)


**Aims & Scope:**

**"The journal publishes principally articles of catalytic research at the molecular level as well as brief notes of scientific innovation and invited reviews of scientific achievements in this field. The main contents include homogeneous catalysis, enzyme catalysis, photo-assisted catalysis, the stereo-chemical aspects in catalytic processes, the reaction mechanism and the application of quantum chemistry to catalytic science. The activation, deactivation and regeneration of the homogeneous catalysts of industrial catalytic processes, supported homogeneous catalysts, immobilized enzyme catalysts, as well as the optimization and characterization of catalysts used in new catalytic processes are also dealt with by the Journal."**

http://www.jmcchina.org/

http://english.licp.cas.cn/sp/jm/

# Widom-Larsen theory explains Lu et al.'s experimental data

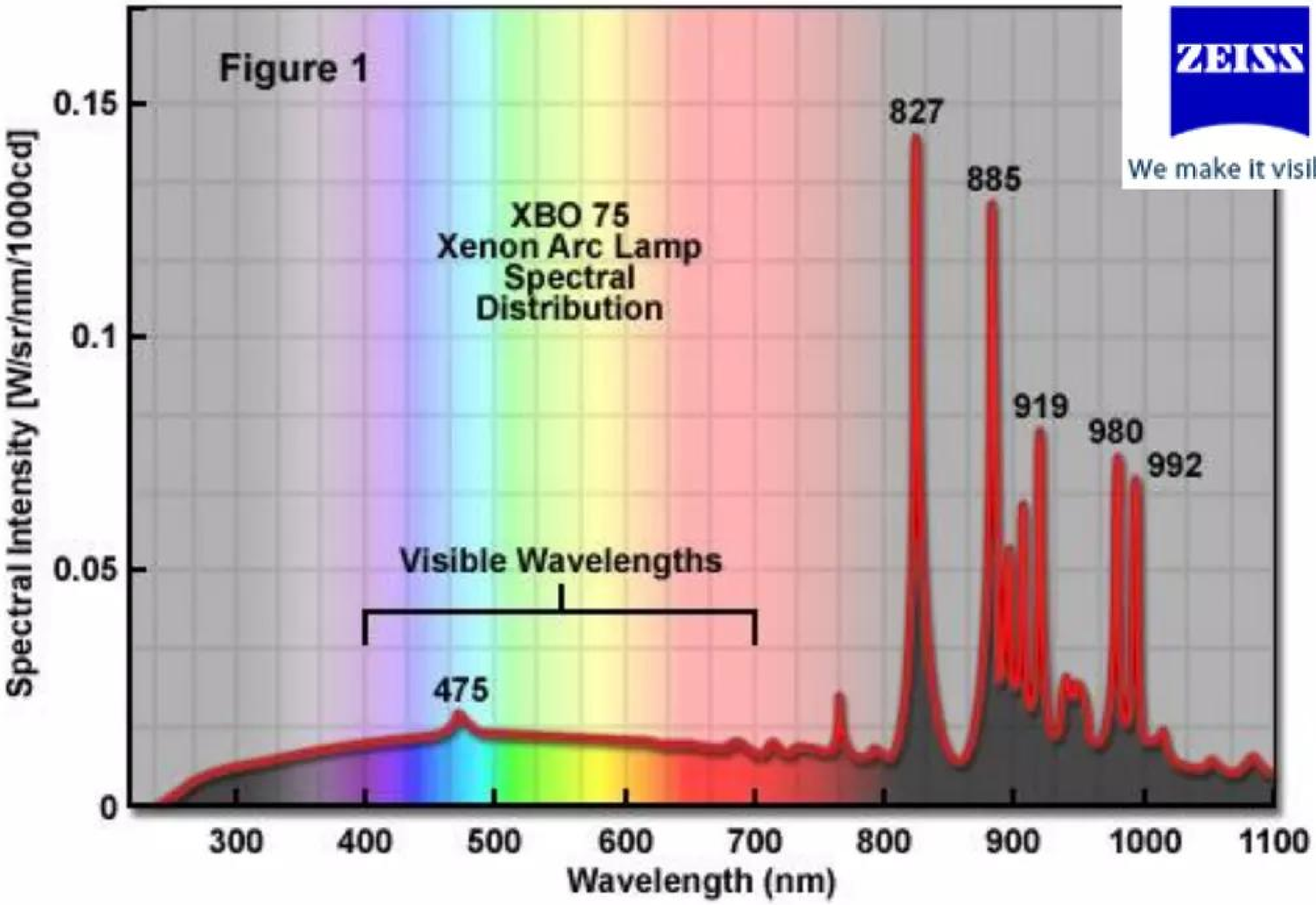
## Light from 300 Watt Xenon lamp provided input energy to trigger LENRs

- Lu et al. provided input energy in form of visible light > 420 nm emitted from a 300 Watt Xenon lamp model HSX-UV300 by Beijing NBeT Technology Co., Ltd. (NBeT) https://www.diytrade.com/china/pd/11082473/simplicity_Arc_Source_Xe.html
- Commercial reagents used in Lu et al.'s experiments were high-purity and well-characterized. Prepared samples mixed into ultrapure (18.2 MΩ $cm^{-2}$) aqueous ($H_2O$) solutions and poured into 150 mL Pyrex reaction flasks. Contents irradiated with NBeT lamp through 10.2 $cm^2$ window on side of flask. Reactions occurred at ~NTP; were accompanied by continuous internal magnetic stirring of flask liquids
- For two experimental variants, Lu et al. specially prepared their own samples of high-purity Graphene oxide "GO" ($C_{140}H_{42}O_{20}$) used as catalytic support substrate for adsorbed Platinum (Pt) cocatalyst compounds as well as for other reactants
- Several types of Pt complexes were utilized and, along with other compounds, mixed into aqueous solutions prior to irradiation. Depending on experiment, important reactants used by Lu et al. were: (April 2017) Potassium platinum (IV) chloride ($K_2PtCl_6$) + Eosin Y ($C_{20}H_6Br_4Na_2O_5$) + Triethanolamine (TEOA - $C_6H_{15}NO_3$) + Graphene oxide; (August 2017) CdS and Platinum (1%)/Cadmium sulfide (Pt/CdS semiconductor suspension) + Hydrogen hexachloroplatinate ($H_2PtCl_6$) + Hydrazine hydrate ($N_2H_4$); (October 2017 shows K → Ca ) $K_2PtCl_6$ + Eosin Y + TEOA + Graphene oxide - control experiment used $H_2PtCl_6$ instead of $K_2PtCl_6$ (no K in it)

# Widom-Larsen theory explains Lu et al.'s experimental data

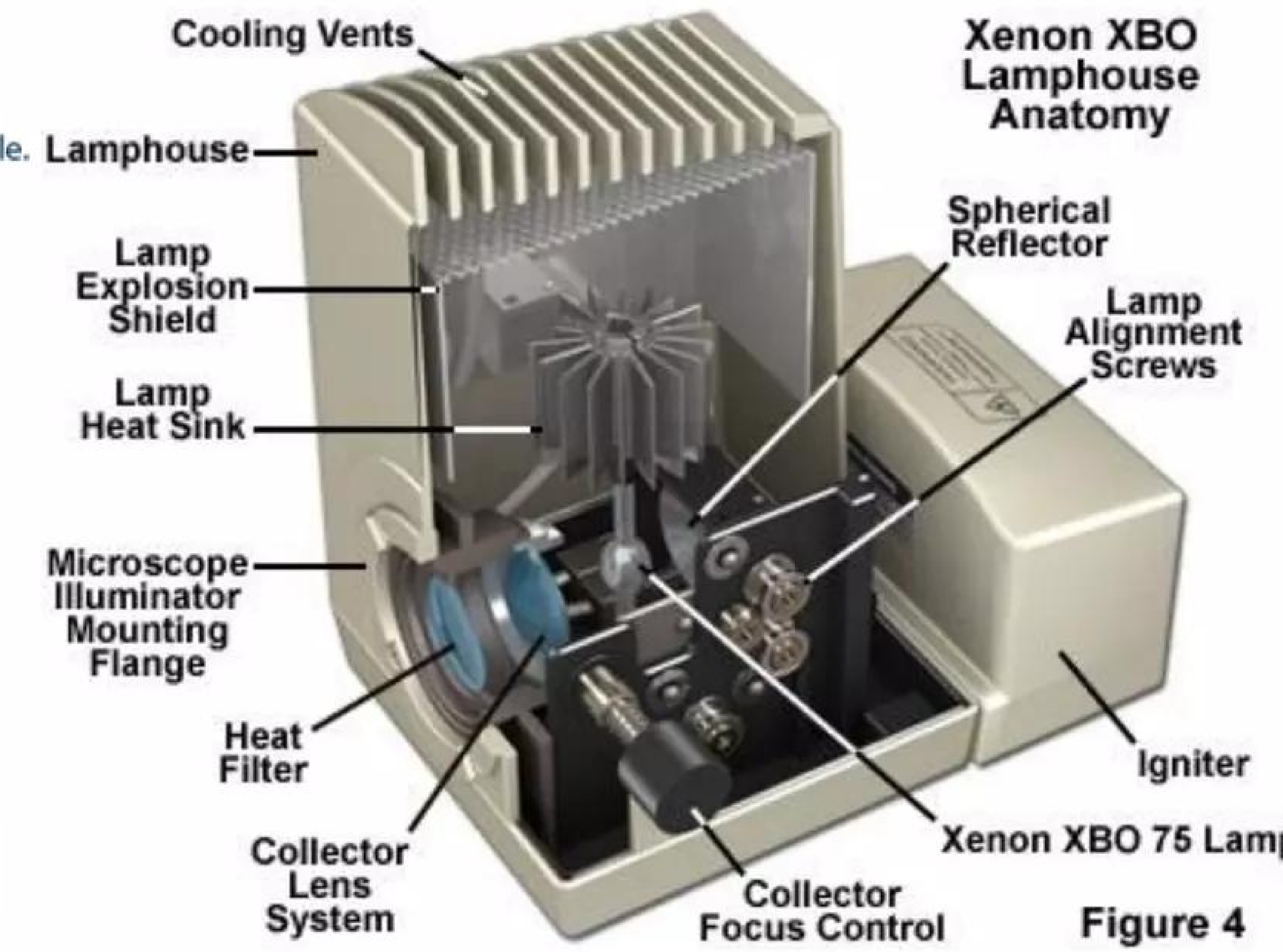
## 300 Watt NBeT Xe lamp provided adequate input energy to trigger LENRs

**Spectrum of light emitted by Xenon lamps**




ZEISS
We make it visible.

**Zeiss XBO 75 Xenon arc lamp**




**Quoting Zeiss:** "Xenon lamps produce broadband, almost continuous emission having a color temperature approximating sunlight in the visible wavelengths (often referred to as white light) … Between 400 and 700 nanometers, approximately 85 percent of the total energy emitted by a Xenon lamp resides in the continuum whereas about 15 percent arises from line spectrum … complete emission profile occurs … upon ignition … lamp output remains linear as function of applied current"

http://zeiss-campus.magnet.fsu.edu/articles/lightsources/xenonarc.html

# Widom-Larsen theory explains Lu et al.'s experimental data

## Production of $H_2$, $D_2$ and He seem to be closely correlated with each other

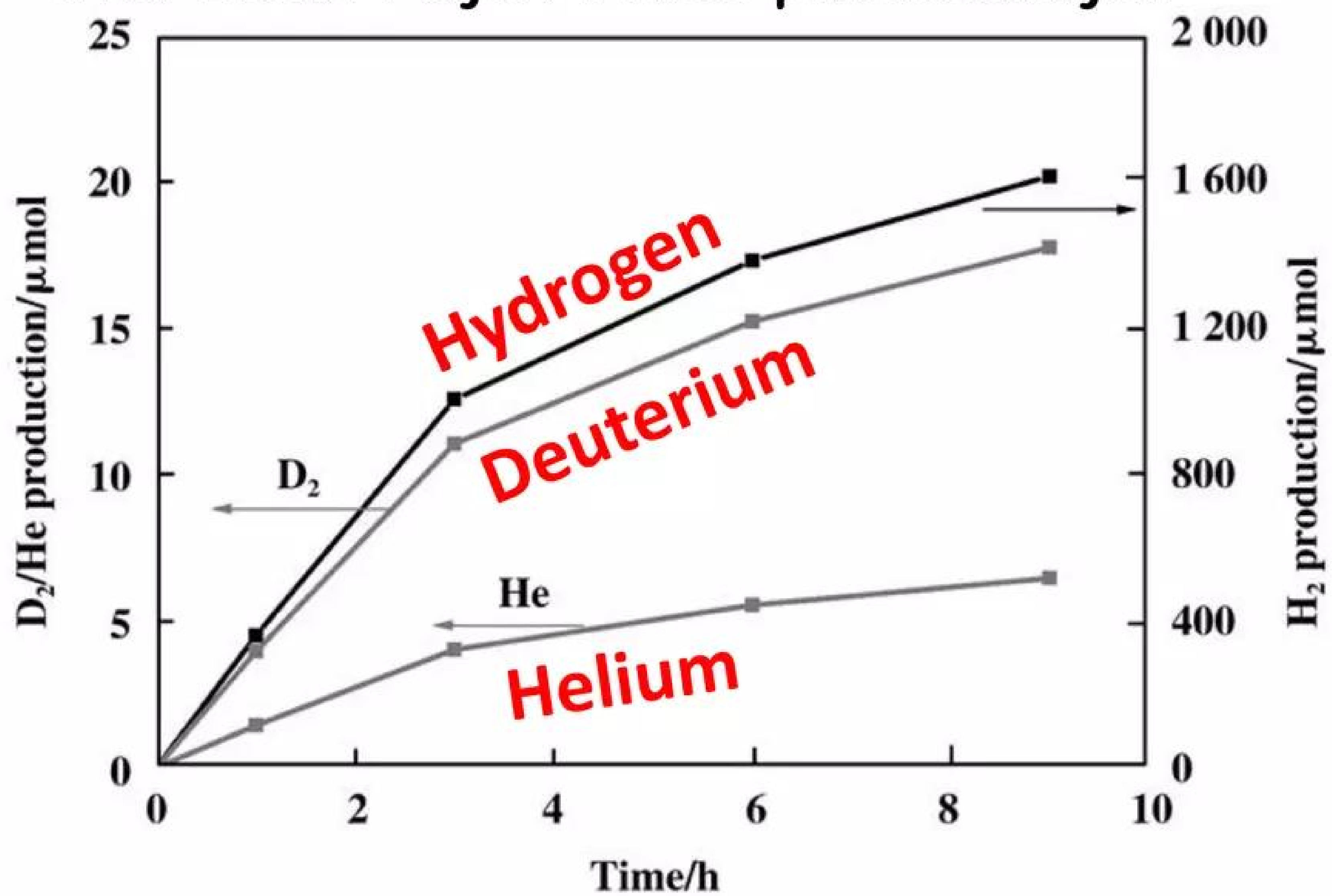
"Formation of Deuterium and Helium during photocatalytic Hydrogen generation from water catalyzed by Pt-Graphene sensitized with Br-dye [Eosin Y] under visible light irradiation" April 2017

**Claims:** production of Deuterium and Helium with $H_2$ in photocatalytic cell at NTP

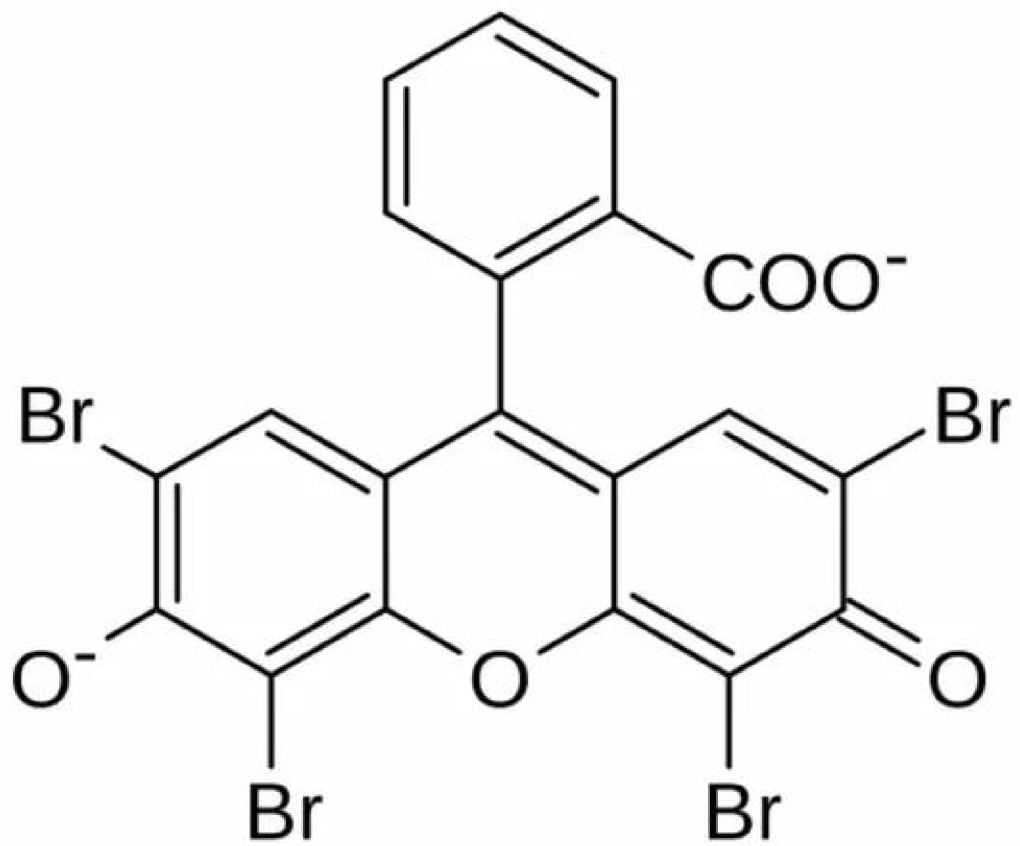
**Analytical equipment used for detection of H, D , and He:** GC-MS (Agilent 5975C Triple-Axis Detector), Quadrupole Mass Spectrometer (LC-D200M), and Rare Gas Isotope Mass Spectrometry System (Nobleless SFT)

**Deuterium and Helium $\mu$mol concentrations increase over time in parallel with Hydrogen (production appears to be closely correlated)**

Fig. 1 "Products of photocatalytic reaction over Eosin Y dye Pt-RGO photocatalyst"




Structure of Eosin Y




$C_{20}H_6Br_4Na_2O_5$

# Widom-Larsen theory explains Lu et al.'s experimental data

## Lu et al. struggled to provide a theoretical explanation for their results

"Formation of Deuterium and Helium during photocatalytic Hydrogen generation from water catalyzed by Pt-Graphene sensitized with Br-dye [Eosin Y] under visible light irradiation" April 2017

- If Deuterium and Helium - Big Bang elements - were NOT present in detectable quantities in aqueous samples prior to their irradiation with visible light in Lu et al.'s photocatalytic cells, then their production signals nuclear processes were at work because everyday chemistry cannot produce any $D_2$ or Helium at NTP
- Lu et al. struggled to explain their very surprising experimental observations by speculating about several different types of nuclear processes; unfortunately, most involve fusion. None of them are technically sound from a nuclear physics perspective; one in particular, "cold fusion," was totally discredited by late-1991
- If not by a fusion reaction, then what types of nuclear processes can explain Lu et al.'s anomalous experimental results? LENRs, as specified by Widom-Larsen theory, can readily explain their reported data: see Slide #29 herein titled, "LENR transmutation reactions from Hydrogen thru Beryllium." This slide describes a ULE neutron-catalyzed LENR transmutation network that begins with Hydrogen (H) and makes heavier Deuterium, Tritium, Helium, Lithium, Beryllium, and so on
- Note: characteristic hard 2.1 MeV gamma ($\gamma$) radiation from neutron captures on Hydrogen will be absent because of $\gamma$ conversion to infrared in LENR active sites

# Widom-Larsen theory explains Lu et al.'s experimental data

## Pt/CdS semiconductor suspension produced Hydrogen, He-3, and He-4

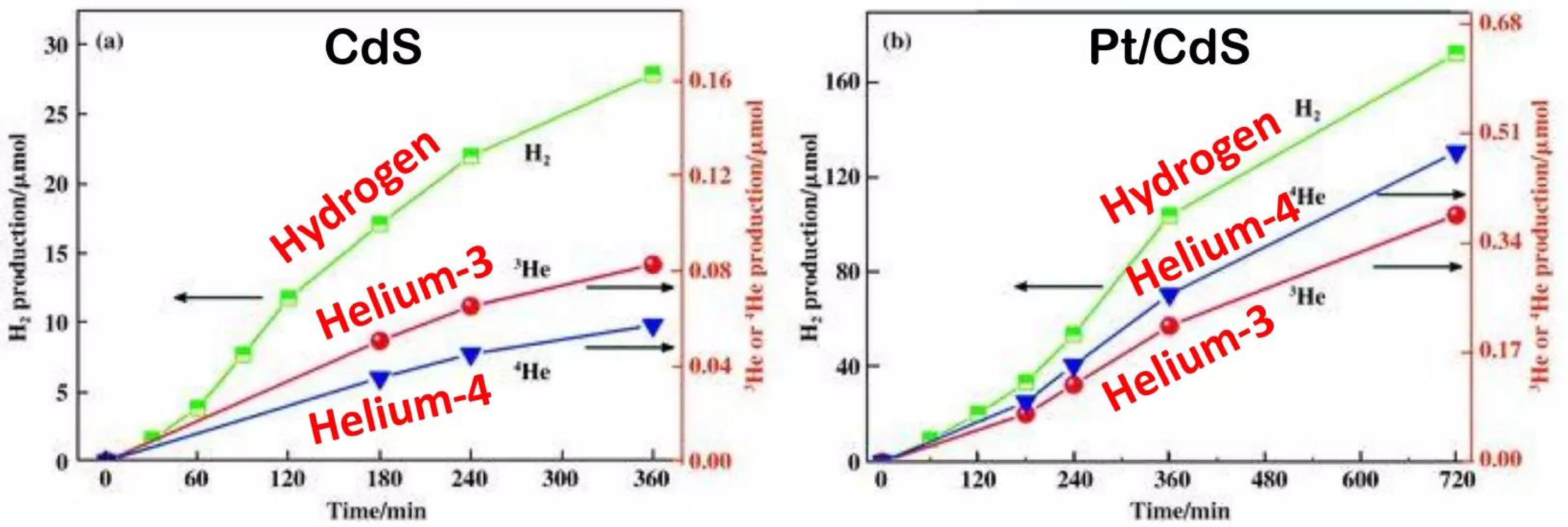
"Formation of Helium-3 and Helium-4 during photocatalytic Hydrogen generation over Cadmium Sulfide under visible light irradiation" August 2017

**Claims:** production of Helium-3 and Helium-4 in photocatalytic cell at NTP

**Analytical equipment used for detection of H, D , and He:** GC-MS (Agilent 5975C Triple-Axis Detector), Quadrupole Mass Spectrometer (LC-D200M), and Rare Gas Isotope Mass Spectrometry System (Nobleless SFT)

For this experiment, Lu et al. specially prepared their own samples of high-purity Cadmium sulfide (CdS) for use as standalone catalyst as well as a support substrate for adsorbed Platinum (Pt) cocatalyst by mixing CdS with $H_2PtCl_6$

Fig. 4 (a) "Production of photocatalytic reaction over CdS and (b) Pt/CdS semiconductor suspension system"



# Widom-Larsen theory explains Lu et al.'s experimental data

## Why wasn't Tritium detected? Maybe $^3He$ is really a mixture of $^3H$ and $^3He$

### "Formation of Helium-3 and Helium-4 during photocatalytic Hydrogen generation over Cadmium Sulfide under visible light irradiation" August 2017

- See Fig. 4 on previous slide: rates of production (μmol/6 hours) for Hydrogen ($^1H_2$) and Helium ($^3He$, $^4He$) are roughly 4x higher for Pt/CdS vs. CdS. However, Pt/CdS exhibited roughly 13x lower rates of Hydrogen and ~22x lower Helium production vs. earlier experiments with Eosin Y/Pt-RGO (Fig.1 on Slide #54)
- See Slide #29 herein titled, "LENR transmutation reactions from Hydrogen thru Beryllium": Widom-Larsen LENR transmutation network can produce Deuterium ($^2H$) as well as Tritium ($^3H$) and Helium ($^3He$, $^4He$). Note that to produce Lithium and Beryllium, neutron fluxes would probably need to be much higher than what could be created by input energy from one 300 Watt Xenon lamp. Note also that in this LENR network, $^3He$ is *only* produced by $beta^-$ decay of Tritium. So then why wasn't Tritium detected by Lu et al.? Maybe because what is now being labeled $^3He$ is really a *mixture* of $^3H$ and $^3He$. Lattice is raising this issue because we looked at recent literature about measurements of $^3H$ and $^3He$ that occur together in natural rock and water samples. We found that special analytical procedures are used to selectively first extract Helium from samples (after which it is measured) and *then* extract and measure Tritium separately; see "Mass spectrometric measurement of Helium isotopes and Tritium in water samples" A. Ludin et al.; paper is at URL:

https://tinyurl.com/ya4evy6h

# Widom-Larsen theory explains Lu et al.'s experimental data

## $K_2PtCl_6$ + Eosin Y + TEOA + Graphene oxide; no-Potassium control = $H_2PtCl_6$

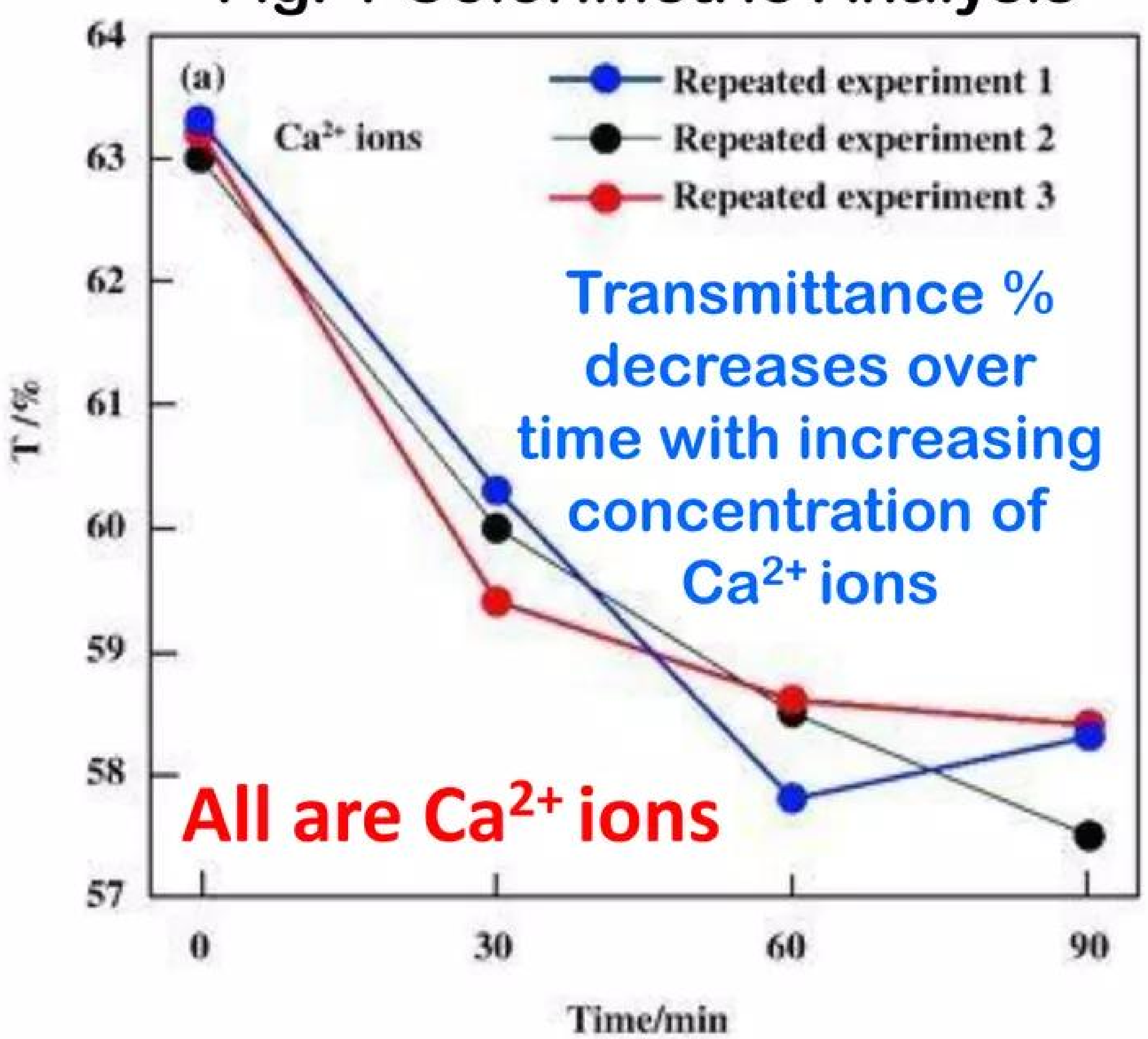
"Photocatalytic Hydrogen evolution and induced transmutation of Potassium to Calcium via low-energy nuclear reaction (LENR) driven by visible light" Oct. 2017

**Claim:** transmutation of Potassium to Calcium in photocatalytic cell at NTP

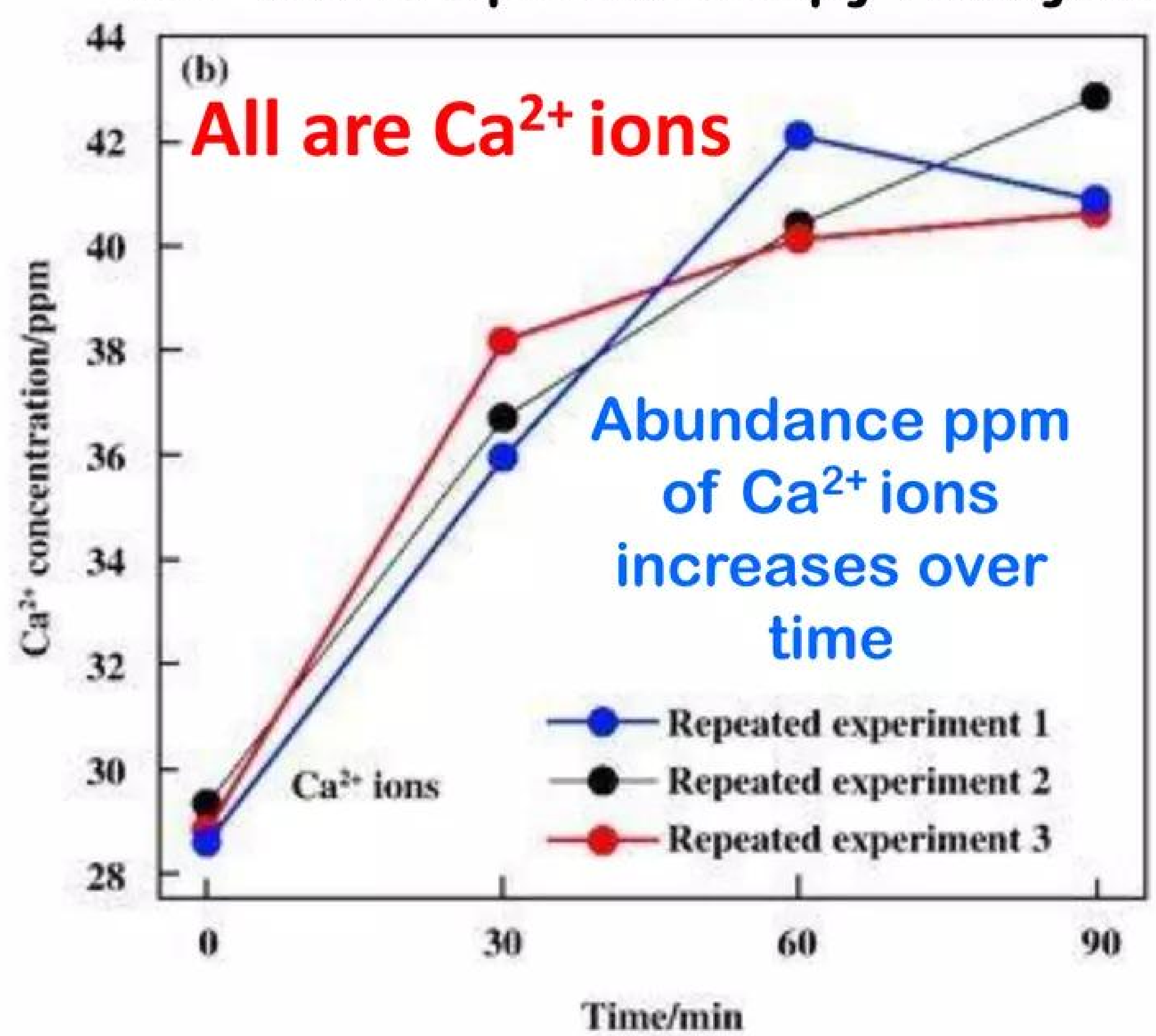
**Analytical equipment used for detection of H, D , and He:** GC-MS (Agilent 5975C Triple-Axis Detector), Quadrupole Mass Spectrometer (LC-D200M), and Rare Gas Isotope Mass Spectrometry System (Nobleless SFT)

Lu et al. observed anomalous increase in local abundance of Calcium over time in presence of Potassium as $K_2PtCl_6$ ; when Potassium-free $H_2PtCl_6$ control was run, Calcium increase disappeared; occurred in parallel with $H_2$ , He production

Fig. 1 Colorimetric Analysis




ICP Mass Spectroscopy Analysis



# Widom-Larsen theory explains Lu et al.'s experimental data

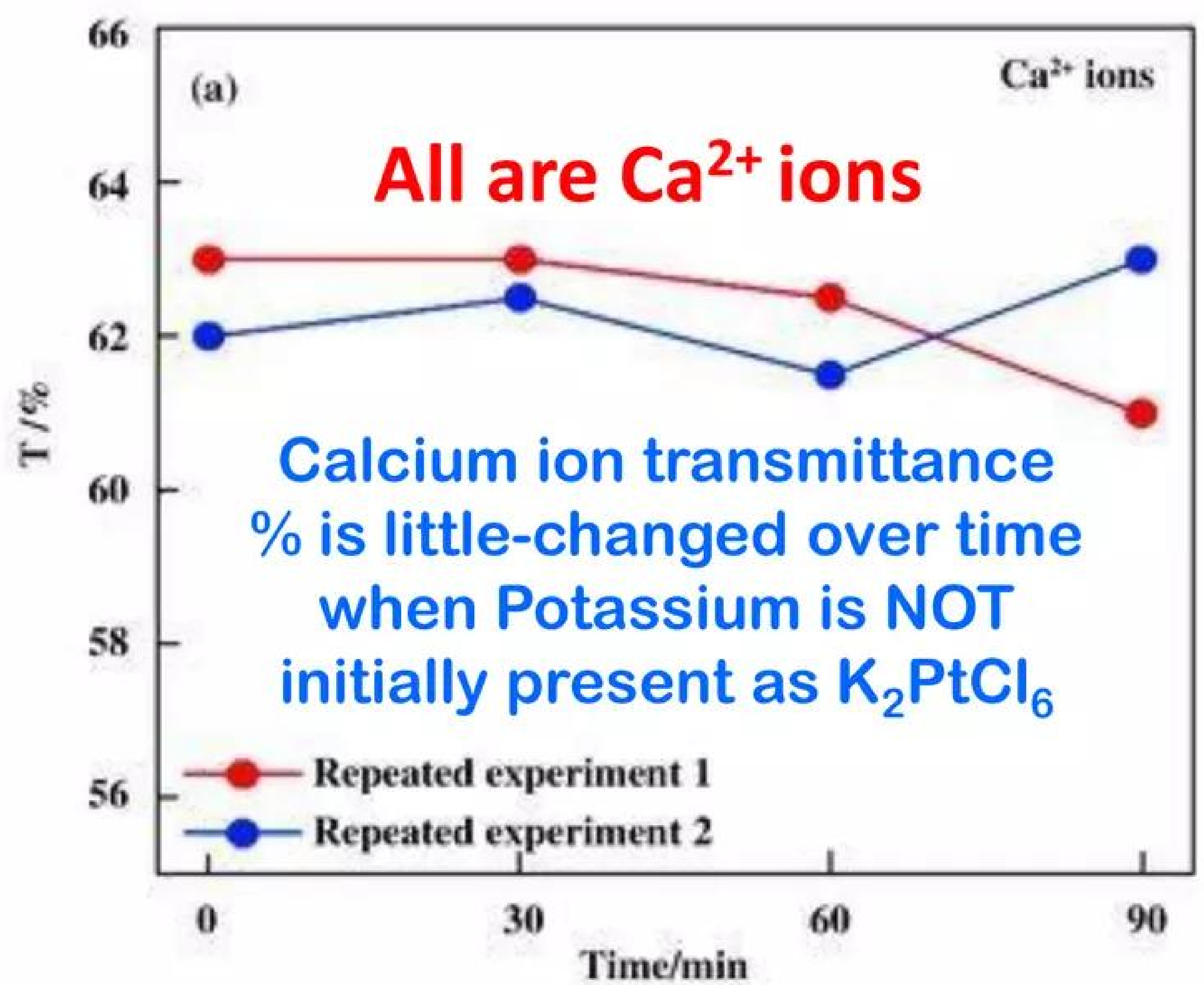
## Results indicate that nuclear process transmuted Potassium into Calcium

"Photocatalytic Hydrogen evolution and induced transmutation of Potassium to Calcium via low-energy nuclear reaction (LENR) driven by visible light" Oct. 2017

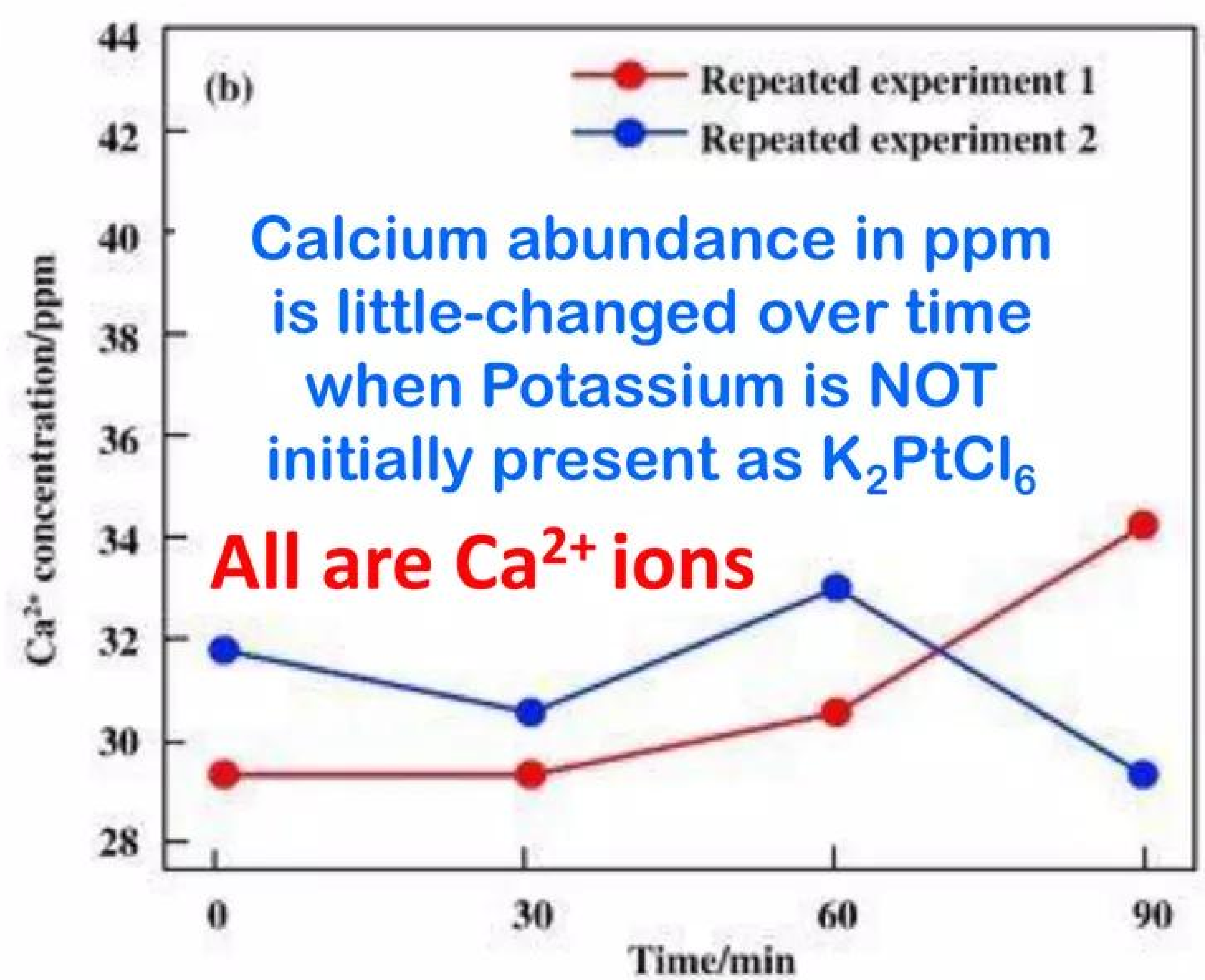
**Quoting:** "Results indicate that almost no variation of Calcium concentration during the photocatalytic HER. Those results provide evidence that the increase of Calcium concentration in the reaction mixture is closely related to the presence of Potassium, namely indicating elemental transmutation from Potassium to Calcium."

**Lu et al. observed anomalous increase in local abundance of Calcium over time in presence of Potassium as $K_2PtCl_6$ ; when Potassium-free $H_2PtCl_6$ control was run, increase in Calcium disappeared; consistent with transmutation of K → Ca**

Fig. 3 Colorimetric Analysis




ICP Mass Spectroscopy Analysis



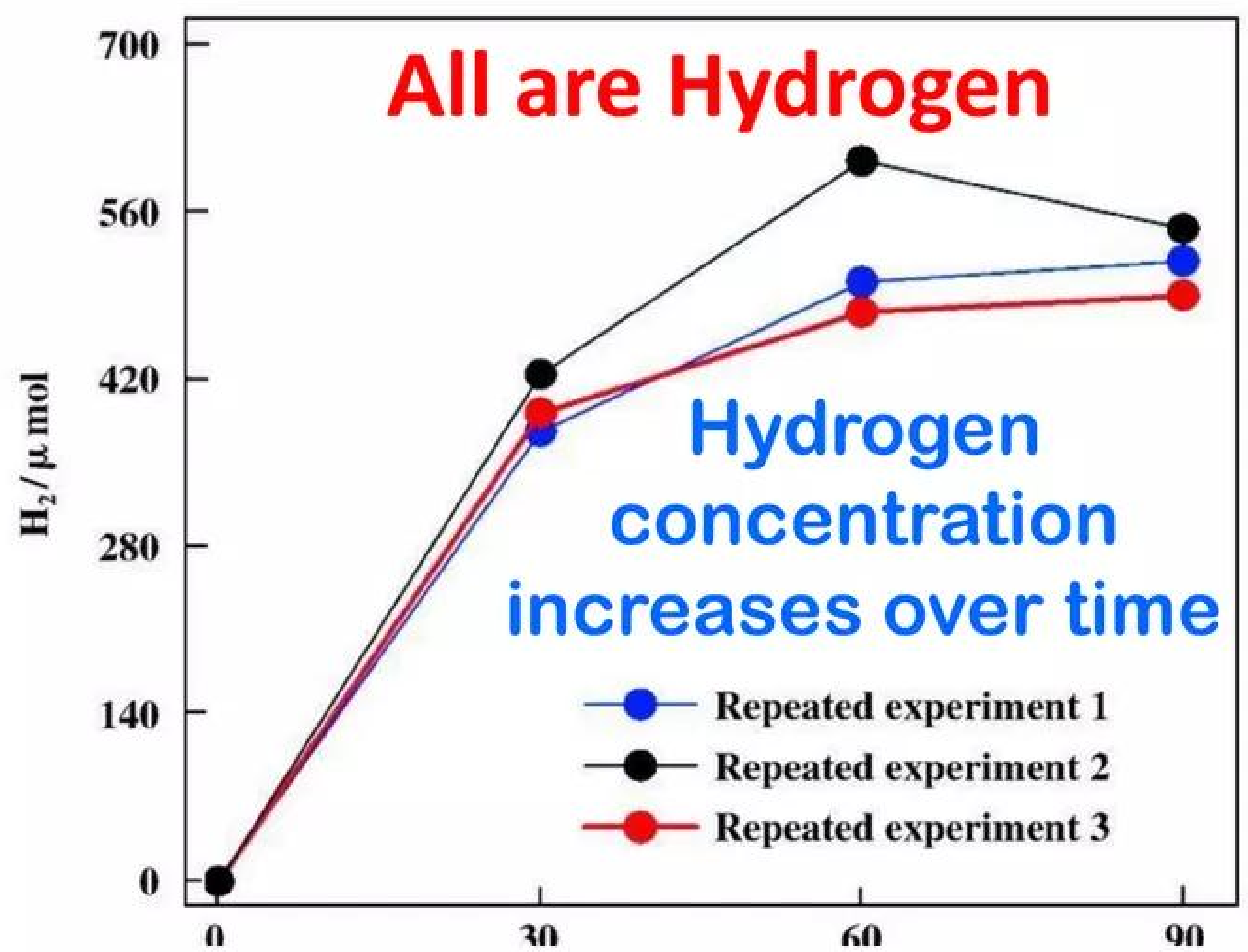
# Widom-Larsen theory explains Lu et al.'s experimental data

## Lattice believes Lu et al.'s conclusion is correct: K was transmuted to Ca

"Photocatalytic Hydrogen evolution and induced transmutation of Potassium to Calcium via low-energy nuclear reaction (LENR) driven by visible light" Oct. 2017

**Quoting:** "Hydrogen evolution tests were conducted: three repeated experiments and the corresponding results were presented in Fig. 4. Clearly … Hydrogen was continuously produced when the mixture was irradiated by visible light"

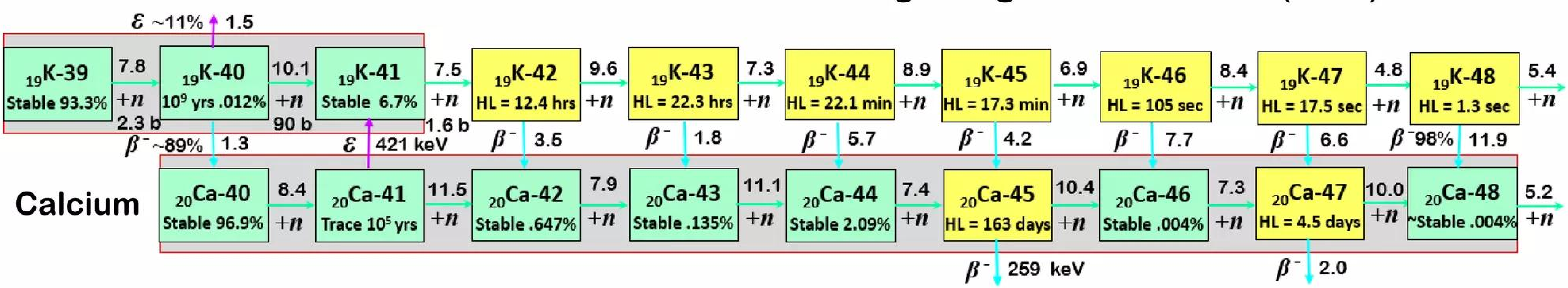
Fig. 4 Hydrogen production in cell




Time/minutes

**Lattice believes Lu et al.'s conclusion was most likely correct:** their experimental results imply Potassium was transmuted to Calcium. Neutron captures on stable isotopes of Potassium will produce Calcium; **hard-radiation-free W-L LENR network that explains this result is shown below:**

Widom-Larsen LENR transmutation network beginning with Potassium (K-39):



# Widom-Larsen theory explains Lu et al.'s experimental data

## Further technical remarks by Lattice concerning their provocative results

- Production of Deuterium, Tritium (?), and Helium are all closely correlated with production of Hydrogen in Lu et al.'s data; i.e., changes in the rates of Hydrogen production are closely mirrored in rates for D, T, and He. This behavior would be expected if: (1) Hydrogen production creates $p^+$, $d^+$, or $t^+$ ions that serve as input reactants in the neutron-producing electroweak $e^+ + p^+$ reaction; and if (2) LENR neutron-catalyzed network (Slide #29) were operating somewhere within system
- Above noted behavior implies that LENR active sites are likely to be located in close proximity to - or congruent with - catalytic sites where $H_2O$ is being split
- High electric fields > $10^{10}$ V/m are known to be very important in enabling both LENRs and chemical catalysis. It is thus likely that water-splitting is occurring in nm- to $\mu$-sized domains characterized by very high local electric fields >$10^{10}$ V/m
- Note that if Deuterium and/or Tritium remain in close proximity to LENR active sites after being produced, they will eventually be converted into ULE neutrons
- In Lu et al.'s data (Fig. 1 - Slide #54), rate of Hydrogen production is > Deuterium > Helium. This ordering of rates would be predicted in LENR network (Slide #29)
- S. Wang et al. (Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian, China) have idea that resembles LENR active sites (next slide)

# Wang et al.'s idea shares some features of LENR active sites

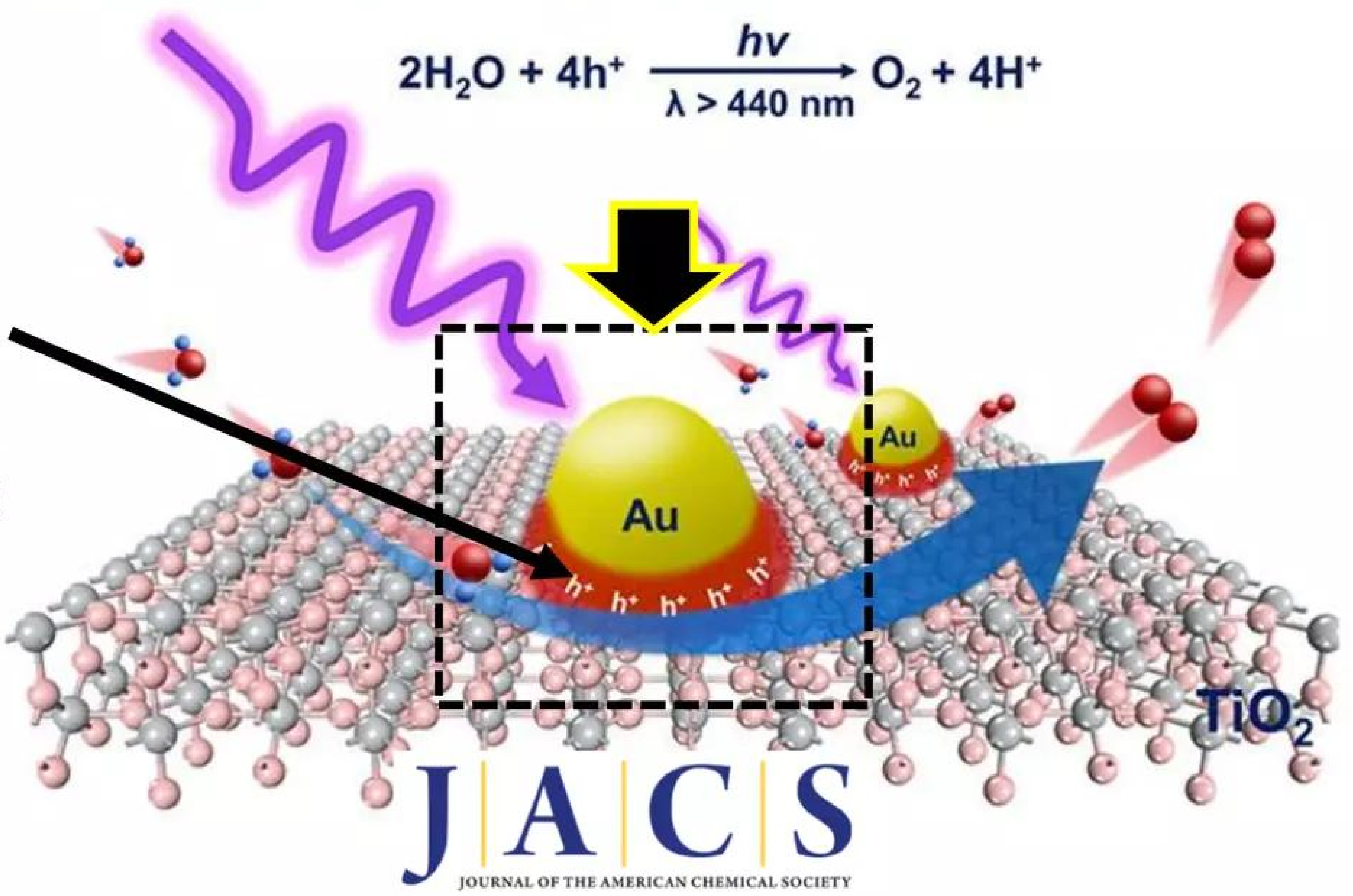
## "Plasmonic holes are concentrated near Gold-semiconductor interface"

"Positioning the water oxidation reaction sites in plasmonic photocatalysts"
S. Wang et al. *Journal of the American Chemical Society* 139 pp. 11771 - 11778 (2017)

https://pubs.acs.org/doi/abs/10.1021/jacs.7b04470

Quoting excerpt from abstract: "… exactly how plasmonic hot holes participate in water splitting reaction has not yet been well understood … where plasmonic hot holes participate in water oxidation is still illusive … taking Au/$TiO_2$ as plasmonic photocatalyst prototype, we investigated plasmonic hot holes involved in water oxidation … [and] demonstrated that plasmonic holes are mainly concentrated near Gold–semiconductor interface, which is further identified as reaction site for plasmonic water oxidation."

Highest local electric fields would probably occur in Au/$TiO_2$ interfacial region



# References to publications re Widom-Larsen theory of LENRs

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"
A. Widom and L. Larsen (author's copy)
*European Physical Journal C - Particles and Fields* 46 pp. 107 - 112 (2006)
http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen (author's copy)
*Pramana - Journal of Physics* 75 pp. 617 - 637 (March 2010)
http://www.slideshare.net/lewisglarsen/srivastava-widom-and-larsenprimer-for-electroweak-induced-low-energy-nuclear-reactionspramana-oct-2010

"Hacking the Atom" (Volume 1 - 484 pages) popular science book
Steven B. Krivit, Pacific Oaks Press, San Rafael, CA, September 11, 2016
Paperback US$16.00; hardcover US$48.00; Kindle US$3.99
https://www.amazon.com/dp/0996886451

"Einstein's lost hypothesis: is a third-act twist to nuclear energy at hand?"
Mark Anderson
*Nautilus* magazine pp. 21 - 29 Winter 2013-14 issue Nov. 28, 2013
http://nautil.us/issue/7/waste/einsteins-lost-hypothesis

# Working with Lattice Energy LLC, Chicago, Illinois USA

## Partnering on LENR commercialization and consulting on other subjects

1-312-861-0115 lewisglarsen@gmail.com

L. Larsen c.v.: http://www.slideshare.net/lewisglarsen/lewis-g-larsen-cv-june-2013

- We believe Lattice is the world-leader in proprietary knowledge about LENR device engineering required to develop high-performance, long lived, scalable power sources. Our published peer-reviewed theoretical papers rigorously explain the breakthrough device physics of LENR processes, including the absence of dangerous energetic neutron or gamma radiation and lack of long-lived radioactive waste production
- Lattice welcomes inquiries from large, established organizations that have an interest in discussing the possibility of becoming Lattice's strategic capital and/or technology development partner
- Lewis Larsen also independently engages in consulting on variety of subject areas that include: Lithium-ion battery safety issues; long-term electricity grid reliability and resilience; and evaluating potential future impact of LENRs from a long-term investment risk management perspective for large CAPEX projects in the oil & gas, petrochemicals, transportation, utility, and aerospace industries

# Ultralow energy neutron reactions (LENRs)

## LENRs could be occurring on dust grains in the famous Eagle Nebula

**HORATIO: "O day and night, but this is wondrous strange!"**

**HAMLET: "And therefore as a stranger give it welcome.**

**There are more things in Heaven and Earth, Horatio, than are dreamt of in your philosophy."**

**William Shakespeare in "Hamlet" (1603)**
**Hamlet (1.5.167-8) where Hamlet is speaking to Horatio**

"Using the MUSE instrument on ESO's Very Large Telescope (VLT), astronomers have produced the first complete three-dimensional view of the famous Pillars of Creation in the Eagle Nebula, Messier 16. The new observations demonstrate how the different dusty pillars of this iconic object are distributed in space and reveal many new details — including a previously unseen jet from a young star. Intense radiation and stellar winds from the cluster's brilliant stars have sculpted the dusty Pillars of Creation over time and should fully evaporate them in about three million years."

Image and caption credit: ESO