Lattice Energy LLC

Commercializing a next-generation source of safe CO_2-free nuclear energy

Possible production of stable Gold (^{197}Au) via LENR neutron - catalyzed transmutation of Platinum catalyst during operation of catalytic converters in cars and trucks

78
Pt
Platinum
195.08

Lewis Larsen
President and CEO
September 28, 2015

79
Au
Gold
196.967

Contact: 1-312-861-0115 Chicago, Illinois USA lewisglarsen@gmail.com

World is already safely coexisting with LENRs in vehicles

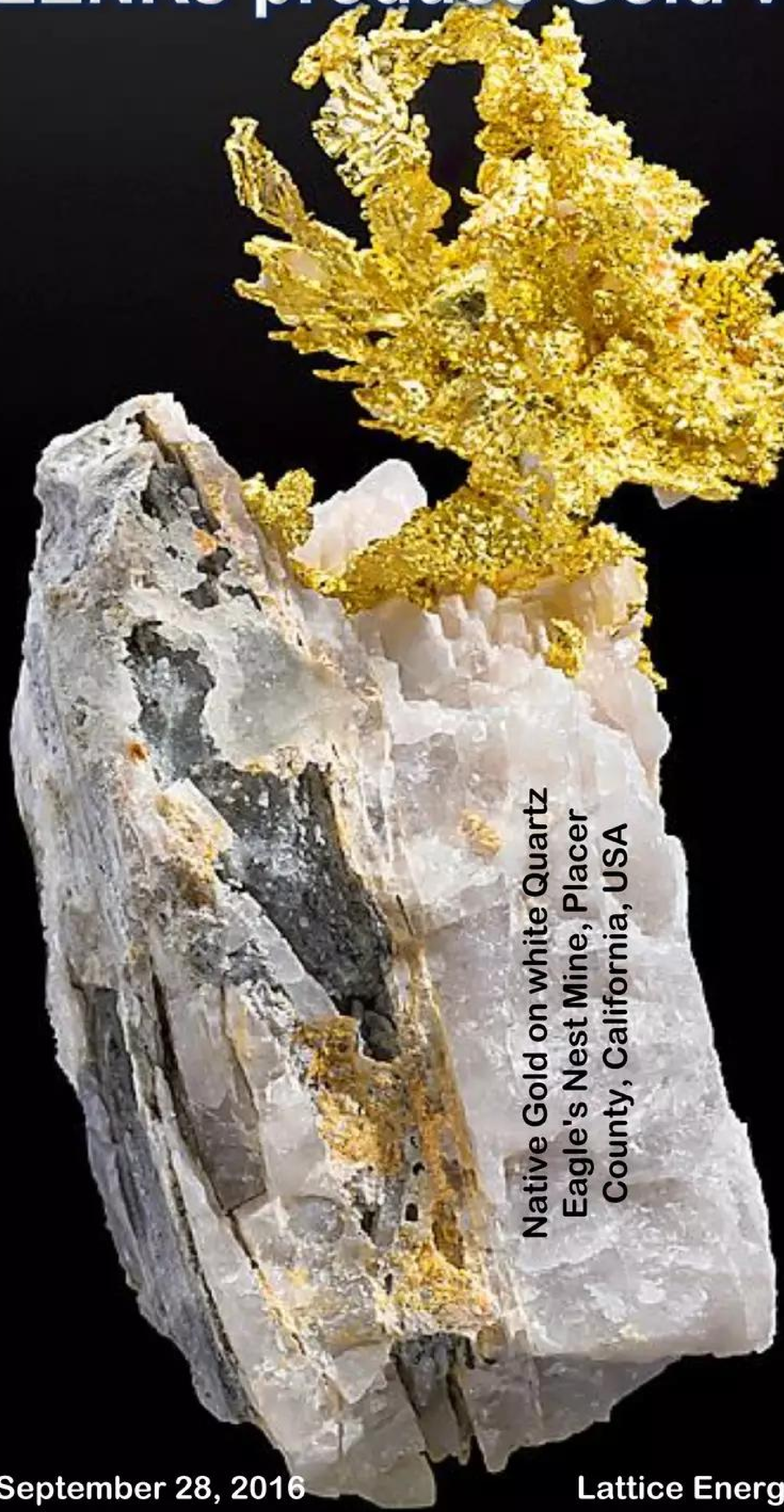
Presently, unbeknownst to unsuspecting drivers worldwide, green LENR transmutation processes are occurring at very low rates during operation of three-way catalytic converters installed in over a billion cars and trucks.

Radiation-free nuclear transmutation of chemical elements by LENRs inside catalytic converters is strongly indicated by the presence of anomalous Gold, excess radiogenic Osmium, and shifts toward heavier isotopes that have been reported in Platinum and Palladium found in nm-μ microscopic nanoparticles that are emitted from vehicle exhaust pipes.

Extensive sampling and chemical analysis of certain roadway dust and roadside soils by environmental scientists have revealed that in scattered locations nanoparticulate Gold emitted from motor vehicle exhaust has accumulated to the point where local concentrations of this precious metal nearing key minimum threshold of 0.5 ppm needed for economic Gold ore.

This surprising nuclear activity in ubiquitous catalytic converters and absence of deleterious consequences for drivers or Earth's environment argue that world is already safely coexisting with LENRs. This supports idea that LENRs could potentially be a very attractive future source of green nuclear energy if the technology is successfully commercialized.

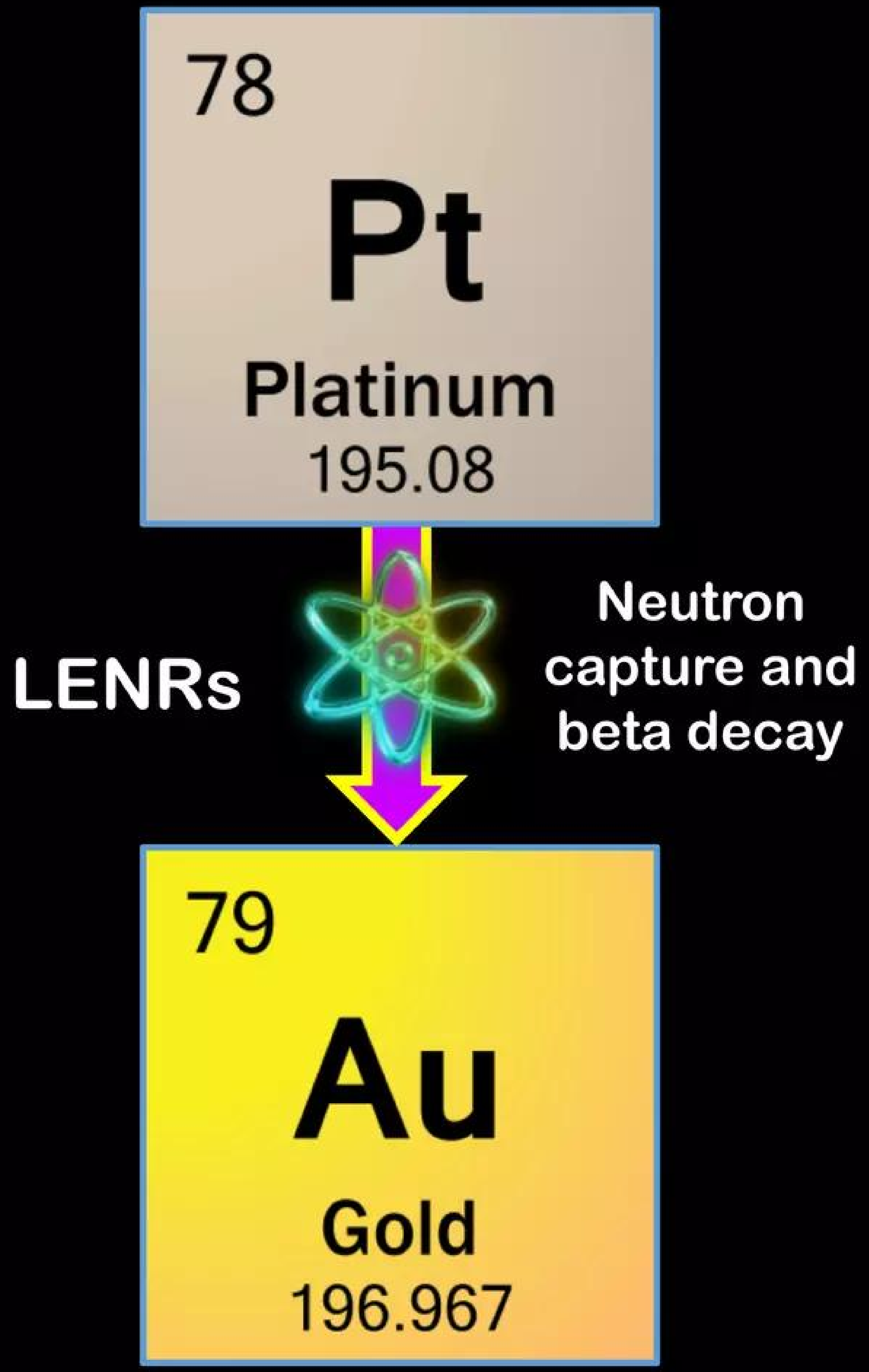
LENRs produce Gold via neutron-catalyzed transmutation



Native Gold on white Quartz
Eagle's Nest Mine, Placer
County, California, USA

Native Platinum crystals
Konder Massif, Aldan Shield,
Ayan-Maya, Khabarovskiy
Kray, Russia

Transmutation of Platinum into stable Gold inside catalytic converters



Comparison of LENRs to fission and fusion

Fission, fusion, and LENRs all involve controlled release of nuclear binding energy (heat) for power generation: no CO_2 emissions; scale of energy release is MeVs (nuclear regime) > 1,000,000x energy density of chemical energy power sources

Heavy element fission: involves shattering heavy nuclei to release stored nuclear binding energy; requires massive shielding and containment structures to handle radiation; major radioactive waste clean-up issues and costs; limited sources of fuel: today, almost entirely Uranium; Thorium-based fuel cycles now under development; heavy element U-235 (fissile isotope fuel) + neutrons → complex array of lower-mass fission products (some are very long-lived radioisotopes) + energetic gamma radiation + energetic neutron radiation + heat

Fusion of light nuclei: involves smashing light nuclei together to release stored nuclear binding energy; present multi-billion $ development efforts (e.g., ITER, NIF, other Tokamaks) focusing mainly on D+T fusion reaction; requires massive shielding/containment structures to handle 14 MeV neutron radiation; minor radioactive waste clean-up $ costs vs. fission

Two key sources of fuel: Deuterium and Tritium (both are heavy isotopes of Hydrogen)

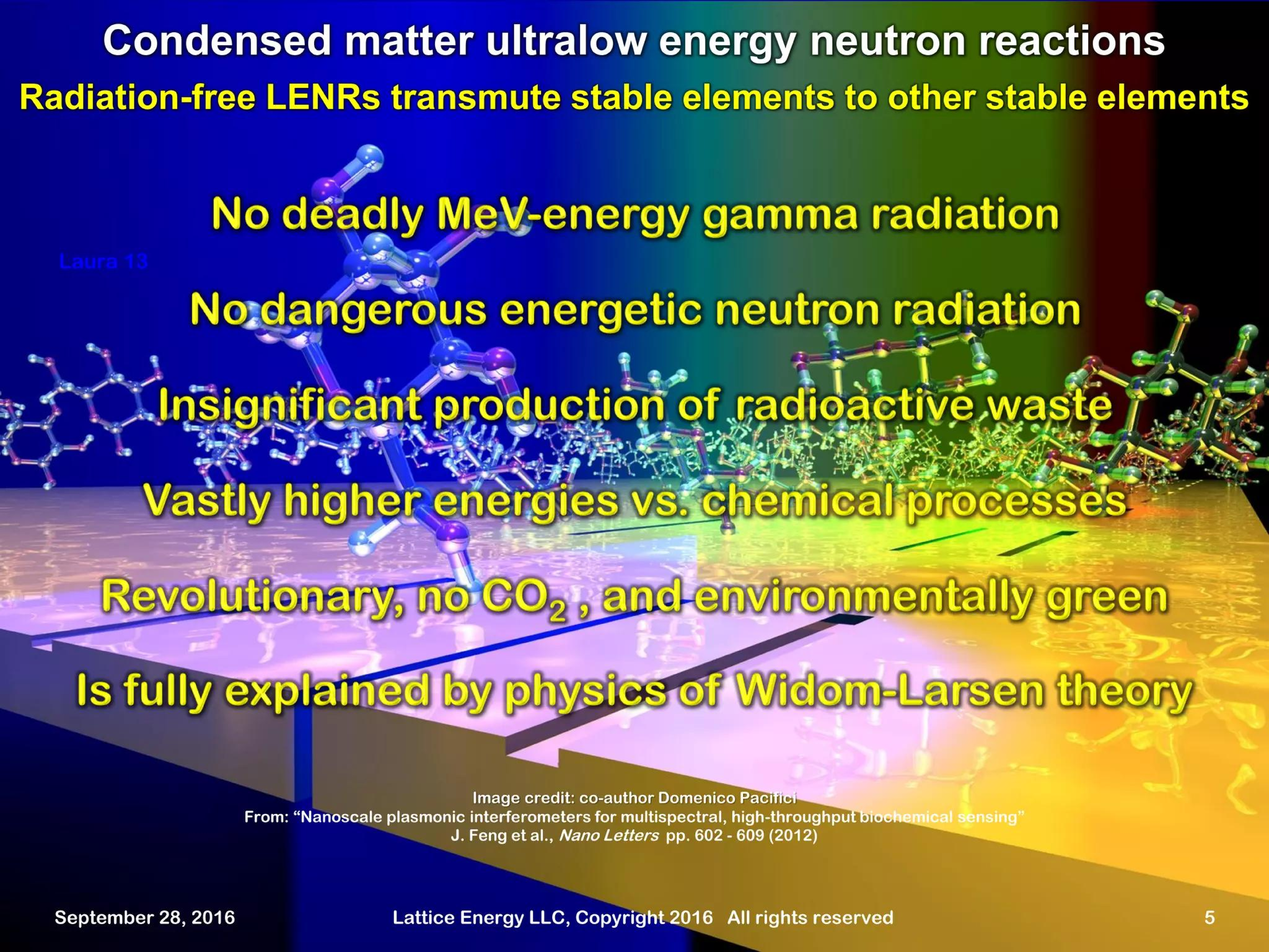
Most likely to be developed commercial fusion reaction involves:

D + T → He-4 (helium) + neutron + heat (total energy yield 17.6 MeV; ~14.1 MeV in neutron)

Ultralow energy neutron reactions (LENRs): distinguishing feature is neutron production via electroweak reaction; neutron capture on fuel + gamma conversion to IR + decays [β^-, α] releases nuclear binding energy; early-stage technology; no emission of energetic neutron or gamma radiation and no long-lived radioactive waste products; LENR systems would not require massive, expensive radiation shielding or containment structures → much lower $$$ cost; many possible fuels --- any element/isotope that can capture LENR neutrons; involves neutron-catalyzed transmutation of fuels into heavier stable elements; process creates heat

Condensed matter ultralow energy neutron reactions

Radiation-free LENRs transmute stable elements to other stable elements



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)

Periodic Table of all chemical elements in the Universe

Each element has a fixed number of protons; # of neutrons can vary

LENR transmutations proceed from left to right across rows of the Periodic Table

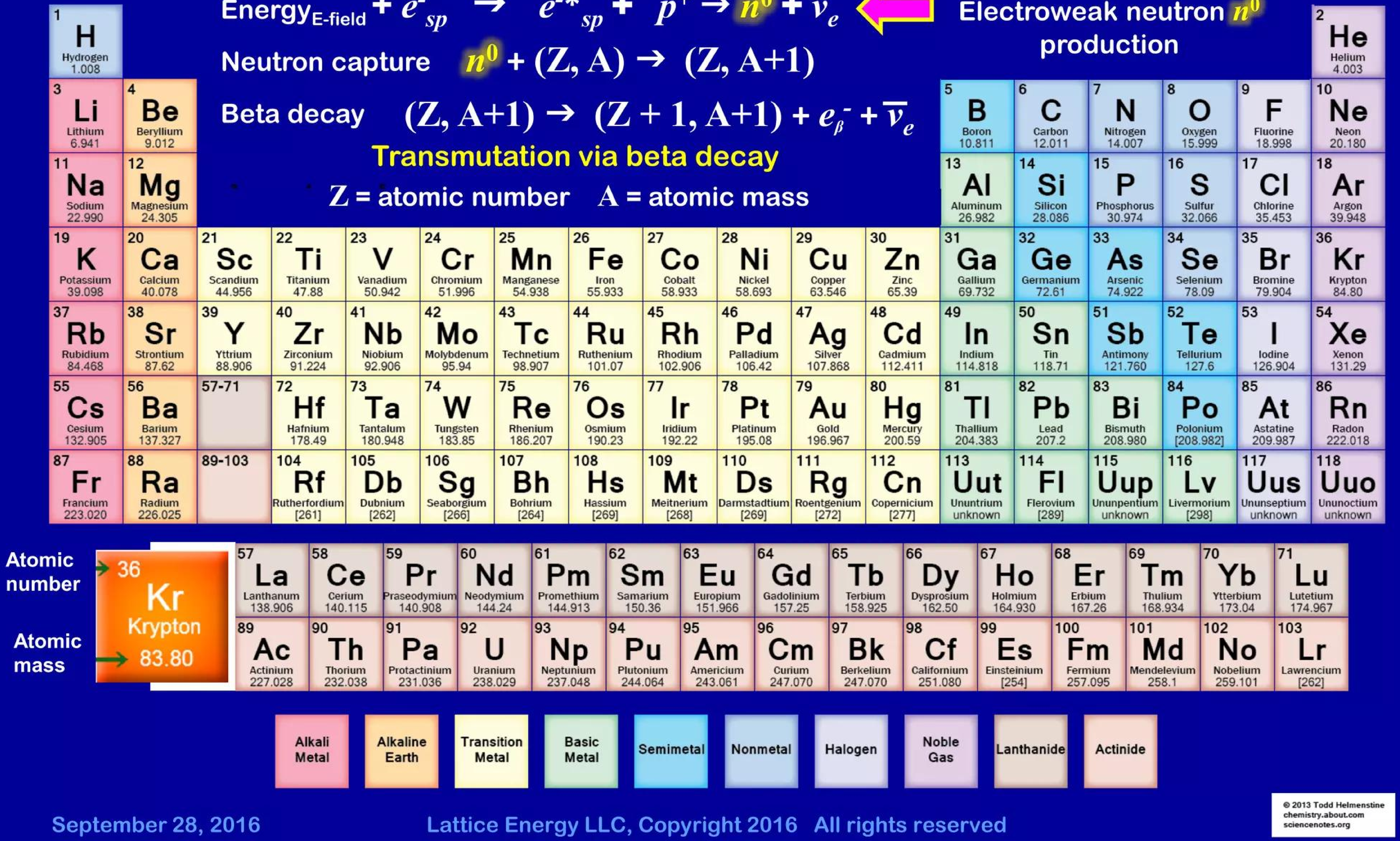
Energy$_{\text{E-field}}$ + e^-_{sp} → e^{-*}_{sp} + $p^+ \rightarrow n^0 + \nu_e$ ⇐ Electroweak neutron n^0 production

Neutron capture $n^0 + (Z, A) \rightarrow (Z, A+1)$

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

Transmutation via beta decay

Z = atomic number A = atomic mass



1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

Atomic number → 36
Kr
Krypton
Atomic mass → 83.80

Alkali Metal | Alkaline Earth | Transition Metal | Basic Metal | Semimetal | Nonmetal | Halogen | Noble Gas | Lanthanide | Actinide

Contents

Scientists have observed LENR phenomena for 100 years

Data was mostly dismissed and ignored because it was not understood

Physics of the Widom-Larsen theory of LENRs rigorously explains all of this data

- ✓ Various manifestations of LENR phenomena have been episodically observed and reported in scientific journals for 100 years. However, prior to publication of the Widom-Larsen theory of LENRs (2005) these very intriguing, anomalous experimental data were generally dismissed and simply ignored by mainstream science. This happened because such data: may have been produced by subtle measurement errors; or, were valid observations but were not reproducible; or, were otherwise believable results that could not be understood theoretically
- ✓ Another contributing factor to decades of dismissal and confusion about the reality of this rather large body of published data was simple fact that LENR transmutation processes do not produce large, easily detectible emissions of dangerous MeV-energy neutron or gamma radiation. Absent such well-known signatures of nuclear fission and fusion reactions, no one imagined that the observed anomalies were actually being created by a more benign nuclear process that is radiation-free and really quite different from fission and fusion
- ✓ Thanks to insights provided by Widom-Larsen theory it is now apparent that LENRs appear to occur naturally at low rates in surprising numbers of familiar settings that include atmospheric lightning, commercial Lithium-ion batteries, electrochemical cells, and as discussed herein, vehicular catalytic converters

Catalytic converters nearly ubiquitous on cars and trucks

Platinum (Pt), Palladium (Pd), Rhodium (Rh) catalysts reduce pollutants

Analyses of particles emitted from exhaust reveals unexpected presence of Gold

- ✓ In mid 1970s, installation of catalytic converters in exhaust systems of cars and trucks was mandated to reduce pollutants emitted by vehicles during operation
- ✓ Around same time, use of tetraethyllead (TEL) as antiknock additive was rapidly phased-out in vehicle fuels because of harmful environmental effects and severe biological toxicity as well as being a ‘poison’ for Pt, Pd, Rh catalysts in converters. TEL replaced by adding 1% - 2% benzene, a 6-Carbon aromatic ring, to such fuels
- ✓ For 30 years it has been known that tiny particles comprising pieces of materials found inside catalytic converters are shed into gaseous exhaust streams, emitted into nearby environments, and locally accumulated in road dust, soils, and plants
- ✓ In past 15 years, environmental scientists began to make greater use of advanced analytical techniques to analyze local environments for presence of molecules and elements emitted by vehicles and trace their movement through ecosystems. One commonly used technique called mass spectroscopy has capability to very accurately measure elements and isotopes on microscopic samples of materials
- ✓ Using mass spectroscopy to measure Platinum, Palladium, and Rhodium in road environments, certain researchers reported detection of significant amounts of Gold. This raises question: did this Gold come from impurities previously present inside converters or was it created *in situ* via transmutation of Platinum catalysts?

What happens if LENRs occur in catalytic converters ?

Isotopic ratios of elements are shifted; different elements are created

Elements present and stable isotopic ratios altered during converter operation

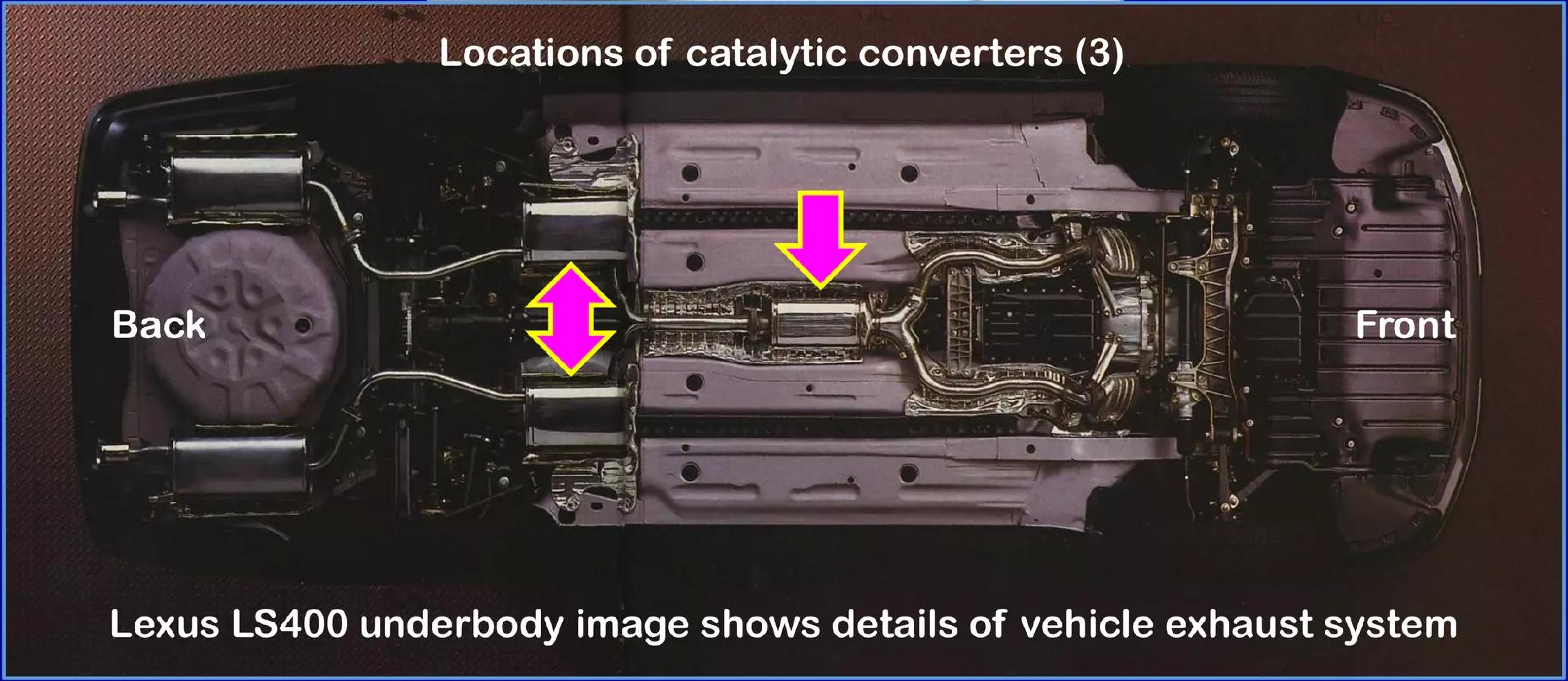
- ✓ Neutron-catalyzed LENR transmutation reactions alter initial isotopic ratios via capture of neutrons. For example, stable ^{195}Pt initially captures a neutron and is transmuted into stable ^{196}Pt. Another name for this effect is an isotopic shift
- ✓ Combination of neutron capture on a stable isotope followed by β-decay of an unstable isotope produced by that capture can change an initial element into a different stable element. For example, stable ^{196}Pt captures a neutron and is transmuted into unstable ^{197}Pt (half-life 19.9 hours) which β-decays into stable ^{197}Au. Another name for this process is nuclear transmutation of elements; in this example, an LENR process transmutes initial Platinum-196 into Gold-197
- ✓ Nuclear isotopic shifts caused by LENRs can be mimicked by certain types of chemical isotopic fractionation processes. What differentiates the two very different alternatives is both magnitude (shifts due to chemical fractionation processes tend to be very small: fractions of 1%) and fact that closed mass balances of individual isotopes are violated with LENRs but fully conserved during chemical processes. Sadly, quantities of materials are so tiny that it is usually impossible to measure closed mass balances with sufficient precision
- ✓ Appearance of new elements initially *absent* at the start of converter operation cannot possibly be caused by chemical processes that must conserve elements

Cars & trucks have catalytic converters in exhaust systems

Lexus LS400 was manufactured with three catalytic converters in system

Lexus LS400 sedan

For years, Toyota has been quietly conducting basic R&D in LENRs; long-term goal might be to replace the internal combustion engine



Locations of catalytic converters (3)

Lexus LS400 underbody image shows details of vehicle exhaust system

Catalytic converters reduce pollutants emitted by vehicles

Pt, Pd, Rh catalysts convert noxious pollutants into benign H_2O, CO_2, N_2

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

- ✓ **Core or substrate:** "is often a ceramic honeycomb in modern catalytic converters, but stainless steel foil honeycombs are used, too. The honey-comb surface increases the amount of surface area available to support the catalyst, and … is called a 'catalyst support' [or also, 'monolith']."
- ✓ **Washcoat:** "is used to make converters more efficient, often as a mixture of silica and alumina … washcoat, when added to the core, forms a rough, irregular surface, which has a far greater surface area than the flat core surfaces do, which then gives the converter core a larger surface area, and therefore more places for active precious metal sites … catalyst is added to the washcoat (in suspension) before being applied to the core …"
- ✓ **Catalyst particles:** "most often a precious metal. Platinum is the most active catalyst and is widely used. It is not suitable for all applications, however, because of unwanted additional reactions and/or cost. Palladium and rhodium are two other precious metals used. Platinum and rhodium are used as a reduction catalyst, while platinum and palladium are used as an oxidation catalyst."

Source: Wikipedia, article titled "Catalytic Converter"

Catalytic converters reduce pollutants emitted by vehicles

Pt, Pd, Rh catalysts convert noxious pollutants into benign H_2O, CO_2, N_2

Cuts emissions of Nitrogen oxides, Carbon monoxide & unburned hydrocarbons

Since 1981, three-way catalytic converters have been used for control of exhaust emissions in road going vehicles in North America; throughout China since 1993. Today, use of these IC engine environmental systems is near-universally mandated by law and essentially ubiquitous in vehicles manufactured all around the world.

Such converters use mostly Platinum, Palladium, and Rhodium catalysts to chemically transform 3 types of noxious exhaust pollutants into more environmentally benign molecules, namely O_2, N_2, CO_2, and H_2O (water).

- ✓ Nitrogen oxides (NO_x) are split into gaseous Nitrogen (N_2) and Oxygen (O_2):

$2NO_x \rightarrow xO_2 + N_2$ Rh mainly used for reduction catalyst

- ✓ Carbon monoxide (CO) is reacted with Oxygen to make Carbon dioxide (CO_2):

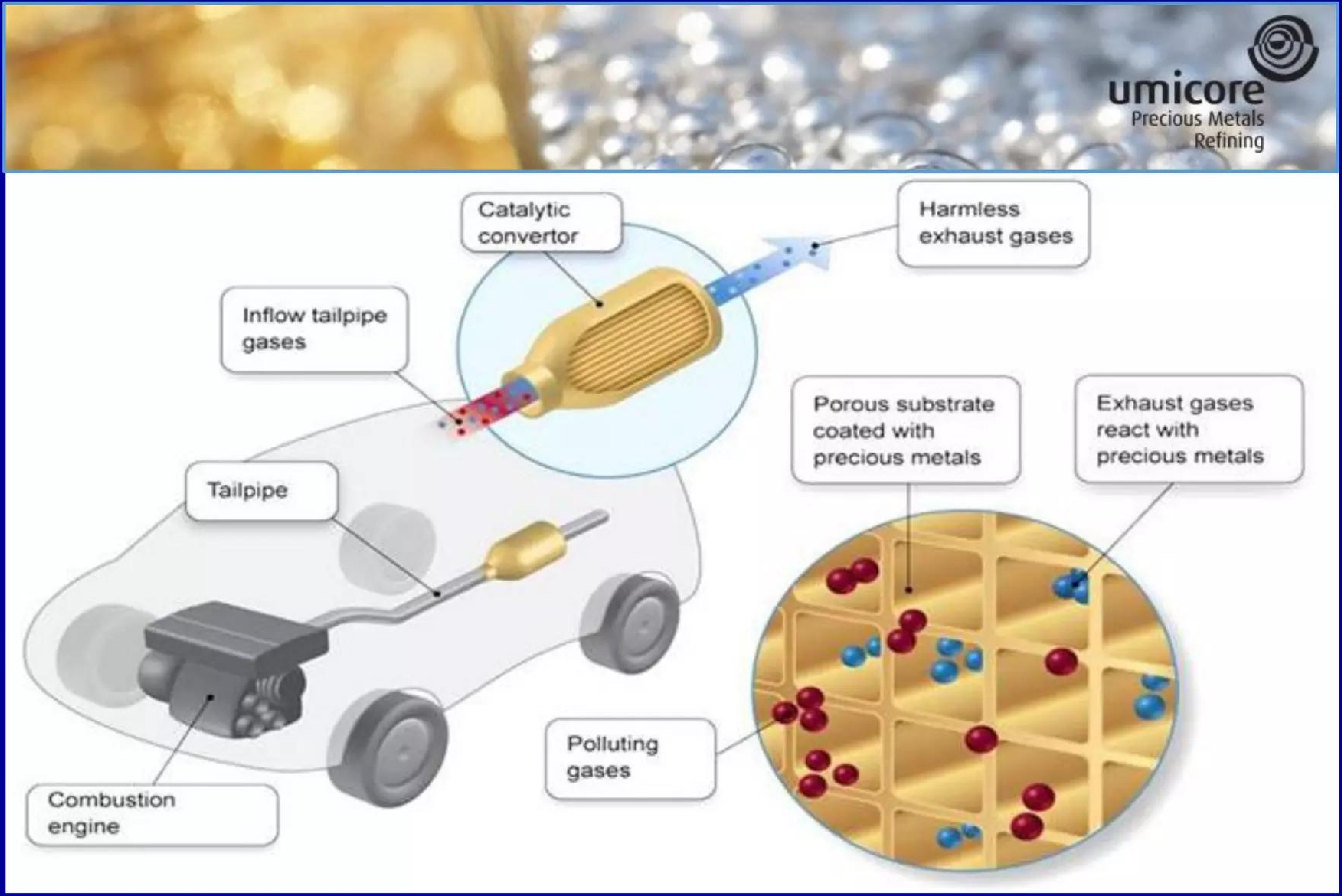
$2CO + O_2 \rightarrow 2CO_2$ Pd mainly used for oxidation catalyst

- ✓ Unburned hydrocarbons (C_xH_{2x+2}) are combusted by reaction with Oxygen into Carbon dioxide and water:

$C_xH_{2x+2} + [(3x+1)/2]O_2 \rightarrow xCO_2 + (x+1)H_2O$ Pt and/or Rh used as oxidation catalyst

Schematic overview of catalytic converter in exhaust system

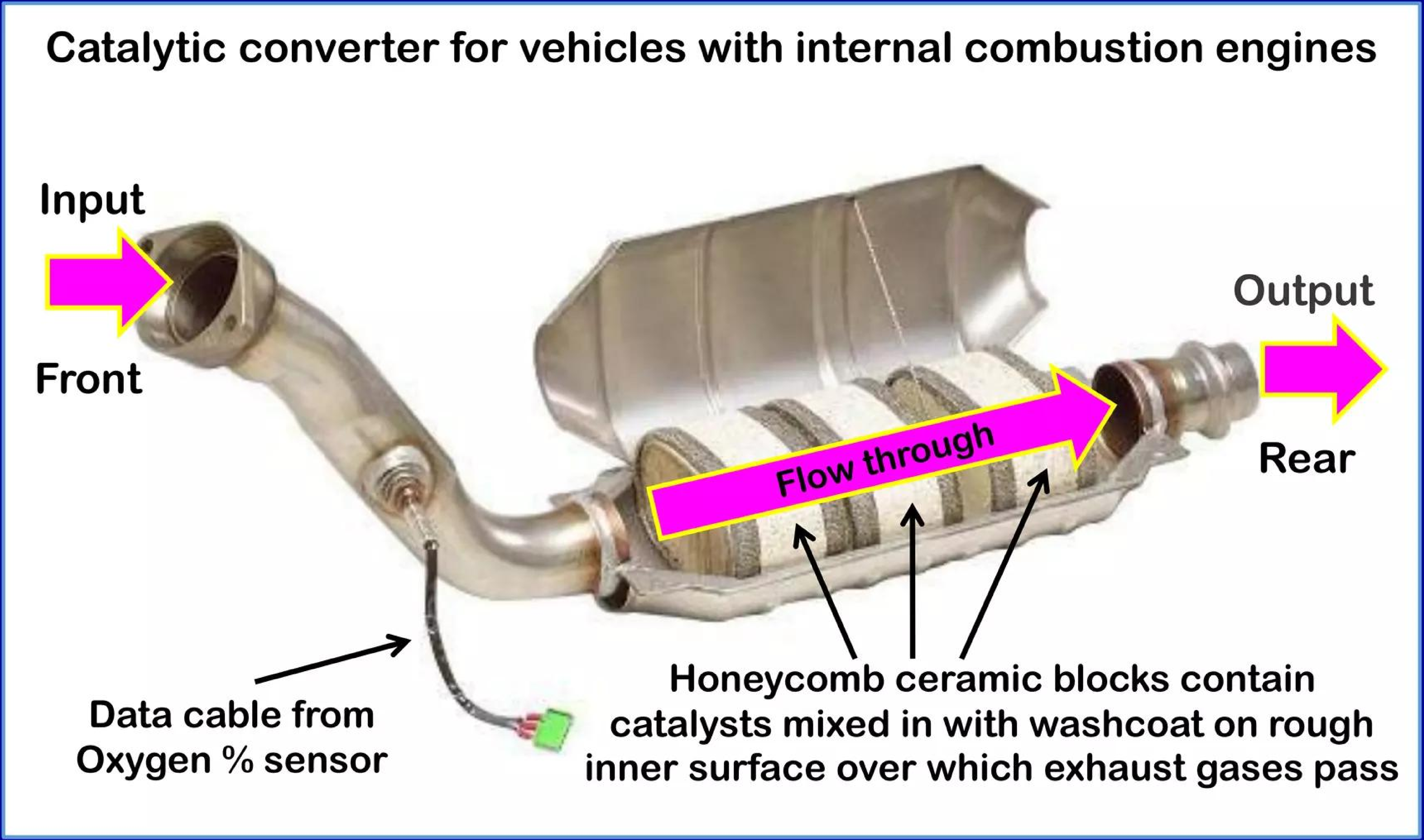
Precious metal catalysts in converter render exhaust emissions harmless



Picture of an actual catalytic converter for a passenger car

Outer case opened to show honeycombs containing Pt, Pd, Rh catalysts

Exhaust gases come directly from IC engine into front and pass through converter

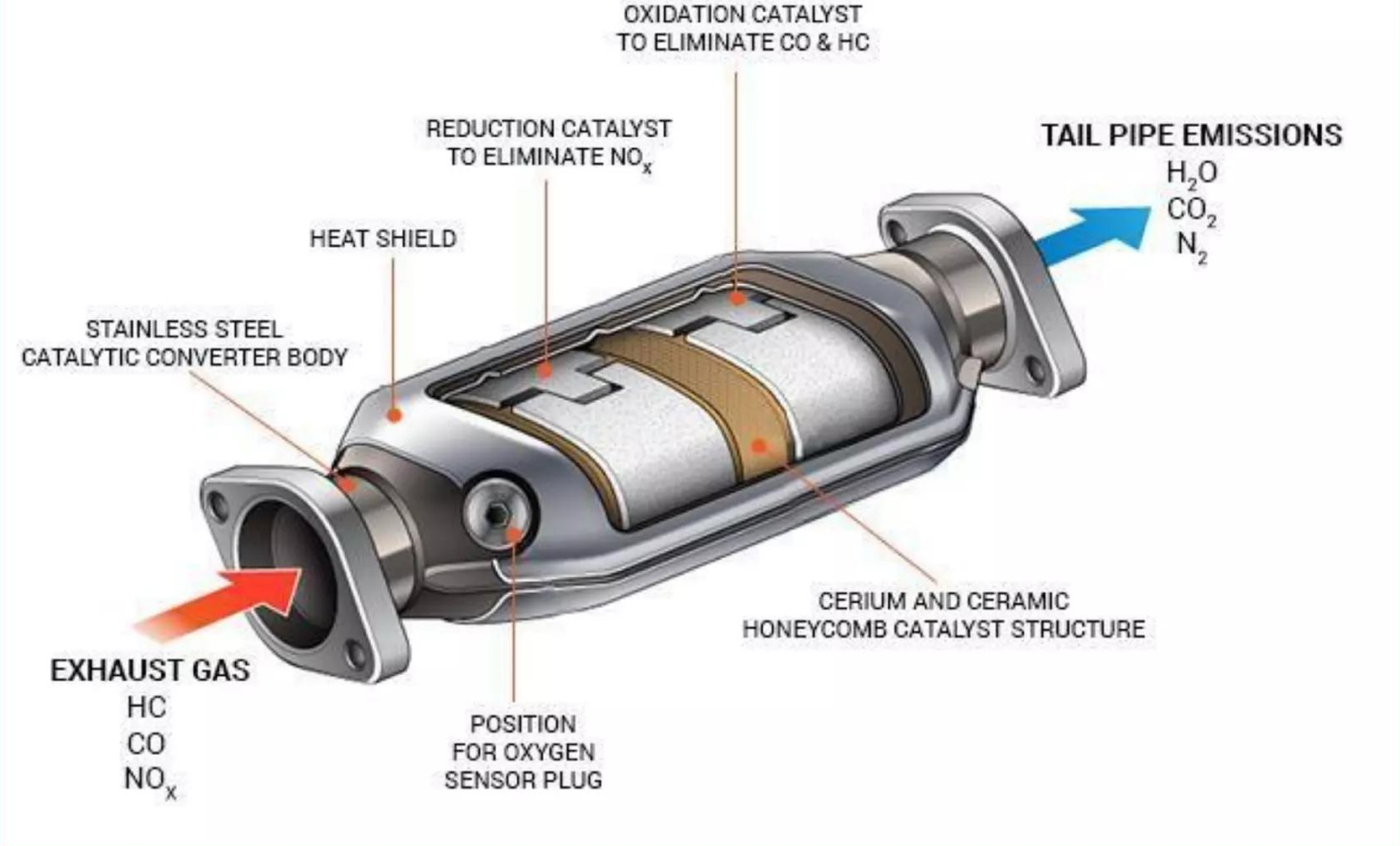


Schematic overview of components in catalytic converters

Converter body & honeycomb can be resonant electromagnetic cavities

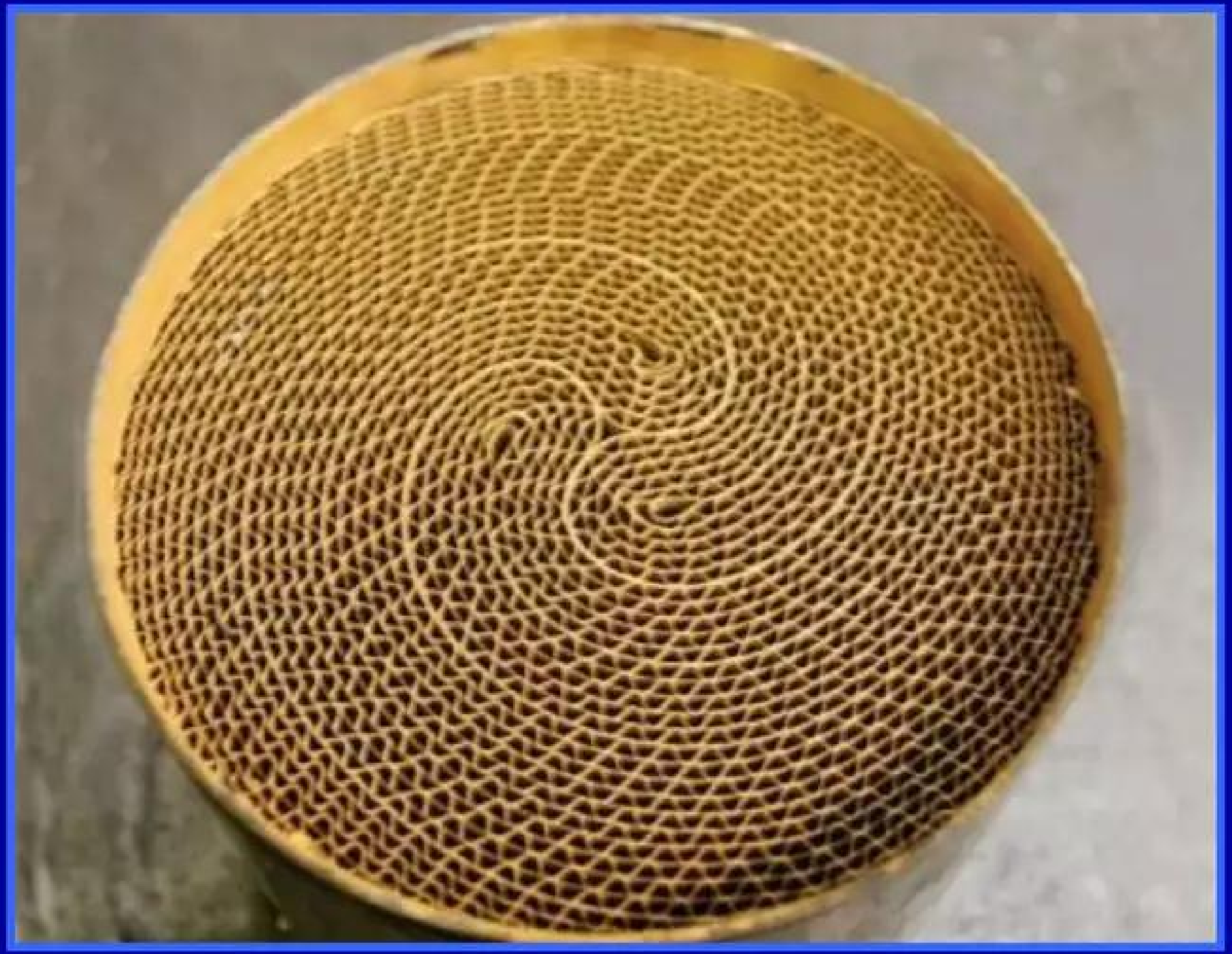
Infrared cavity radiation created by heating provides E-M input energy for LENRs

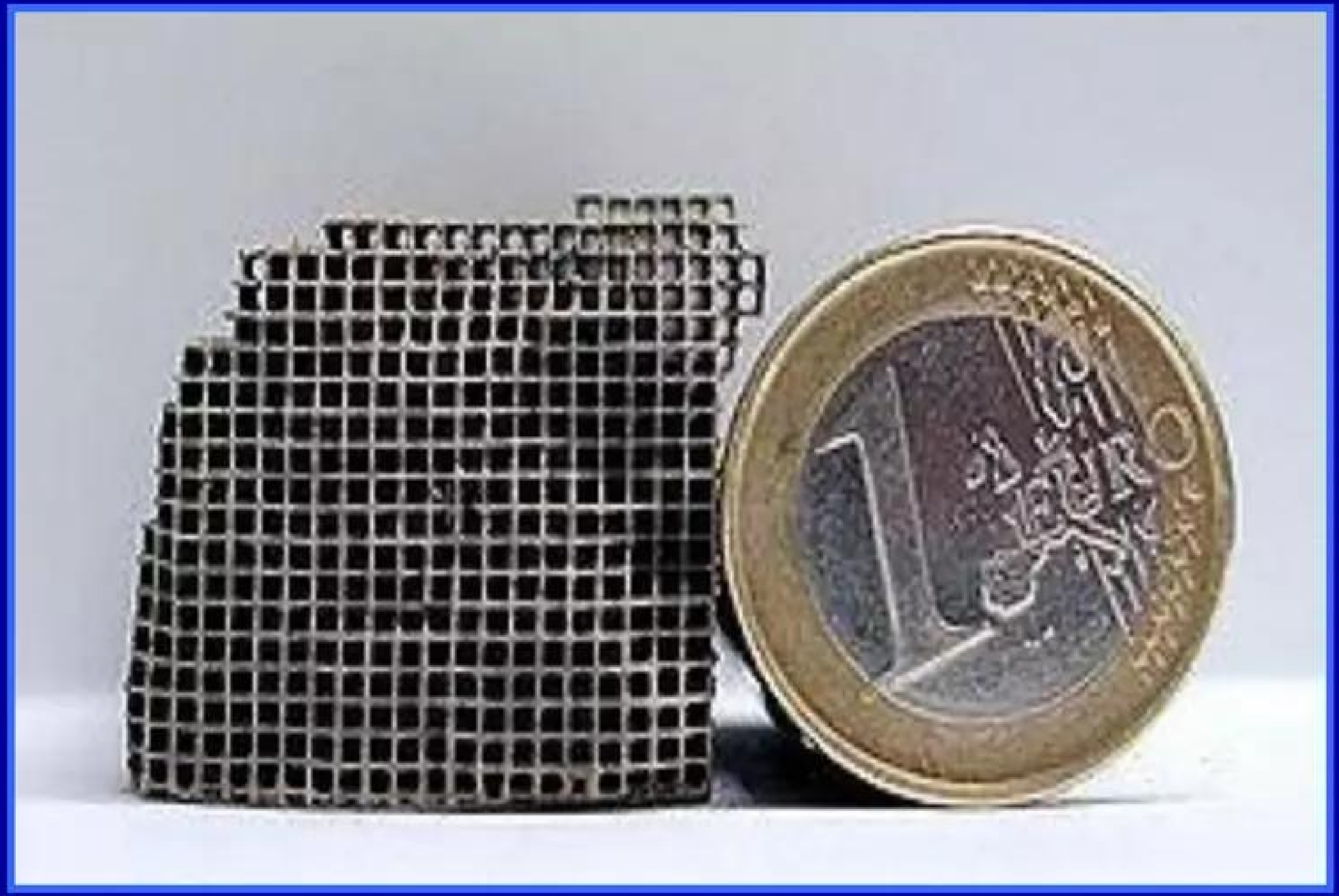
Exhaust gases heat-up converter to operating temperature of 650 - 870 ºC



Honeycombs can be made of metal or ceramic materials

Examples of spiral steel honeycomb on left and square ceramic on right





Top: cross-section of BMW honeycomb

Bottom: interior at operating temperature

Top: broken piece of ceramic honeycomb

Bottom: melted honeycomb post thermal runaway

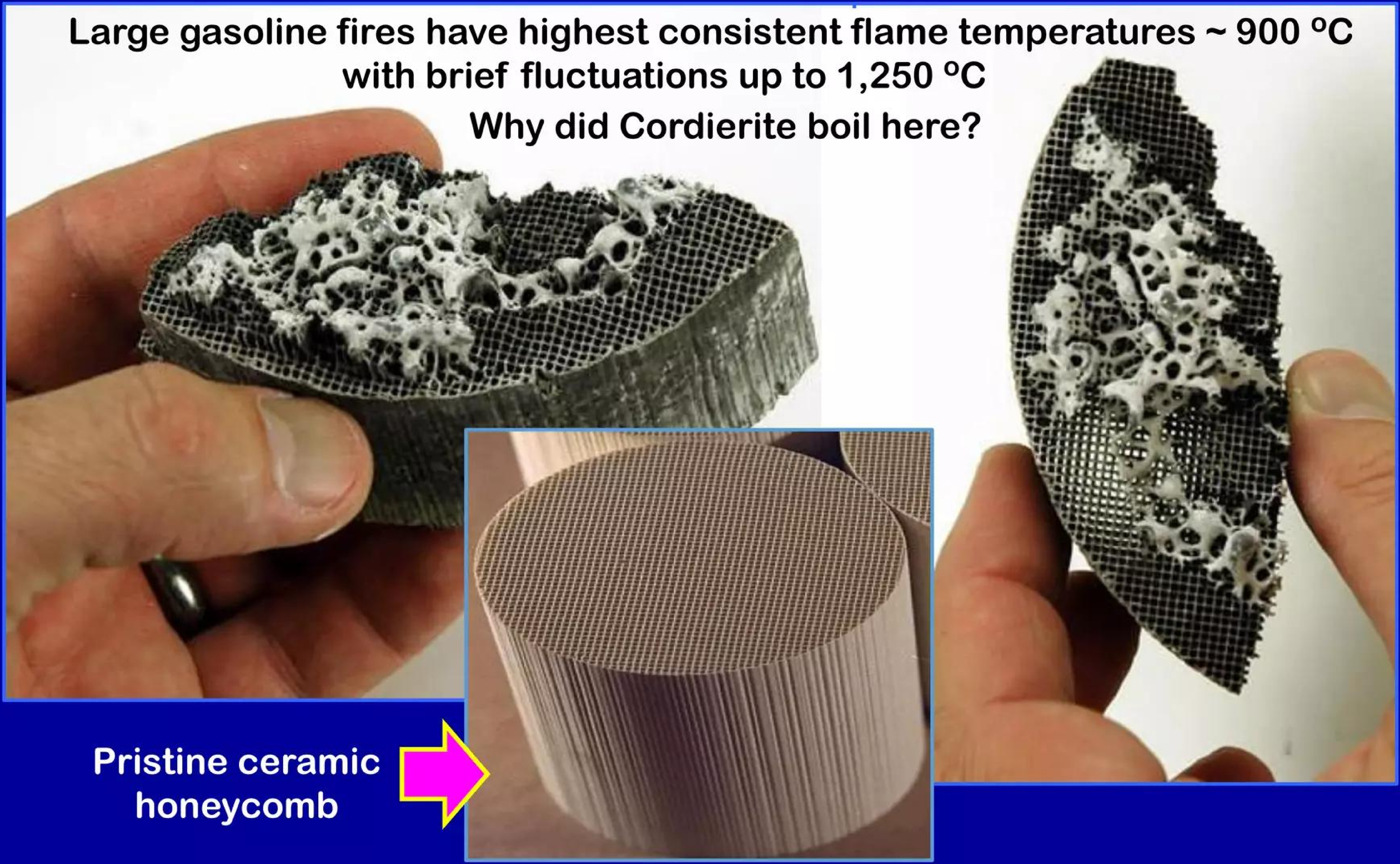
12/12/2008

Ceramic honeycomb was melted by internal thermal runaway

Melted ceramic's morphology suggests possible heating to boiling point

Cordierite ceramic melting point is 1,460 ºC; boiling point higher at >2,000 ºC

Cordierite = $Al_4Mg_2Si_5O_{18}$



Large gasoline fires have highest consistent flame temperatures ~ 900 ºC with brief fluctuations up to 1,250 ºC

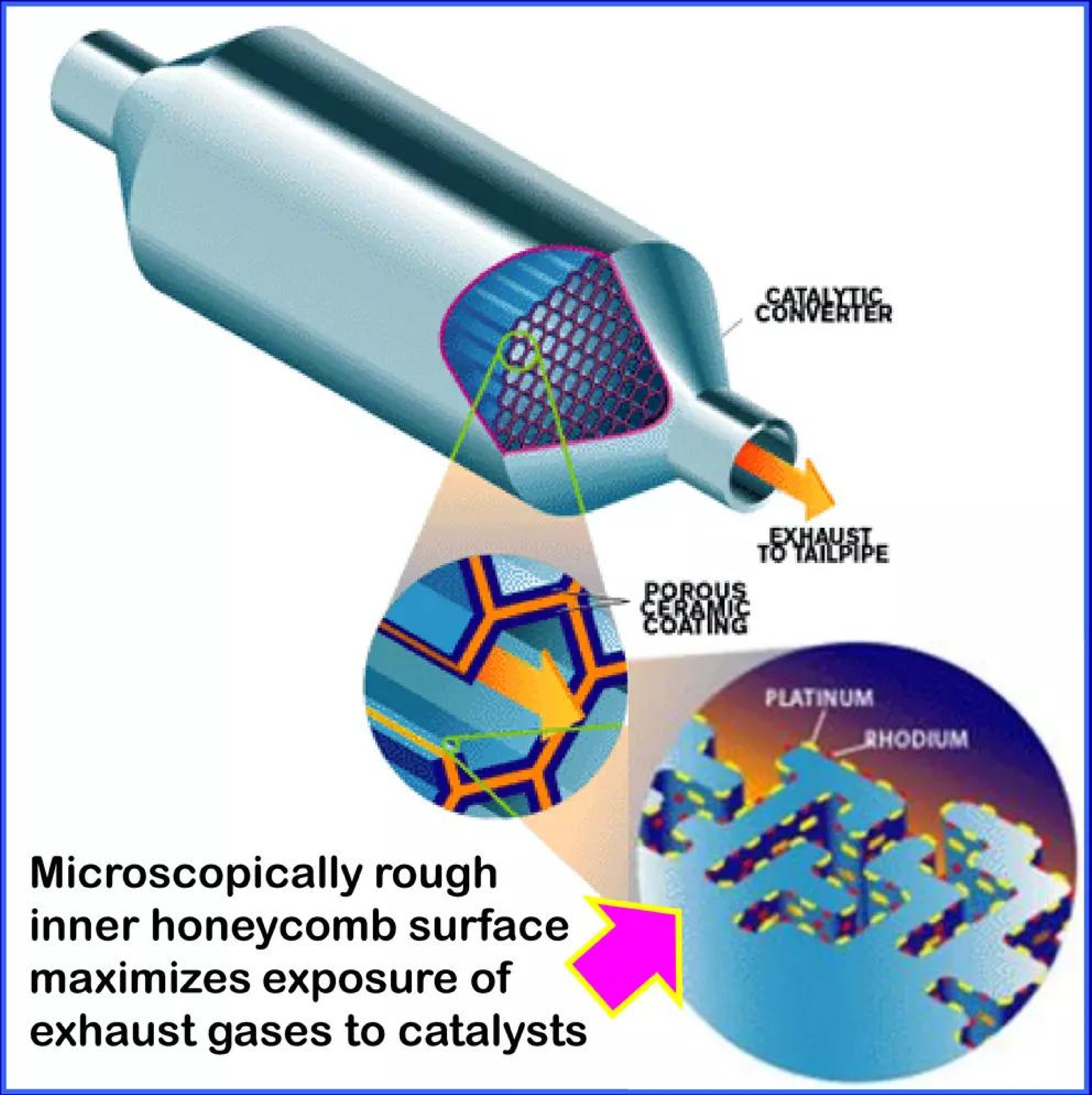
Why did Cordierite boil here?

Pristine ceramic honeycomb

Exploded graphic shows microscopic details of inner surface

Honeycomb's rough surface maximizes area of catalyst exposed to gases

U.S. recyclers of scrapped converters try to recover Pt, Pd, and Rh but not Gold



Microscopically rough inner honeycomb surface maximizes exposure of exhaust gases to catalysts

- ✓ **New catalytic converters in U.S. may contain 3 - 7 grams (gm) of Pt and lesser amounts of Pd and Rh; OEM manufacturers protect their catalyst compositions as key trade secrets**
- ✓ **Recyclers shred metal honeycombs; ceramics are ground into a powder:**

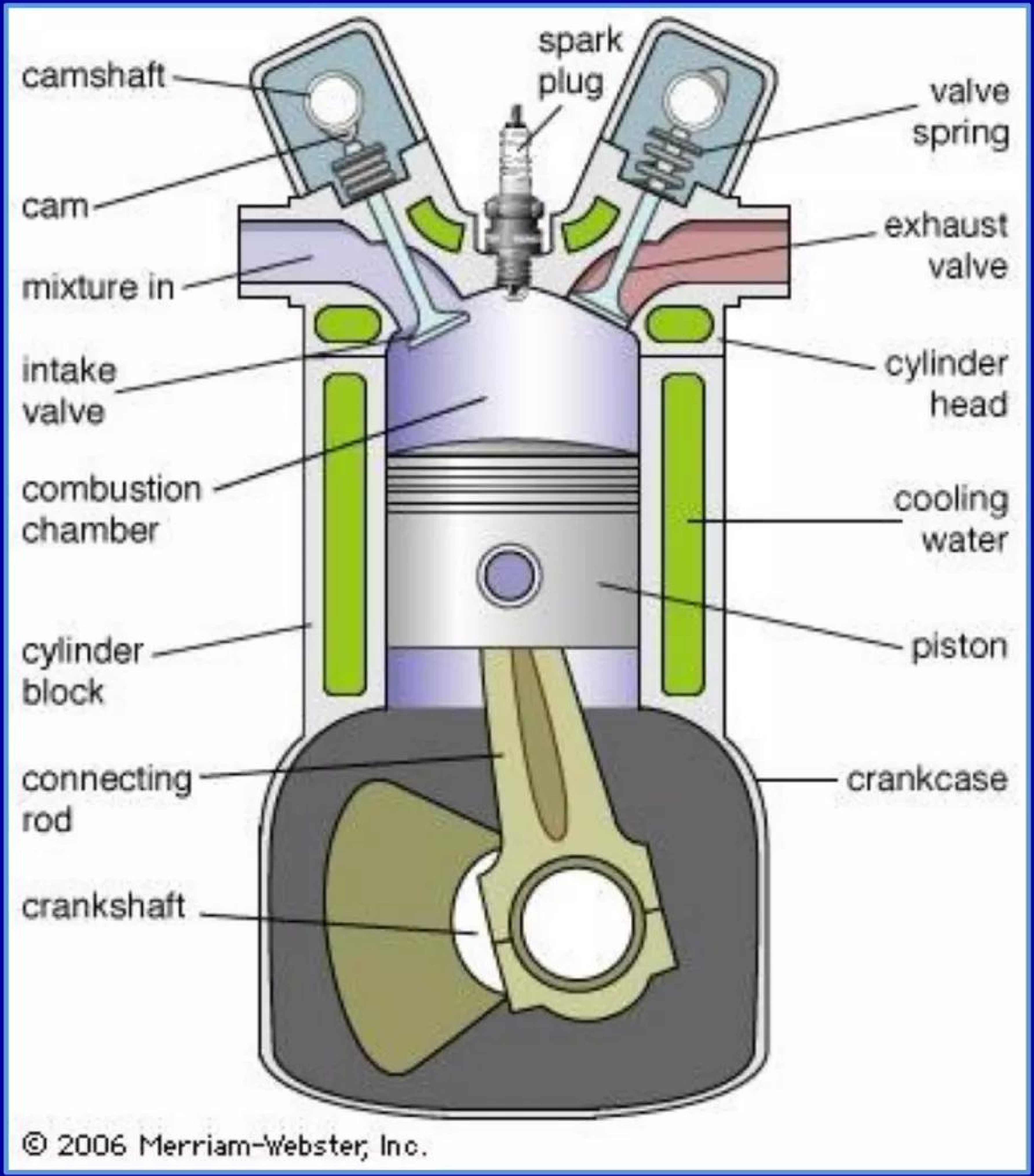
Typically can recover 1- 2 gm of Pt, Pd, and Rh from small cars' catalytic converters; up to 12 - 15 gm of these metals recovered from large trucks

Materials recovered from scrapped converters in U.S. come in 3 grades (amounts in parts per million - ppm) namely, Grade 1: Pt = 1200 ppm, Pd = 200 ppm, Rh = 300 ppm; Grade 2: Pt = 1000, Pd = 200, Rh = 100; Grade 3: Pt = 875, Pd = 250, Rh = 30

Overview of combustion chambers in gasoline IC engines

Metal electrodes create high-voltage electric discharges in gasoline vapor

Conditions that could permit LENRs also present in vehicle combustion chambers



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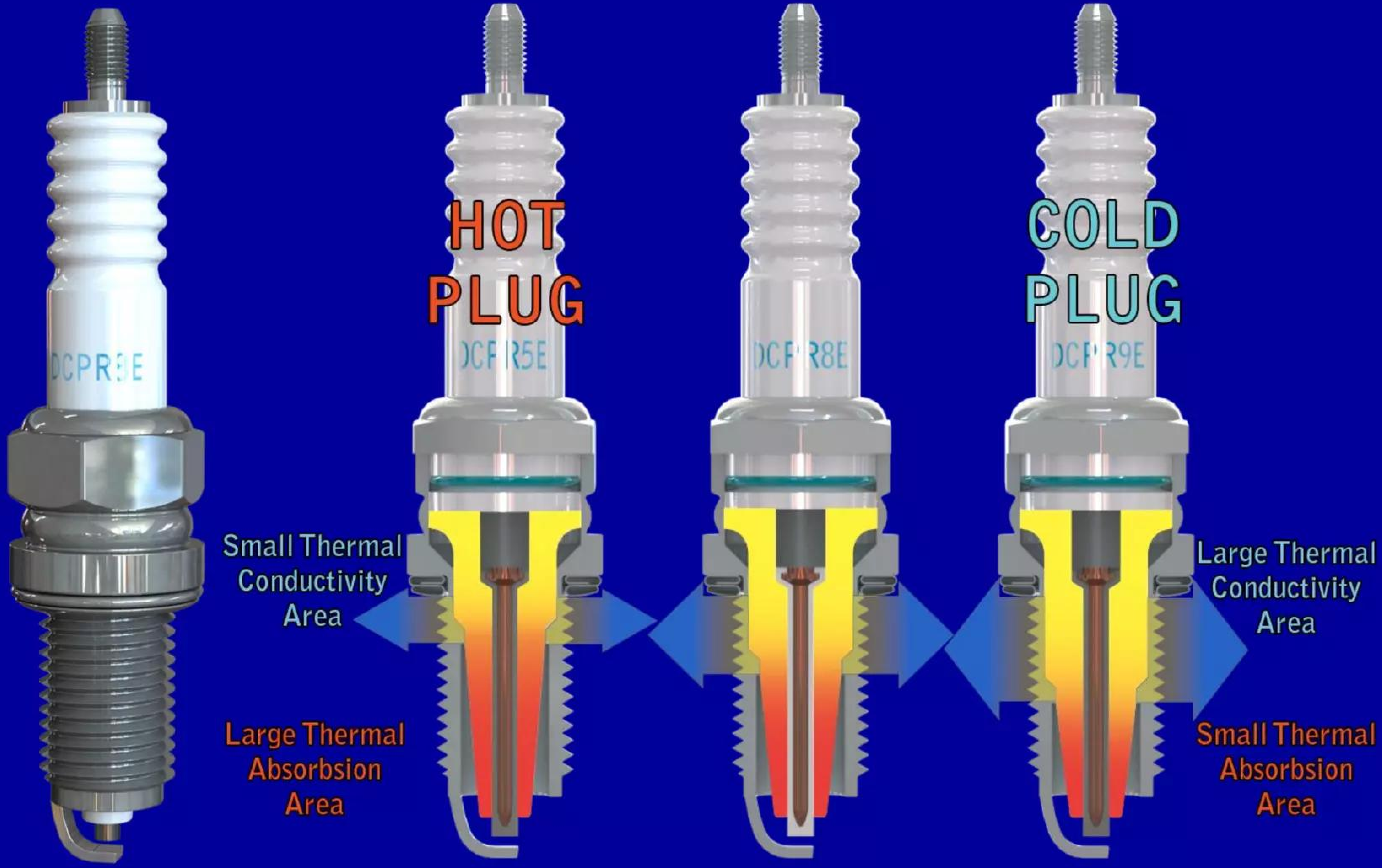
- ✓ In many types of vehicles, varied thin-film coatings, e.g. Tungsten disulfide, Molybdenum disulfide, and Tungsten carbide, are used on inner combustion chamber component surfaces to reduce friction. These materials will slowly wear, break down, shed into exhaust gases, and end-up inside catalytic converters
- ✓ Mechanical abrasion of direct contacting surfaces of pistons, piston rings, valves, and inner walls of combustion chamber will produce nanoparticles that are shed into hot engine exhaust gases which pass quickly into catalytic converters
- ✓ Ablation of center & side electrodes on spark plug by electric discharges will produce varied nanoparticles that are shed into exhaust gases which then pass quickly into catalytic converters

Spark plugs in combustion chambers of gasoline engines

Several hundred different types of spark plugs are on the market today

Application requirements for “hot plug” vs. “cold plug” drive choices of materials



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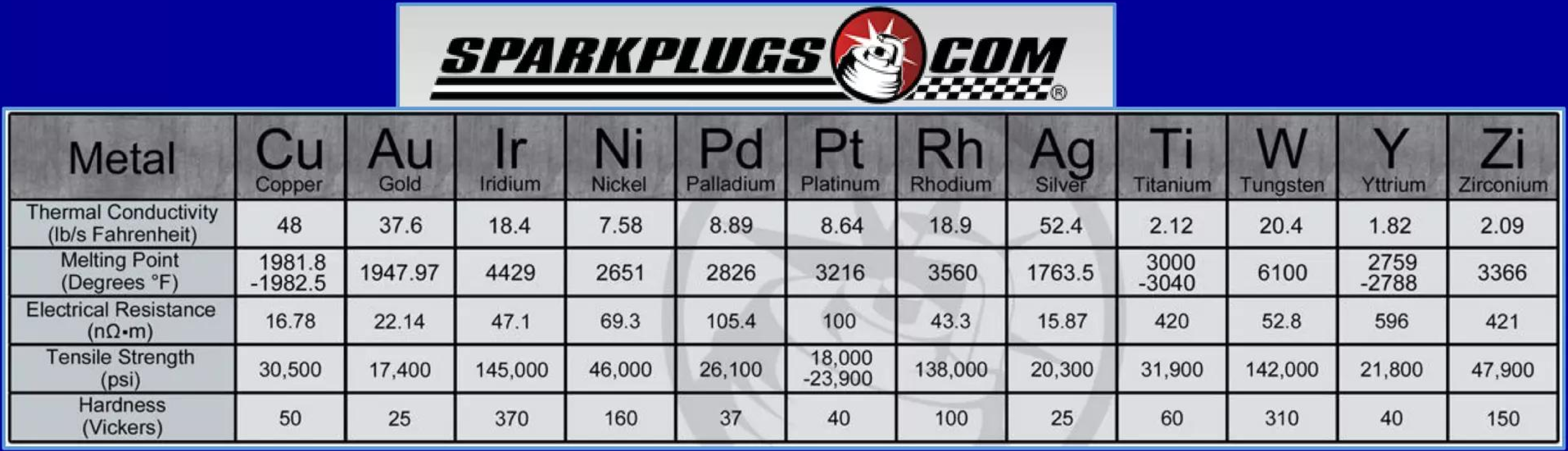


SPARKPLUGS.COM

Metal	Cu Copper	Au Gold	Ir Iridium	Ni Nickel	Pd Palladium	Pt Platinum	Rh Rhodium	Ag Silver	Ti Titanium	W Tungsten	Y Yttrium	Zi Zirconium
Thermal Conductivity (lb/s Fahrenheit)	48	37.6	18.4	7.58	8.89	8.64	18.9	52.4	2.12	20.4	1.82	2.09
Melting Point (Degrees °F)	1981.8 -1982.5	1947.97	4429	2651	2826	3216	3560	1763.5	3000 -3040	6100	2759 -2788	3366
Electrical Resistance (nΩ•m)	16.78	22.14	47.1	69.3	105.4	100	43.3	15.87	420	52.8	596	421
Tensile Strength (psi)	30,500	17,400	145,000	46,000	26,100	18,000 -23,900	138,000	20,300	31,900	142,000	21,800	47,900
Hardness (Vickers)	50	25	370	160	37	40	100	25	60	310	40	150

“The term Heat Range refers to the speed with which a plug can transfer heat from the combustion chamber to the engine head. Whether the plug is to be installed in a boat, lawnmower or race car, it has been found the optimum combustion chamber temperature for gasoline engines is between 500°C - 850°C. Within that range it is cool enough to avoid pre-ignition and plug tip overheating (which can cause engine damage), while still hot enough to burn off combustion deposits that cause fouling.”

Spark plugs in combustion chambers of gasoline engines

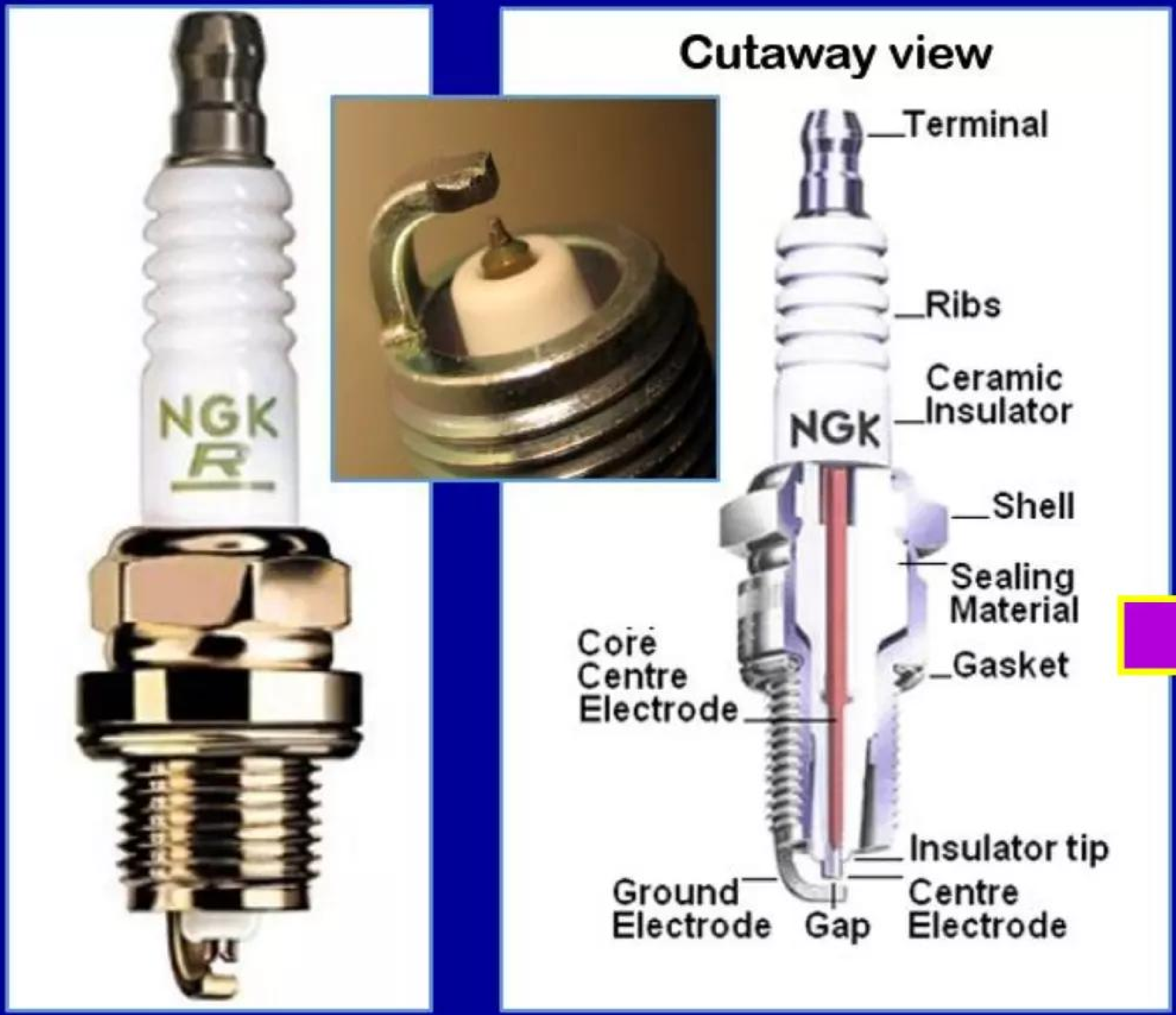
Electric discharges can provide energy for LENRs if Hydrogen is present

Specific metals used in spark plug electrodes vary with types of engine and usage

Depending on price-point and end-user application electrodes may commonly contain:

Nickel alloys, Copper, Platinum, Tungsten, Iridium, Yttrium; rarely Gold, Silver, or Palladium

Overview of spark plugs for gasoline engines

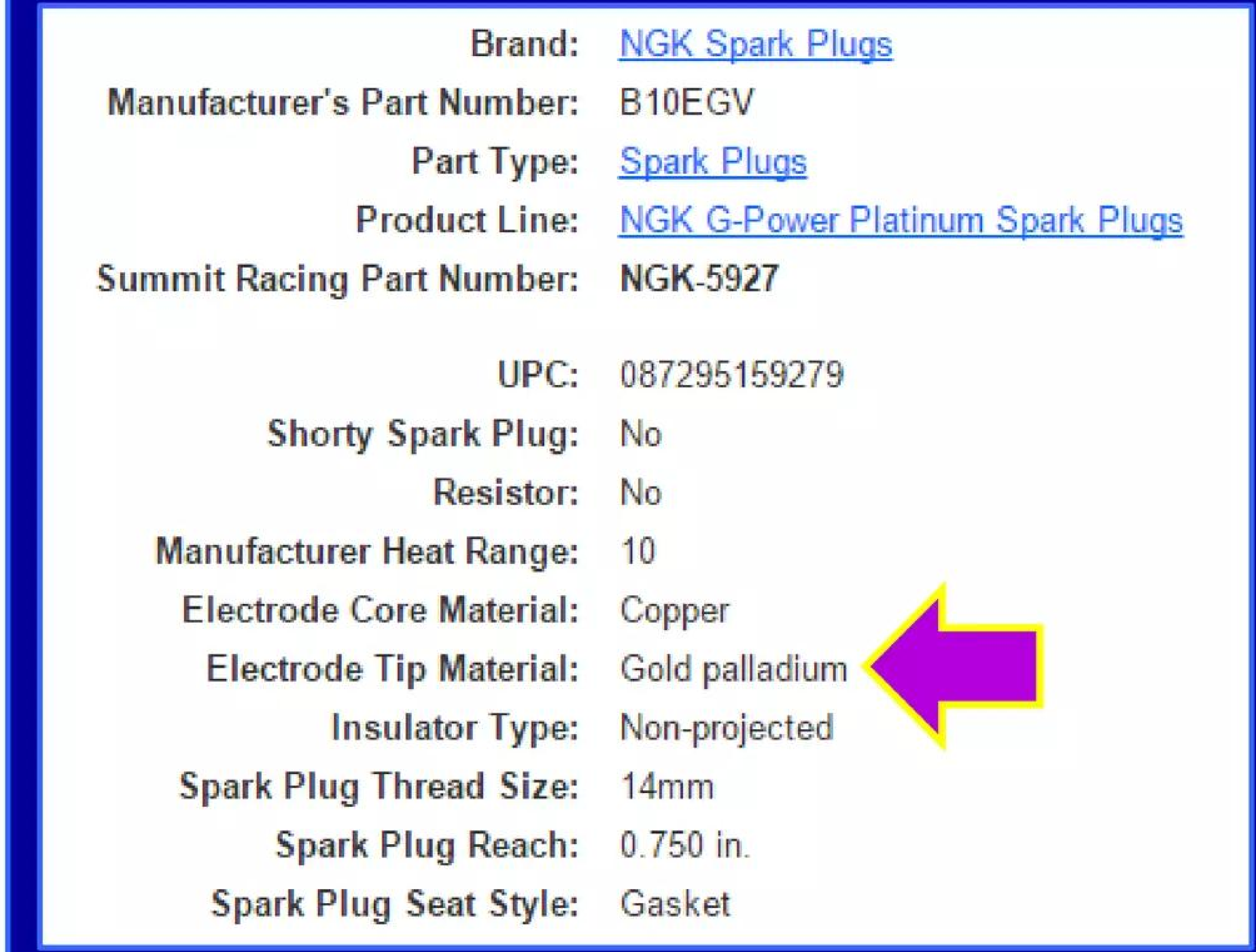


- ✓ Metals used in center and side electrodes of spark plugs vary greatly and depend upon engine type, design lifetime, and typical range of operating temperatures
- ✓ Typical operating voltages range from 12,000 to 45,000 V but can get as high as 45,000 V; avg. operating temperatures across entire spark plug ranges from 500 - 800 ºC but temperature of hot plasma in spark channel can briefly touch 20,000 ºC
- ✓ Prices of noble metals and target application requirements have strong impact on materials used; top-grade spark plugs can often last from 100,000 to 120,000 miles

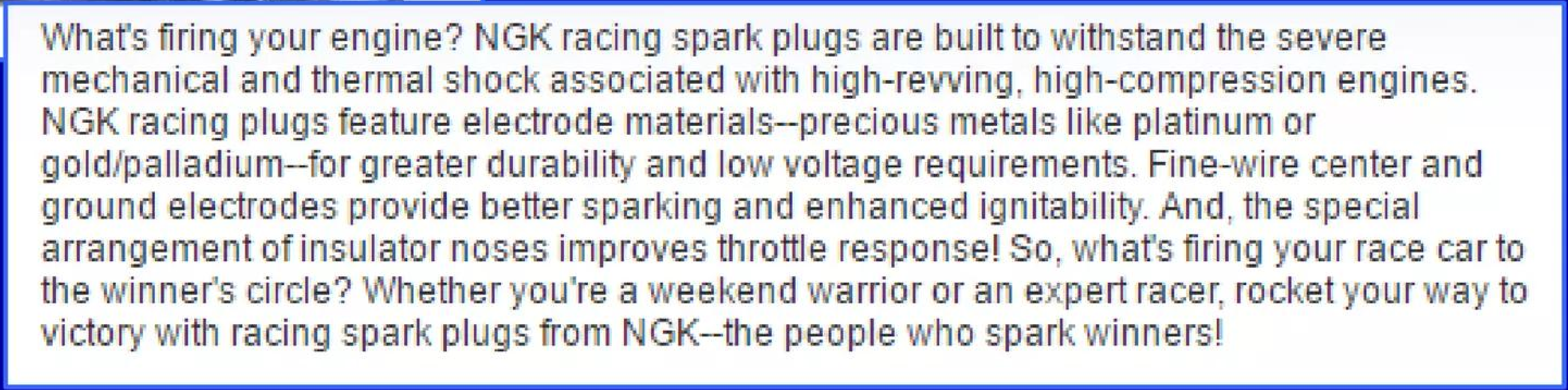
Specialized very expensive racing sparkplugs can use Gold

Gold-Palladium alloy: high-enough melting point for use in electrode tip

Can cost US$ 20.00 to $33.00 each



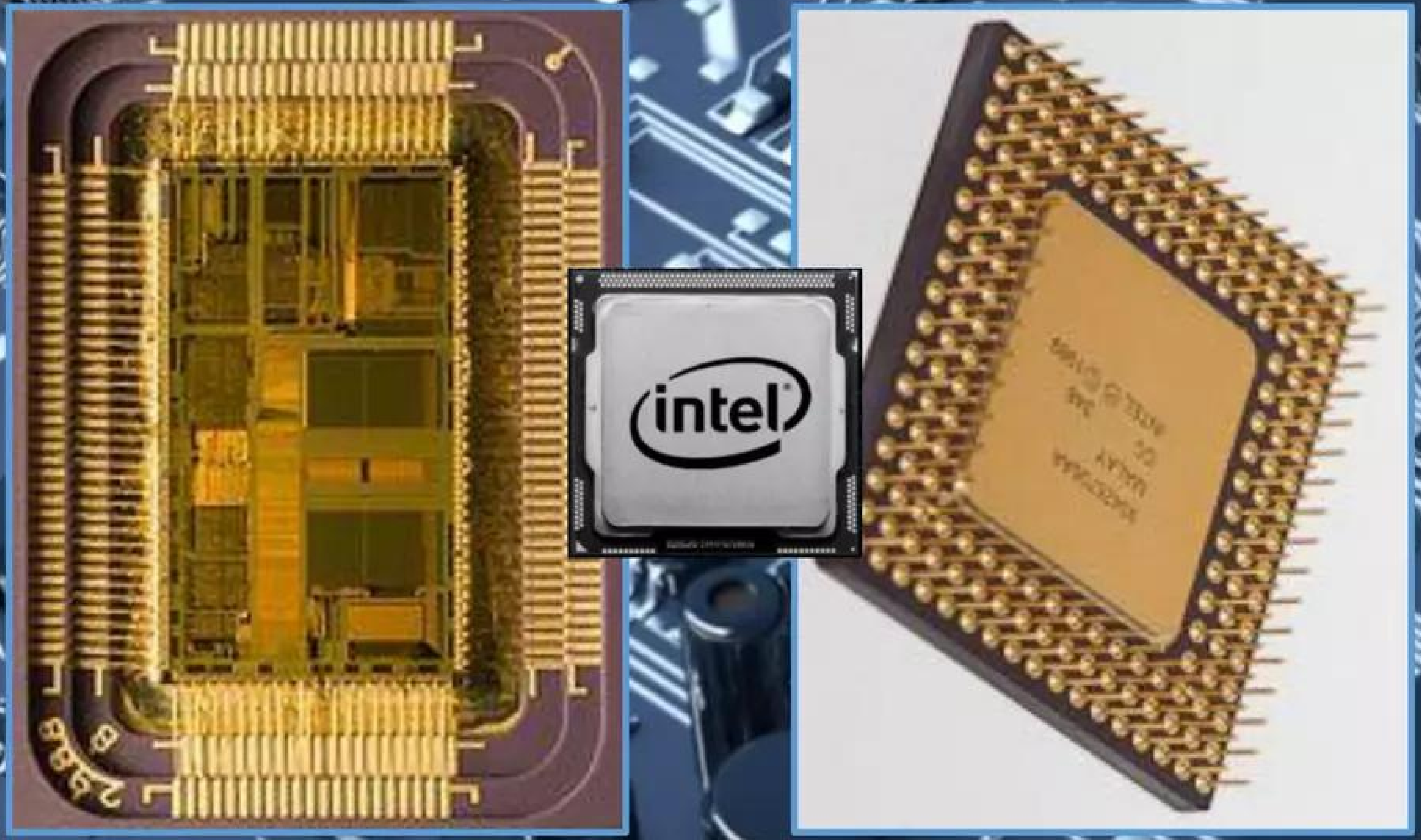
Brand:	NGK Spark Plugs
Manufacturer's Part Number:	B10EGV
Part Type:	Spark Plugs
Product Line:	NGK G-Power Platinum Spark Plugs
Summit Racing Part Number:	NGK-5927
UPC:	087295159279
Shorty Spark Plug:	No
Resistor:	No
Manufacturer Heat Range:	10
Electrode Core Material:	Copper
Electrode Tip Material:	Gold palladium
Insulator Type:	Non-projected
Spark Plug Thread Size:	14mm
Spark Plug Reach:	0.750 in.
Spark Plug Seat Style:	Gasket



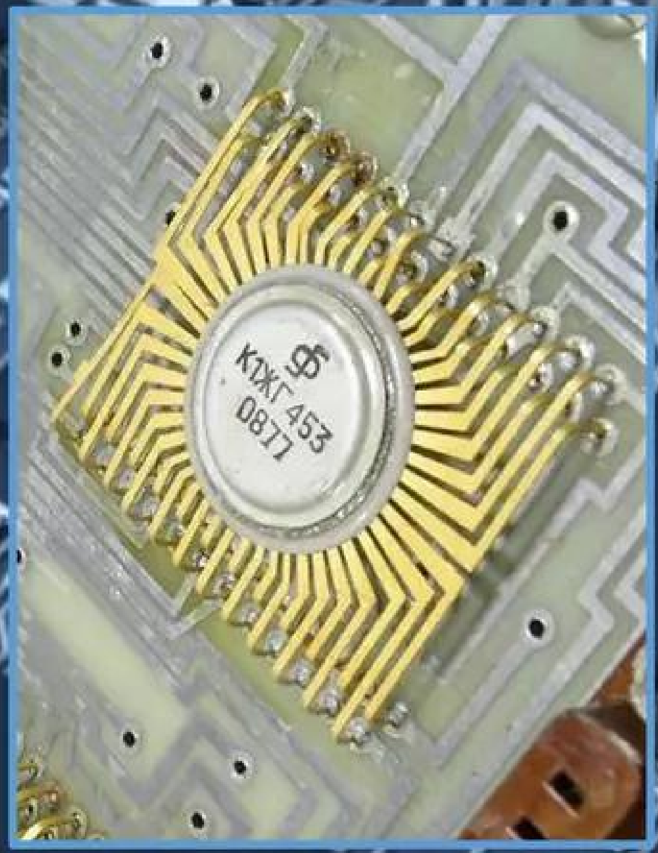
What's firing your engine? NGK racing spark plugs are built to withstand the severe mechanical and thermal shock associated with high-revving, high-compression engines. NGK racing plugs feature electrode materials--precious metals like platinum or gold/palladium--for greater durability and low voltage requirements. Fine-wire center and ground electrodes provide better sparking and enhanced ignitability. And, the special arrangement of insulator noses improves throttle response! So, what's firing your race car to the winner's circle? Whether you're a weekend warrior or an expert racer, rocket your way to victory with racing spark plugs from NGK--the people who spark winners!

Gold in vehicle electronics inside packaging and enclosures

Intel 486 chip (2007) with Gold plated connectors on bare IC die (left) and on pins (right) from plastic chip package



Chip with Gold plated connectors on PCB



Gold plated edge connectors on motherboard PCB (printed circuit board)

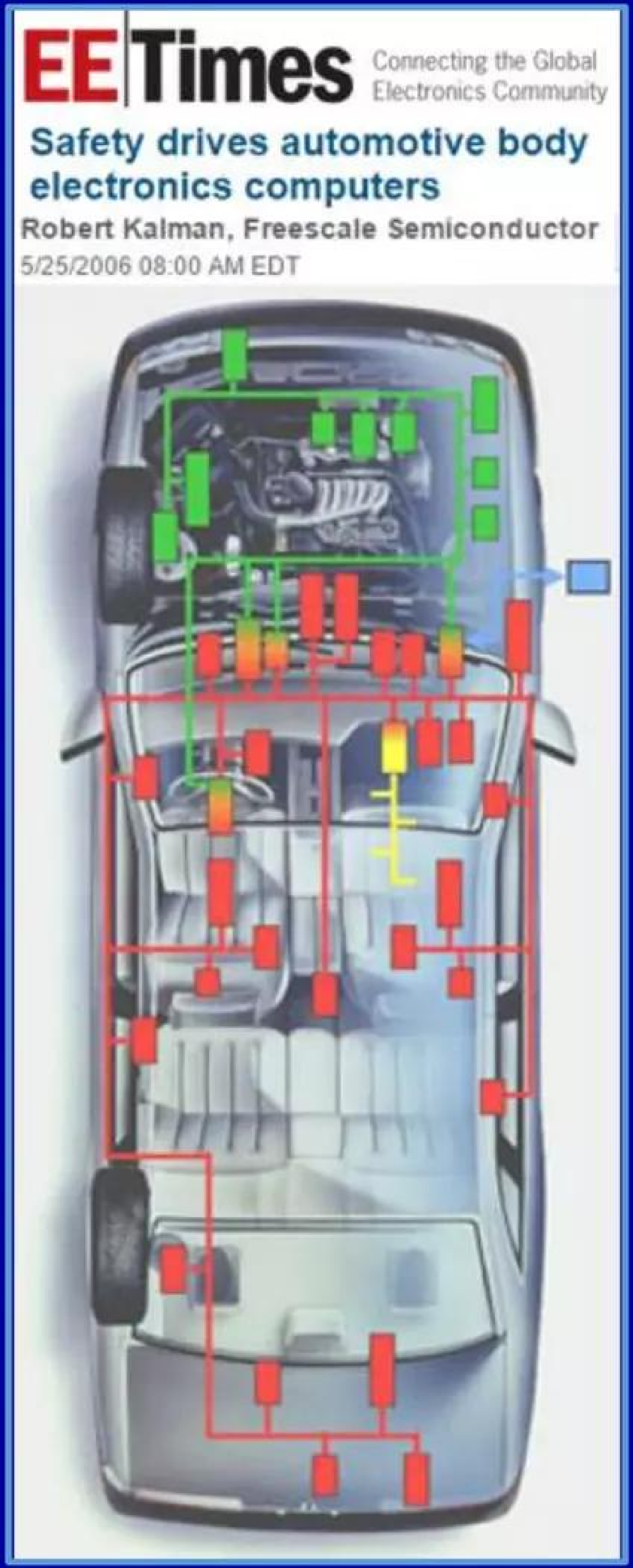
Cinch Connectors Ltd. automotive product for vehicle electronics: heavy-duty modular integrated connector enclosure

Electronics crucial in control systems of modern vehicles

Consequently are protected from mechanical damage and environment

Chips shielded in plastic packaging and located in very robust sealed enclosures

- ✓ *EE-Times* graphic at right shows how today's cars utilize many different computerized modules distributed across many different locations throughout entire motor vehicle
- ✓ In cars and trucks, high-speed CAN bus networking is used to interconnect fast acting real-time electronic systems such as engine and power train controls, active suspensions, as well as (in certain car models) complex collection of sensors and actuators that are involved with very new autonomous vehicle driving capabilities
- ✓ Functional integrity and predictable functioning of Gold-plated electrical connectors used in such electronic systems are crucial for motor vehicle safety and reliable operation. They must be protected from any mechanical damage such as abrasion or ablation, water, excessive heat, and open exposure to ambient atmosphere. This is achieved with chip packaging, placing all PCB boards in robust enclosures, and outdoor-grade network cabling
- ✓ Given the above, it is unlikely that Gold will escape from vehicle electronic systems if they are structurally intact



EE Times Connecting the Global Electronics Community

Safety drives automotive body electronics computers

Robert Kalman, Freescale Semiconductor

5/25/2006 08:00 AM EDT

Platinum, Palladium, Rhodium dominant catalysts since 1975

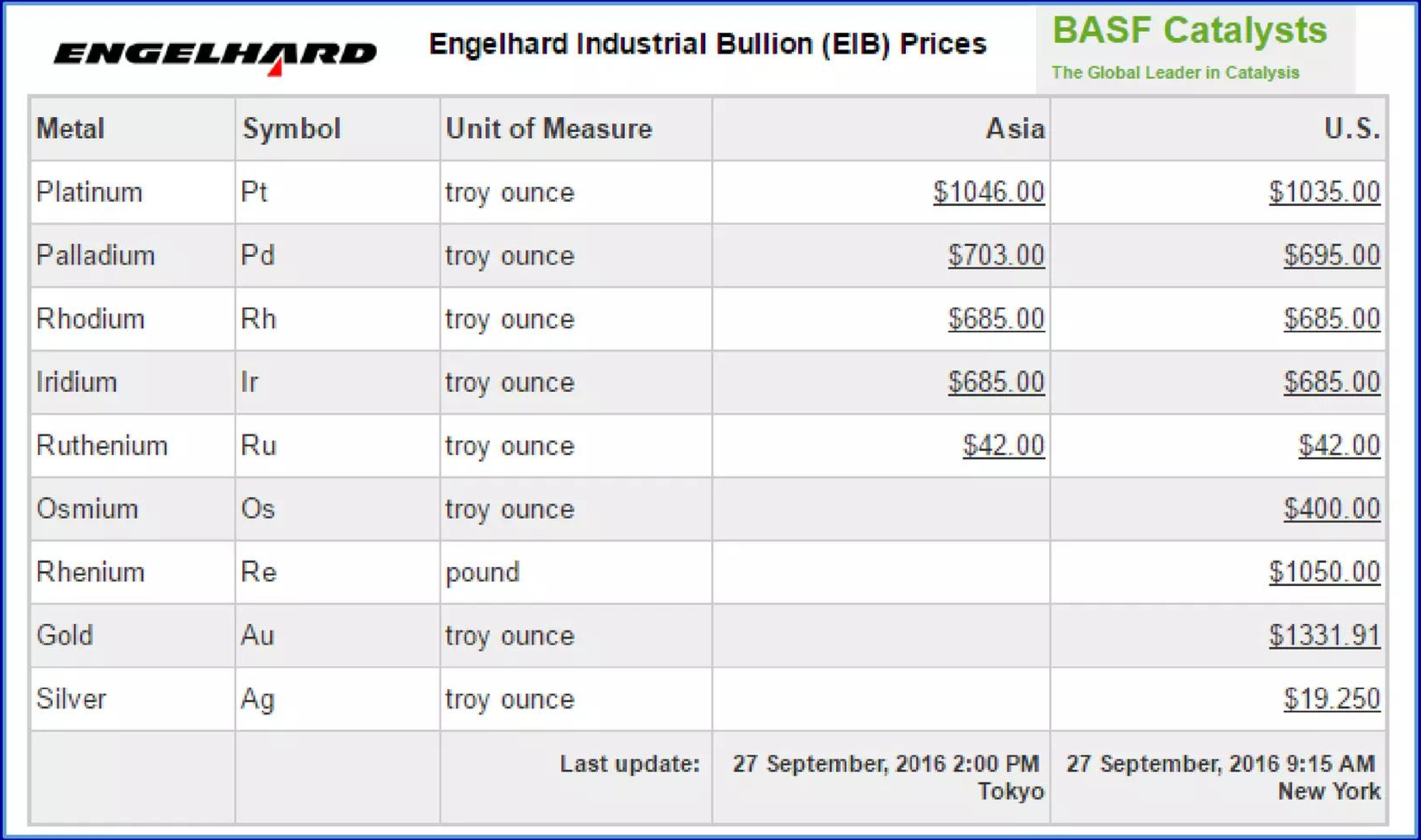
Why is Gold found in nanoparticulates emitted from vehicular tailpipes?

- ✓ Platinum, Palladium, and Rhodium have overwhelmingly comprised principal catalysts used worldwide in catalytic converters since they were first legally mandated for use in motor vehicles in mid-1970s in U.S., and later elsewhere
- ✓ Well-known that catalysts embedded in washcoats that cover interior surfaces of honeycombs inside catalytic converters will slowly ablate over time, enter exhaust gases as nanoparticles, and then be deposited in local environments
- ✓ As we noted, environmental scientists have been measuring elemental and isotopic compositions of particles and gases emitted from vehicle exhausts. Samples have been collected directly from urban and rural: vehicle exhausts on highways and in laboratories; local air; dusts accumulated on and in vicinity of traveled roadways; and from tissues of plants growing very close to highways
- ✓ Given the above, if local environments around roads were sampled and then selectively analyzed for presence of specific elements and stable isotopes, one would assume finding tiny amounts of Platinum, Palladium, and Rhodium having normal isotopic abundances; relatively little or no Gold should ever be observed
- ✓ Those assumptions are wrong: surprising amounts of Gold have been detected. Other oddities have been reported in such samples, such as: excess radiogenic Osmium; anomalous isotopic shifts in Platinum and Palladium; as well as heavy-isotope enrichment of Carbon, Oxygen, and Nitrogen moieties in exhaust gases

Current market price: metals used or present in converters

Gold is most expensive metal at $1,322 Troy ounce; Pt second at $1,035

Palladium = $695; Rhodium = $685; Iridium = $685; Osmium = $400; Silver = $19



ENGELHARD

Engelhard Industrial Bullion (EIB) Prices

BASF Catalysts

The Global Leader in Catalysis

Metal	Symbol	Unit of Measure	Asia	U.S.
Platinum	Pt	troy ounce	$1046.00	$1035.00
Palladium	Pd	troy ounce	$703.00	$695.00
Rhodium	Rh	troy ounce	$685.00	$685.00
Iridium	Ir	troy ounce	$685.00	$685.00
Ruthenium	Ru	troy ounce	$42.00	$42.00
Osmium	Os	troy ounce		$400.00
Rhenium	Re	pound		$1050.00
Gold	Au	troy ounce		$1331.91
Silver	Ag	troy ounce		$19.250
		Last update:	27 September, 2016 2:00 PM Tokyo	27 September, 2016 9:15 AM New York

https://apps.catalysts.basf.com/apps/eibprices/mp/

Gold (Au) very rarely used as catalyst in vehicle converters

Still minimal usage though lean-burning diesels are potential application

Analysis of elements emitted from converters shows anomalous amounts of Gold

- ✓ While there has been recent academic discussion of using Gold catalyst in the converters of lean-burning diesel engines, there still appears to be little or no use of Gold in that application. Thus, worldwide since 1975 very little Gold has ever been knowingly used during manufacturing of vehicle catalytic converters
- ✓ Present Gold price of $1,322 per Troy ounce is ~29% more expensive than price of Platinum, 92% higher than Palladium, and 95% higher than Rhodium. These relative prices of alternative, somewhat substitutable catalysts suggest that, if such pricing continues, use of Gold in converters will be strongly discouraged
- ✓ Limited instances of refereed published data reveal that since 1975 in the U.S. and Europe, and from 1990s in China and India, enhanced local abundances of Gold (significantly larger than normal crustal values) have been observed in and around traveled roads. Since Gold is little-used in catalytic converters, such odd enhancements are not readily explainable as being impurities in catalyst metals
- ✓ Largest industrial usage of Gold is in the electronics industry where it is used in electrical connectors found in printed circuit boards and many different kinds of semiconductor chips. However, these connectors are normally located inside very tight packaging and are not subjected to abrasion or ablation, so vehicular electronics are unlikely to be source of anomalous Gold found around highways

Numerical values of isotopic shifts are usually small numbers

Parts-per-thousand or δ notation therefore used to express such values

Chemical isotopic fractionation processes typically only cause per mil shifts

Actual magnitude of isotopic fractionation resulting from kinetic and equilibrium chemical fractionation processes typically represents a very small numerical value.

Thus, + or - enrichments are usually reported in "per mil" (‰ , parts per thousand).

Shifts in stable isotope ratios are commonly expressed in δ notation:

$$\delta = \left(\frac{R_{sample} - R_{standard}}{R_{standard}} \right) \times 1000$$

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

e.g.,

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

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

Early report of Gold emitted from vehicle exhausts (2003)

Pt, Pd, and Au observed in needles of urban Pine trees in Palermo, Italy

Pt - Pd highly cross-correlated ($R^2 = 0.74$) indicating a common origin from traffic

"Occurrence of Platinum, Palladium, and Gold in Pine needles of
Pinus pinea L. from the city of Palermo (Italy)"
G. Dongarra et al., *Applied Geochemistry* 18 pp. 109 - 116 (2003)
http://www.sciencedirect.com/science/article/pii/S0883292702000513

https://www.academia.edu/6265443/Occurrence_of_platinum_palladium_and_gold_in_pine_needles_of_Pinus_pinea_L._from_the_city_of_Palermo_Italy?auto=download

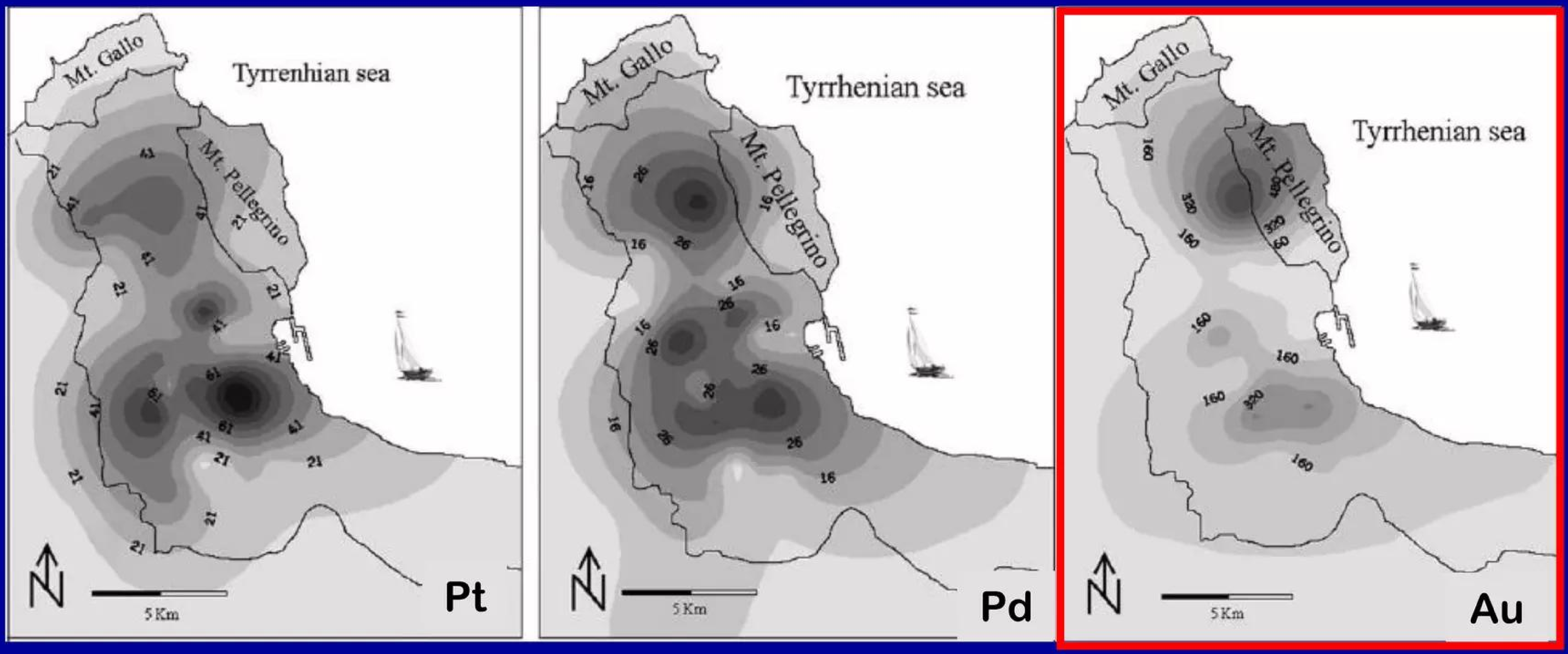
- ✓ Analyzed selected elements present in 40 samples of pine needles from trees growing in and near city of Palermo, Italy; found Pt, Pd, and Au, among others
- ✓ Amounts of Pt, Pd, and Pd found in living pine needles were substantially higher than normal earthly crustal abundances (about two orders of magnitude higher)
- ✓ Abundances of Pt and Pd at given sampling location were highly correlated with each other ($R^2 = 0.74$); this is consistent with common origin in vehicle exhausts
- ✓ Abundances of Pt, Pd, Au much higher *inside* city vs. at well beyond its borders; traffic density much higher inside city; this is also consistent with a traffic origin
- ✓ Most surprising and anomalous feature in Dongarra *et al.*'s reported data is that the observed abundance of Gold is often *higher* than Pt and Pd; quite puzzling

Early report of Gold emitted from vehicle exhausts (2003)

Pt, Pd, and Au observed in needles of urban Pine trees in Palermo, Italy

Abundance data in Figure 5 from G. Dongarra et al., *Applied Geochemistry* (2003)

Fig. 5. “Areal distribution maps of Pt, Pd, and Au chemical concentrations (mg/kg) in pine needles from the city of Palermo (Italy) … solid lines delimit the urban agglomeration.”



Platinum (Pt) Palladium (Pd) Gold (Au)

Once emitted from exhaust into environment, physical-chemical-biological transport mechanisms as well as mobility can vary greatly between each of these precious metals

Early report of Gold emitted from vehicle exhausts (2003)

Pt, Pd, and Au observed in needles of urban Pine trees in Palermo, Italy

Abundance data in Table 1 from G. Dongarra et al., *Applied Geochemistry* (2003)

Table 1. from G. Dongarra et al. (2003)

Note especially that 1 μg/kg = 1 ppm

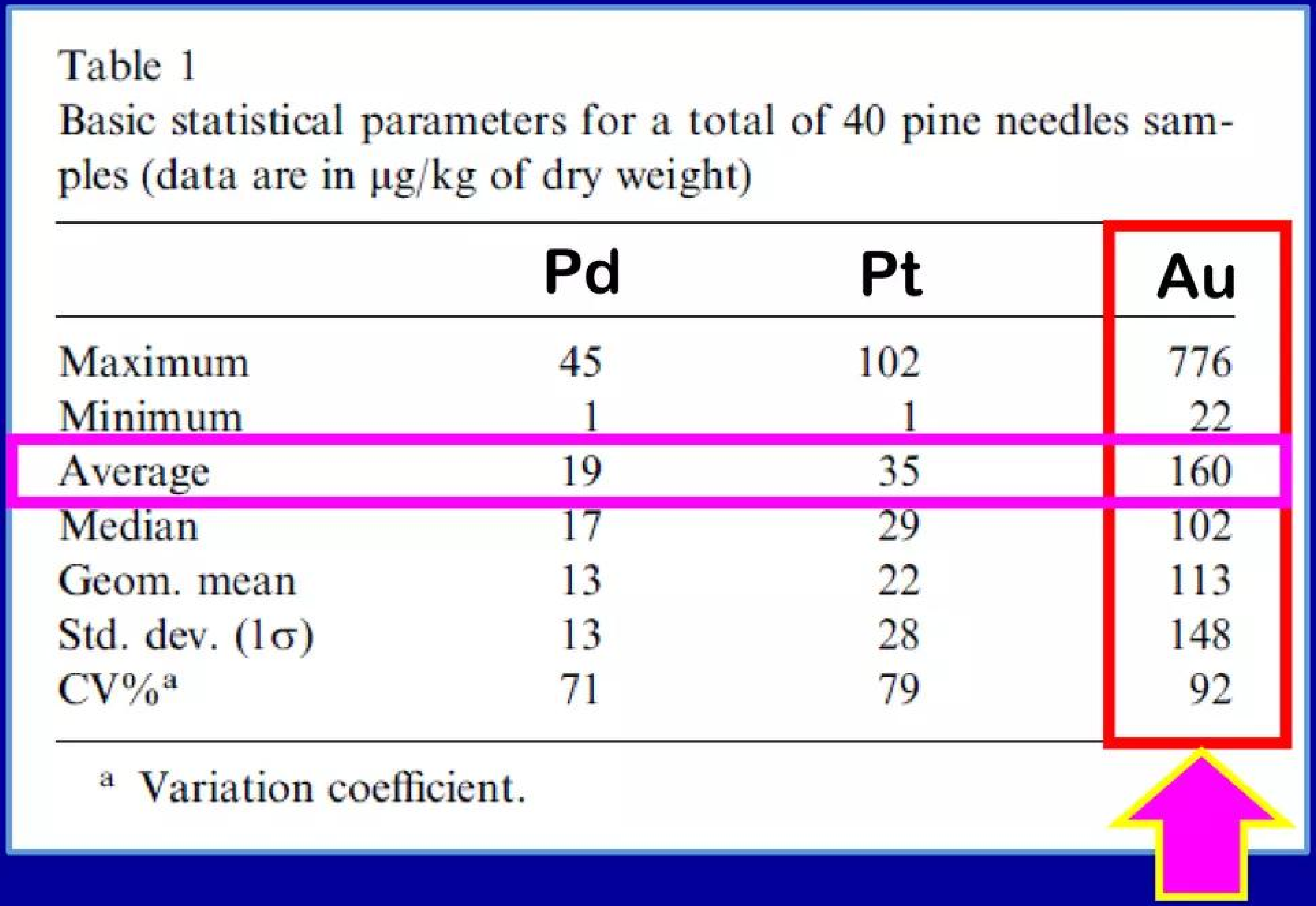


Table 1

Basic statistical parameters for a total of 40 pine needles samples (data are in µg/kg of dry weight)

	Pd	Pt	Au
Maximum	45	102	776
Minimum	1	1	22
Average	19	35	160
Median	17	29	102
Geom. mean	13	22	113
Std. dev. (1σ)	13	28	148
CV%[a]	71	79	92

[a] Variation coefficient.

Quoting: "Gold concentrations were found to lie in the 22 - 776 mg/kg range. Tables 1 and 2 clearly show that Au is found in concentrations which are higher than crustal values and those found in some samples from the local surface soils. Areal distribution (Fig. 5) shows that the highest Au concentrations are located in the same areas of the city in which Pt, Pd are particularly enriched … in the present case, dispersion patterns exclude non-local sources for these elements. Gold is not used in catalysts, since its catalytic reaction temperature is too high … Significant Au impurities are likely to be found in the alloys used in converter production, resulting in Au showing a similar distribution to that of the PGE. As far as the authors know no emission factors for Au have been published previously."

Gold observed in soils and grass adjacent to UK roads (2007)

Analyzed samples show amounts of Pt, Pd, Rh, and Au in soils & grass

Maximum amount of measured Gold was at site having highest traffic flows

"The distribution of automobile catalysts-cast Platinum, Palladium and Rhodium in soils adjacent to roads and their uptake by grass"
P. Hooda et al., *Science of the Total Environment* 384 pp. 384 - 392 (2007)

http://www.sciencedirect.com/science/article/pii/S0048969707006390

https://www.researchgate.net/publication/6233716_The_Distribution_of_Automobile_Catalysts-cast_platinum_Palladium_and_Rhodium_in_Soils_Adjacent_to_Roads_and_Their_Uptake_by_Grass

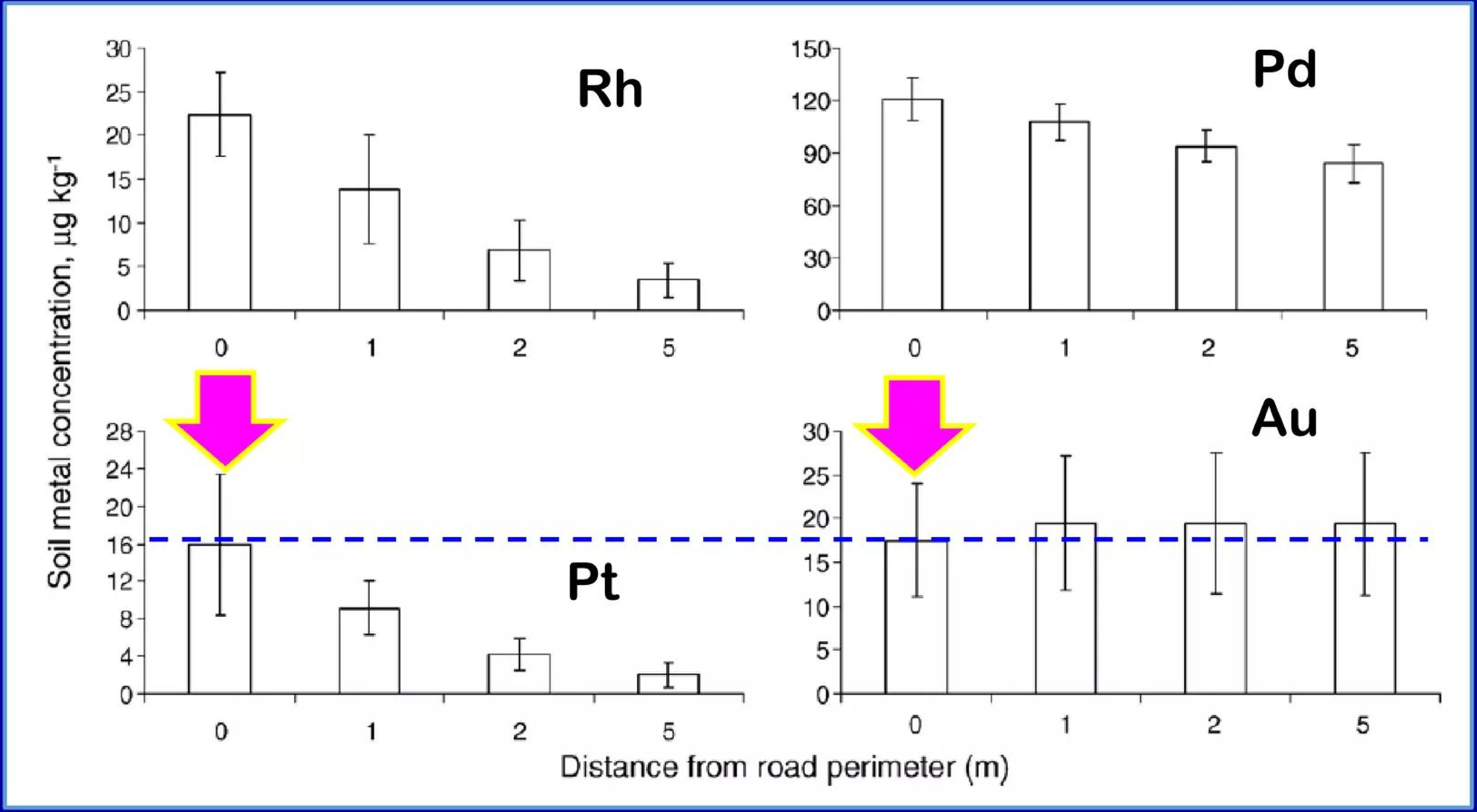
"In this paper we report on a study designed to assess the distribution and plant uptake of Pt, Pd and Rh from soils adjacent to several road networks. Gold (Au) was additionally, measured because of its increasing use in automotive electronics (ignition control, anti-lock brake and electronic fuel injection) in recent years (Corti, 2003). The specific objectives of the study were to: (a) examine the pattern of soil PGE concentrations with increasing distance from roads in order to evaluate their depositional behaviour; (b) assess the effect of traffic characteristics and local landscape on PGE distribution in the soils; and (c) evaluate PGE uptake by grass and test any relationship with their soil concentrations."

Gold has been observed in soils adjacent to UK roads (2007)

Hoodah et al. Fig. 1 - average metal concentration vs. distance from road

Even adjacent to side of roadway avg. Gold concentration ~ same as Platinum

Concentration of metals in soils at specified distances from UK roads

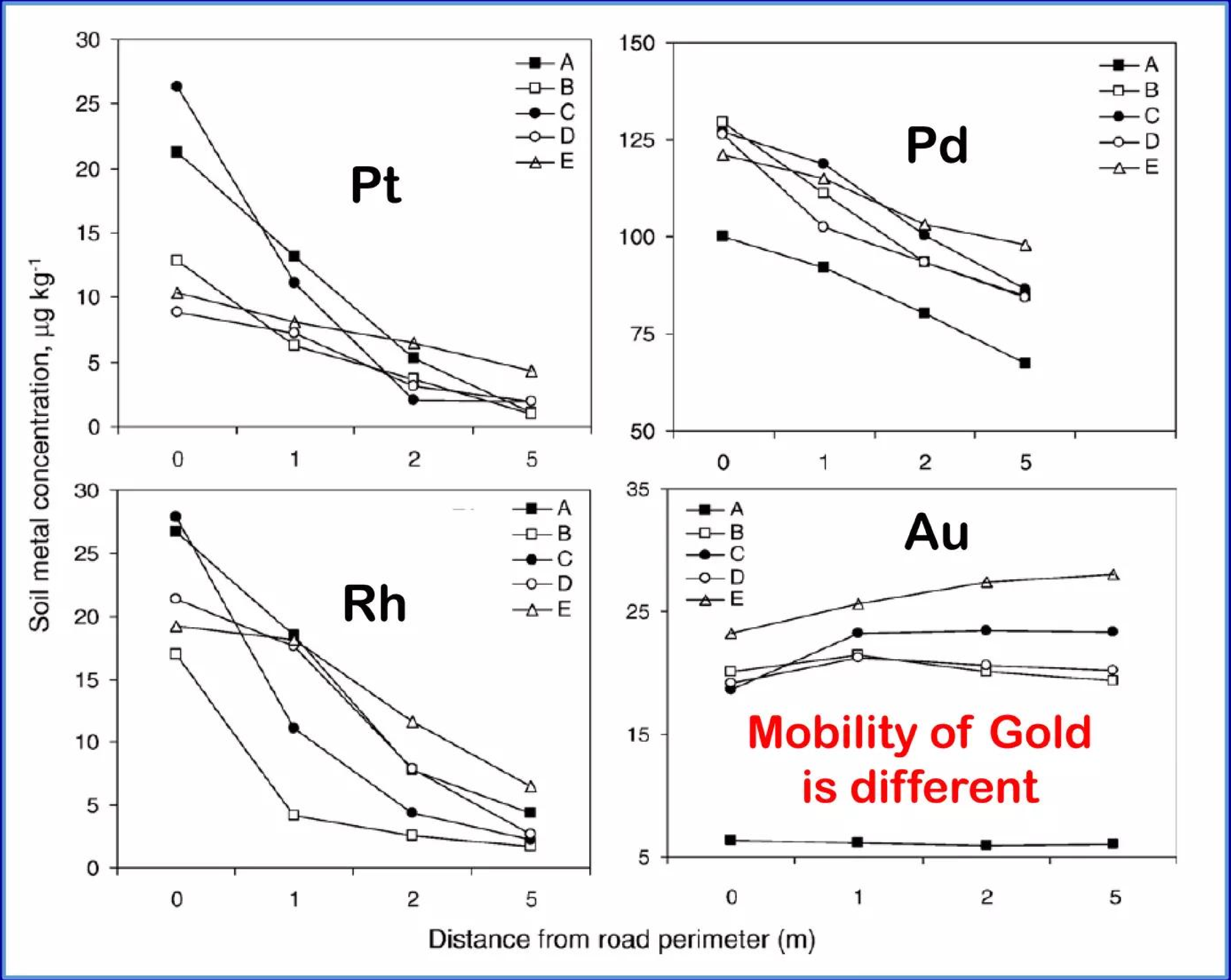


Once emitted from exhaust into environment, physical-chemical-biological transport mechanisms as well as mobility can vary greatly between each of these precious metals

Gold has been observed in soils adjacent to UK roads (2007)

Hoodah et al. Fig. 2 - metal concentration vs. distance away from road

Data below for soils - shows these metals are associated with vehicular traffic

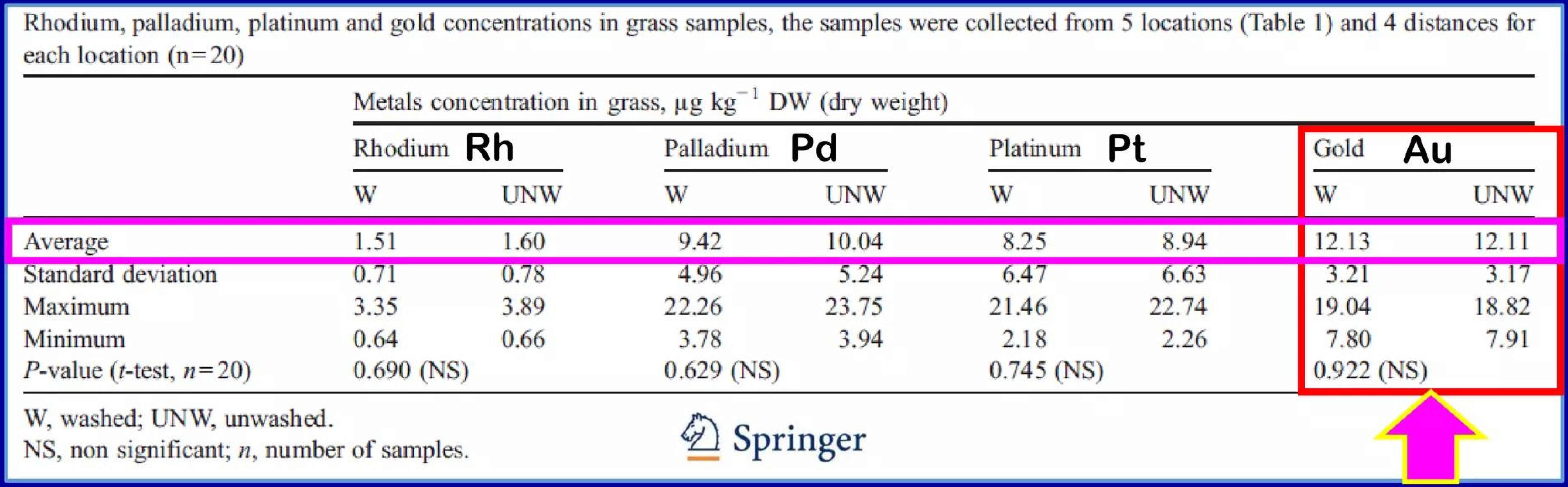


Mobility of Gold is different

Gold observed in grass samples adjacent to UK roads (2007)

Hoodah et al. Table 2 - avg. concentrations in samples from 5 locations

Average concentrations of Gold (μg/kg) in grass *greater* than Rh, Pd, and Pt



Rhodium, palladium, platinum and gold concentrations in grass samples, the samples were collected from 5 locations (Table 1) and 4 distances for each location (n=20)

	Metals concentration in grass, μg kg^{-1} DW (dry weight)							
	Rhodium **Rh**		Palladium **Pd**		Platinum **Pt**		Gold **Au**	
	W	UNW	W	UNW	W	UNW	W	UNW
Average	1.51	1.60	9.42	10.04	8.25	8.94	12.13	12.11
Standard deviation	0.71	0.78	4.96	5.24	6.47	6.63	3.21	3.17
Maximum	3.35	3.89	22.26	23.75	21.46	22.74	19.04	18.82
Minimum	0.64	0.66	3.78	3.94	2.18	2.26	7.80	7.91
P-value (*t*-test, *n*=20)	0.690 (NS)		0.629 (NS)		0.745 (NS)		0.922 (NS)	

W, washed; UNW, unwashed.
NS, non significant; *n*, number of samples.

Springer

- ✓ Concentrations of Gold are unexpectedly high versus those of Rh, Pd and Pt
- ✓ High amounts of Gold vs. Pt, Pd, and Rh very similar to data of Dongarra et al.
- ✓ Quoting: "The soil Au concentrations varied across the sites, with maximum concentrations measured at site E, which also had the highest traffic flow."
- ✓ Concentrations of these metals near UK roads much higher vs. crustal values
- ✓ Altogether the data indicates that Pt, Pd, Rh, and Au are emitted from vehicles

Elements in Chinese city road dusts and roadside soils

Platinum (Pt), Palladium (Pd), Gold (Au), Iridium (Ir), and Osmium (Os)

Catalytic converter emissions created abundances way above natural background

"The characteristics of automobile catalyst-derived Platinum group elements in road dusts and roadside soils: a case study in the Pearl River Delta region, South China" L. Qi et al. in *Environmental Earth Sciences* 64 pp. 1683 - 1692 (2011)

http://link.springer.com/article/10.1007/s12665-010-0635-y

Quoting: "The contents of Au in dusts from Hong Kong (42 - 453 ng/g, average 209 ng/g) and Shenzhen (148 - 1345 ng/g, average 471 ng/g) are much higher than soils (average 19.4 and 14.7 ng/g) and the background values (average 0.98 ng/g). Dust samples from Hong Kong and Shenzhen show clearly positive correlation between Au and Pt (Fig. 4). Because these samples were collected from the commercial streets and highways with no industrial input, the anomalies are likely related to contamination from automobile catalysts. The contents of Au in all the samples from Guangzhou (average 12.2 ng/g) are much lower than those from Shenzhen and Hong Kong and show no correlations between Pt and Au (Fig. 4). The similarity between Shenzhen and Hong Kong may have caused by the frequent shuttle traffic between these two cities. The difference between Guangzhou and Hong Kong may reflect the different automobile catalyst systems between mainland China and Hong Kong."

Elements in Chinese city road dusts and roadside soils

Table 3. Qi et al. (2011) Abundances in upper crust and local background

Qi et al. measure uncontaminated soils near cities to determine background levels

Table 3. Springer

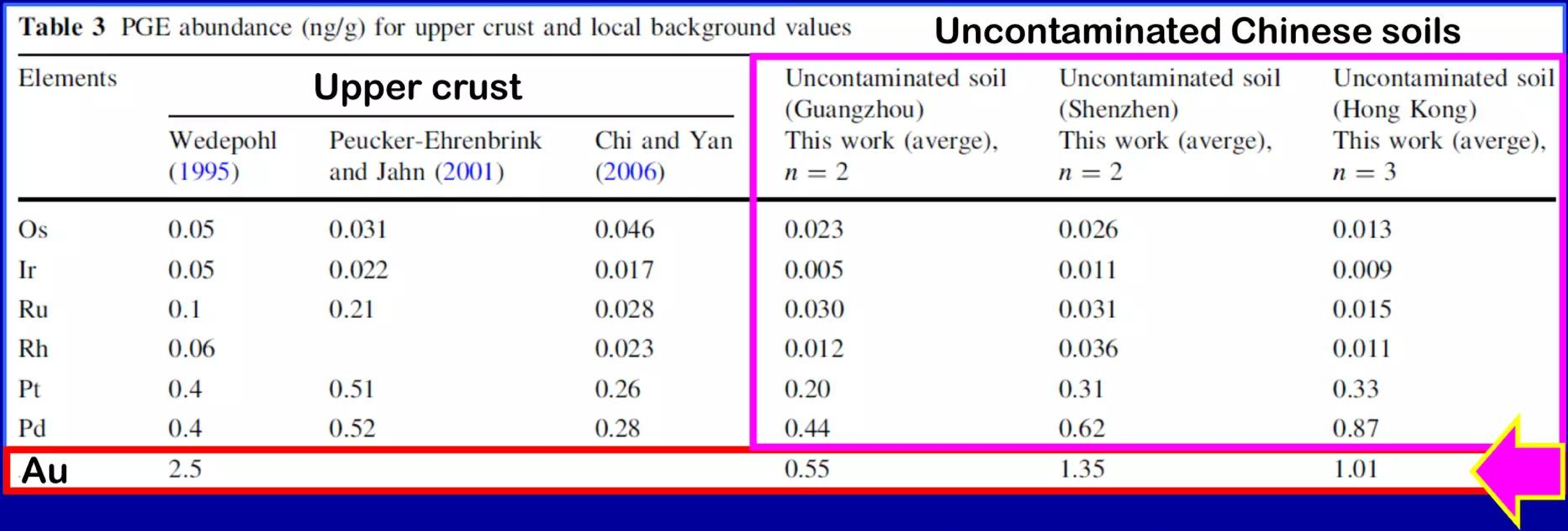


Table 3 PGE abundance (ng/g) for upper crust and local background values

Uncontaminated Chinese soils

Elements	**Upper crust**					
	Wedepohl (1995)	Peucker-Ehrenbrink and Jahn (2001)	Chi and Yan (2006)	Uncontaminated soil (Guangzhou) This work (averge), $n = 2$	Uncontaminated soil (Shenzhen) This work (averge), $n = 2$	Uncontaminated soil (Hong Kong) This work (averge), $n = 3$
Os	0.05	0.031	0.046	0.023	0.026	0.013
Ir	0.05	0.022	0.017	0.005	0.011	0.009
Ru	0.1	0.21	0.028	0.030	0.031	0.015
Rh	0.06		0.023	0.012	0.036	0.011
Pt	0.4	0.51	0.26	0.20	0.31	0.33
Pd	0.4	0.52	0.28	0.44	0.62	0.87
Au	2.5			0.55	1.35	1.01

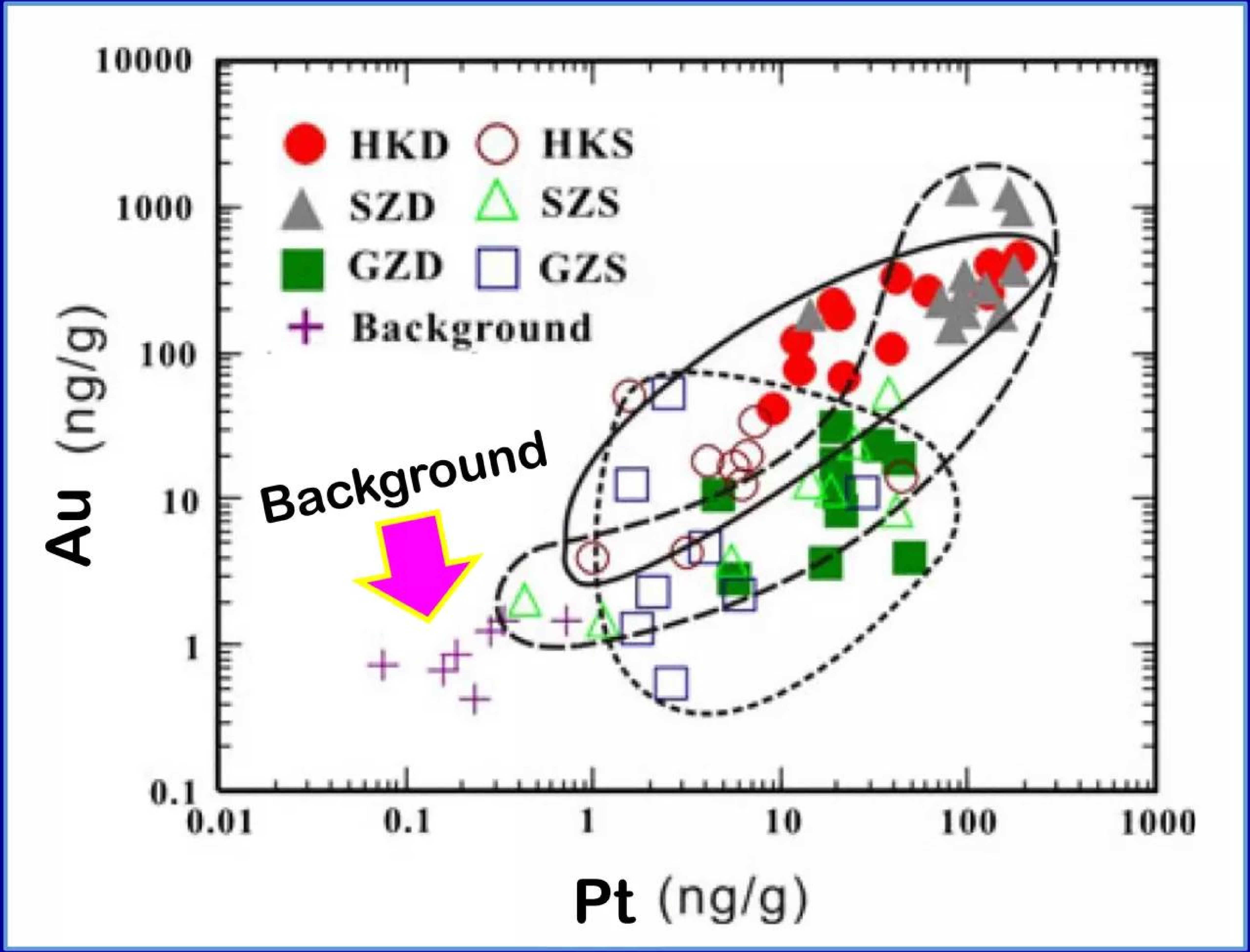
Quoting: "To identify the elevated PGE contents through anthropogenic contributions in environmental samples, a local natural background level is required to establish as a reference point. Therefore, the local uncontaminated soils can be considered as the background values. As listed in Table 3, the background values have PGE abundances generally similar to those reported for the Upper Continental Crust (Wedepohl 1995; Peucker-Ehrenbrink and Jahn 2001) and the crust levels in eastern part of China (Chi and Yan 2006)."

Elements in Chinese city road dusts and roadside soils

Fig. 4 in Qi et al. (2011) Gold (Au) versus Platinum (Pt) concentrations

Catalytic converter emissions created abundances way above natural background

Figure 4. Springer

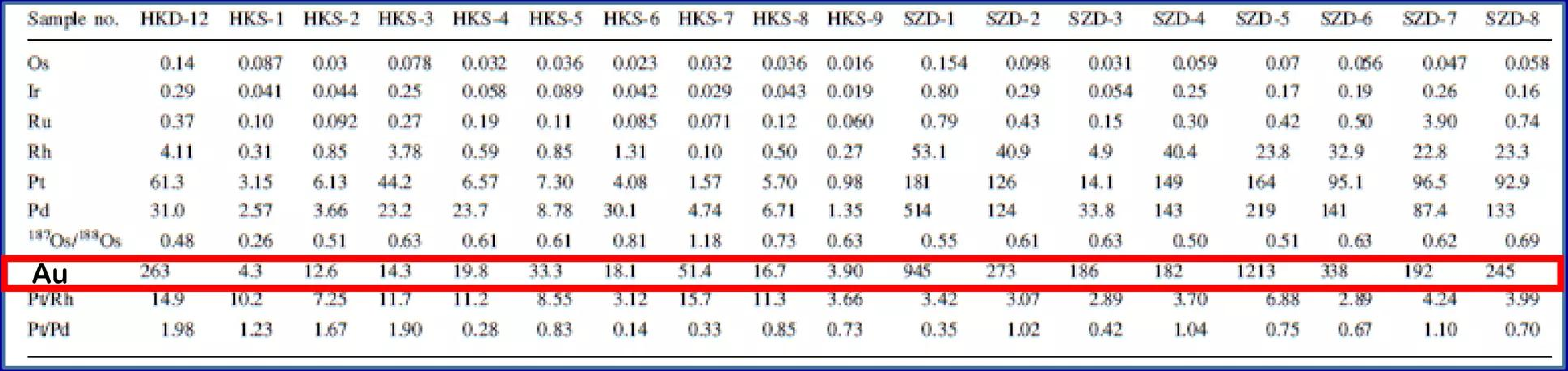


Elements in Chinese city road dusts and roadside soils

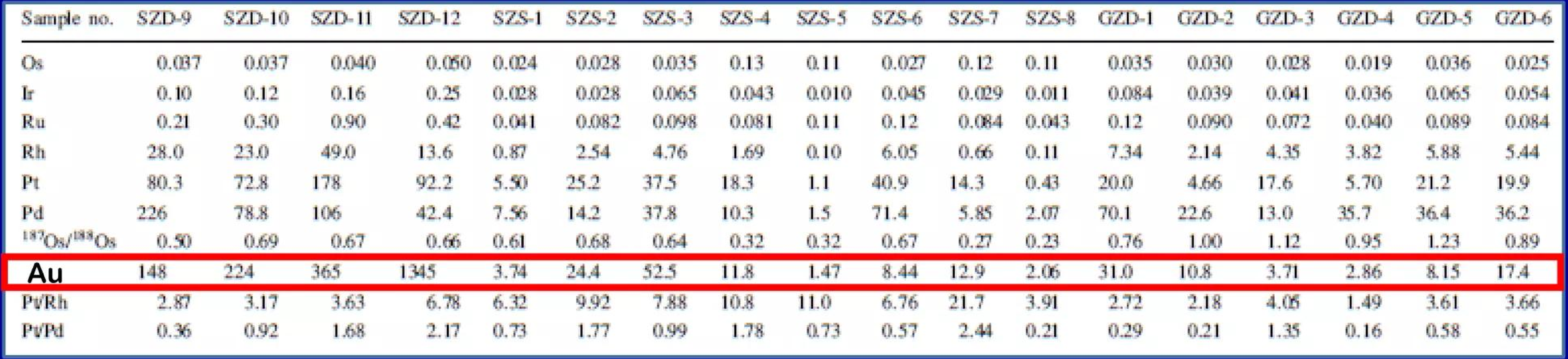
Excerpts from Table 4. Qi et al. (2011) Hong Kong & Shenzhen samples

Similar to Dongarra and Hooda: Gold concentration oddly high vs. Pt, Pd, and Rh

Table 4. Springer



Sample no.	HKD-12	HKS-1	HKS-2	HKS-3	HKS-4	HKS-5	HKS-6	HKS-7	HKS-8	HKS-9	SZD-1	SZD-2	SZD-3	SZD-4	SZD-5	SZD-6	SZD-7	SZD-8
Os	0.14	0.087	0.03	0.078	0.032	0.036	0.023	0.032	0.036	0.016	0.154	0.098	0.031	0.059	0.07	0.056	0.047	0.058
Ir	0.29	0.041	0.044	0.25	0.058	0.089	0.042	0.029	0.043	0.019	0.80	0.29	0.054	0.25	0.17	0.19	0.26	0.16
Ru	0.37	0.10	0.092	0.27	0.19	0.11	0.085	0.071	0.12	0.060	0.79	0.43	0.15	0.30	0.42	0.50	3.90	0.74
Rh	4.11	0.31	0.85	3.78	0.59	0.85	1.31	0.10	0.50	0.27	53.1	40.9	4.9	40.4	23.8	32.9	22.8	23.3
Pt	61.3	3.15	6.13	44.2	6.57	7.30	4.08	1.57	5.70	0.98	181	126	14.1	149	164	95.1	96.5	92.9
Pd	31.0	2.57	3.66	23.2	23.7	8.78	30.1	4.74	6.71	1.35	514	124	33.8	143	219	141	87.4	133
^{187}Os/^{188}Os	0.48	0.26	0.51	0.63	0.61	0.61	0.81	1.18	0.73	0.63	0.55	0.61	0.63	0.50	0.51	0.63	0.62	0.69
Au	263	4.3	12.6	14.3	19.8	33.3	18.1	51.4	16.7	3.90	945	273	186	182	1213	338	192	245
Pt/Rh	14.9	10.2	7.25	11.7	11.2	8.55	3.12	15.7	11.3	3.66	3.42	3.07	2.89	3.70	6.88	2.89	4.24	3.99
Pt/Pd	1.98	1.23	1.67	1.90	0.28	0.83	0.14	0.33	0.85	0.73	0.35	1.02	0.42	1.04	0.75	0.67	1.10	0.70



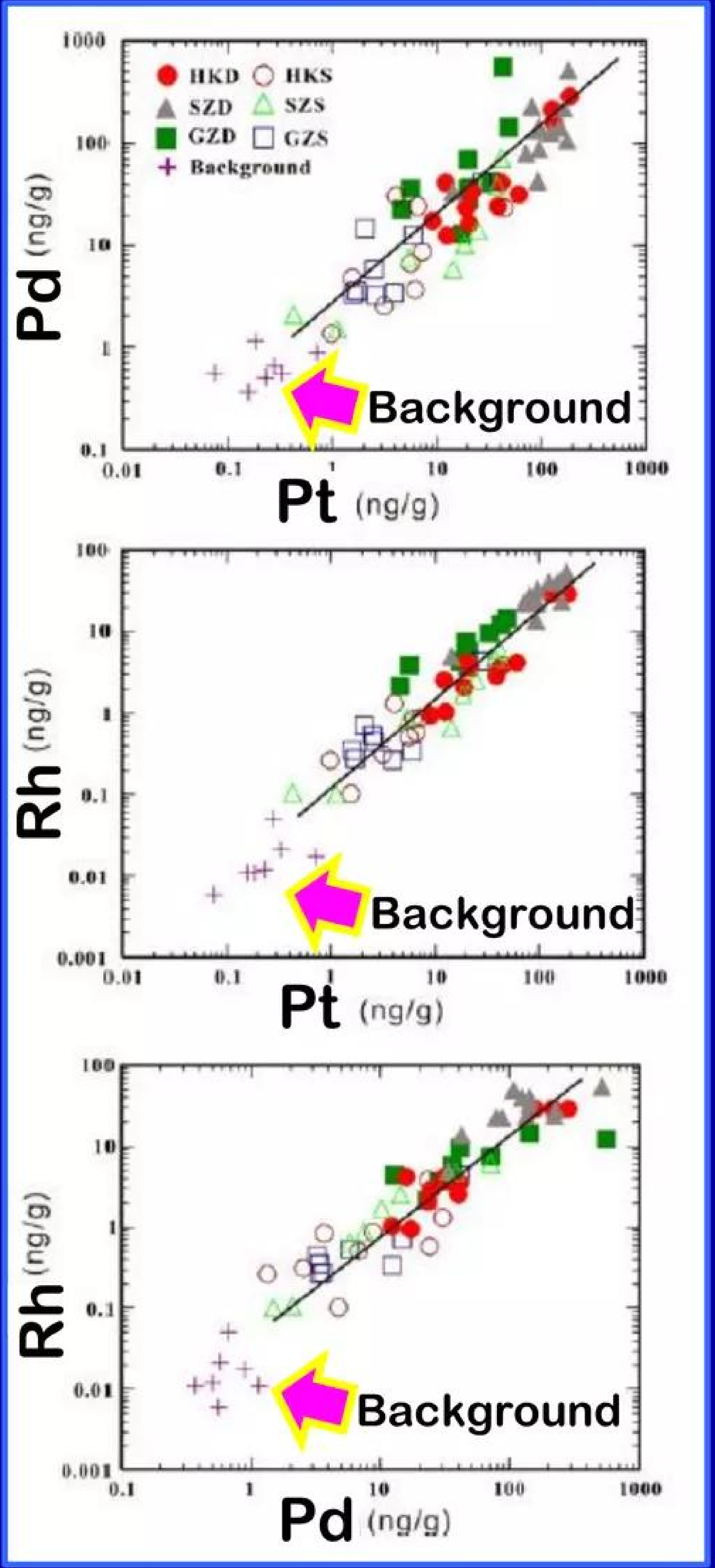
Sample no.	SZD-9	SZD-10	SZD-11	SZD-12	SZS-1	SZS-2	SZS-3	SZS-4	SZS-5	SZS-6	SZS-7	SZS-8	GZD-1	GZD-2	GZD-3	GZD-4	GZD-5	GZD-6
Os	0.037	0.037	0.040	0.050	0.024	0.028	0.035	0.13	0.11	0.027	0.12	0.11	0.035	0.030	0.028	0.019	0.036	0.025
Ir	0.10	0.12	0.16	0.25	0.028	0.028	0.065	0.043	0.010	0.045	0.029	0.011	0.084	0.039	0.041	0.036	0.065	0.054
Ru	0.21	0.30	0.90	0.42	0.041	0.082	0.098	0.081	0.11	0.12	0.084	0.043	0.12	0.090	0.072	0.040	0.089	0.084
Rh	28.0	23.0	49.0	13.6	0.87	2.54	4.76	1.69	0.10	6.05	0.66	0.11	7.34	2.14	4.35	3.82	5.88	5.44
Pt	80.3	72.8	178	92.2	5.50	25.2	37.5	18.3	1.1	40.9	14.3	0.43	20.0	4.66	17.6	5.70	21.2	19.9
Pd	226	78.8	106	42.4	7.56	14.2	37.8	10.3	1.5	71.4	5.85	2.07	70.1	22.6	13.0	35.7	36.4	36.2
^{187}Os/^{188}Os	0.50	0.69	0.67	0.66	0.61	0.68	0.64	0.32	0.32	0.67	0.27	0.23	0.76	1.00	1.12	0.95	1.23	0.89
Au	148	224	365	1345	3.74	24.4	52.5	11.8	1.47	8.44	12.9	2.06	31.0	10.8	3.71	2.86	8.15	17.4
Pt/Rh	2.87	3.17	3.63	6.78	6.32	9.92	7.88	10.8	11.0	6.76	21.7	3.91	2.72	2.18	4.05	1.49	3.61	3.66
Pt/Pd	0.36	0.92	1.68	2.17	0.73	1.77	0.99	1.78	0.73	0.57	2.44	0.21	0.29	0.21	1.35	0.16	0.58	0.55

Qi (2011) Pt, Pd, Rh, Ir, Ru emitted from catalytic converters

These elements found in roadside dust & soils are well above background

- ✓ “Automobile catalytic converters were introduced to China in 1993.”
- ✓ “Automobile catalysts mainly contain Pt, Pd and Rh, and may release into the environment through exhausting system. Thus, these three elements show positive correlations for the roadside dusts and soils samples. Our data indicate that there are clearly positive correlations between Pt and Pd, Pt and Rh and Pd and Rh (Fig. 2) for the samples from three cities in the Pearl River Delta region, again consistent with automobile catalyst sources.”
- ✓ “Until present, other than Pt, Pd and Rh, only limited studies have been reported for automobile catalyst-related Ru and Ir in environmental samples … The Ir and Ru concentrations of our samples are clearly higher than the background values and Upper Continental Crust … There are clearly positive correlations between Pt and Ir, Pt and Ru, and Ir and Ru in our samples, except no correlations between Pt and Ru, and Ir and Ru in Guangzhou (Fig. 3). We suggest that the elevated Ir and Ru in soil and dust samples from the Pearl River Delta region are related to emission of automobile catalyst in which these elements occur as impurities.”

Fig. 2 Springer



Qi et al. (2011) concluded: catalytic converters emit metals

Pt, Pd, Rh, Au, Ir, Ru, Os nanoparticles found in roadside soils and dust

Anomalous high Au concentrations are related to catalytic converters' emissions

Springer

Conclusions:

"This study presents the results of PGE and Au in road dusts and roadside soils collected from three major cities in Pearl River Delta region, South China. The proposed low procedure blank and effective Carius tube technique together have improved the precision of PGE and Au determination in environmental samples, especially for the uncontaminated soil samples for establishing the background values. The background values of PGE and Au in the study area were established. The highest levels of Pt, Rh and Pd were found in road dusts and are due to contamination from automobile catalyst. Similar Pt/Pd ratios for the samples from Hong Kong, Guangzhou and Shenzhen reflect similar Pt/Pd ratios in the automobile catalysts used in these cities. The Pt/Rh ratios of dust samples from Hong Kong are higher than those from Guangzhou and Shenzhen, reflecting the different automobile catalyst system between Hong Kong and mainland China. The elevated levels of Ru, Ir and Os in road dust and roadside soil samples are possibly related to the impurity of these elements in the automobile catalysts. Anomalous high concentrations of Au in the dust samples from Shenzhen and Hong Kong may also be related to emission from automobile catalyst systems."

Gold not normally used as catalyst in catalytic converters

Gold is found in roadside dust, soils, plant tissues along with Pt, Pd, Rh

Anomaly: Gold concentrations at some sampled locations are similar to Pt and Pd

- ✓ Since the mid-1970s in U.S./Europe and 1993 in China when three-way catalytic converters were initially mandated on all motor vehicles with IC engines, little or no Gold appears to have been deliberately used in OEM manufacturing of these important, universal air pollution control devices
- ✓ Yet when roadside soils, dusts, and tissues of nearby growing plants are carefully analyzed for the presence of a wide range of different metals, anomalous Gold is commonly found and is also well-correlated with the obviously expected presence of Platinum, Palladium, and Rhodium PGE metals that have customarily been used in three-way catalytic converters
- ✓ Even more odd, experimental data discussed herein that was published by Dongarra et al. (2003), Hooda et al. (2007), and Qi et al. (2011) clearly reveal that at many sampled locations, observed Gold concentrations can even locally *exceed* the concentrations of Platinum and/or Palladium
- ✓ Gold concentrations approaching or exceeding those of Pt and Pd is a highly anomalous, totally unexpected result given that little or no Gold should be present inside converters when they are initially manufactured and prior to their use on the road in motor vehicles

LENR production of Au from Pt can explain anomalous data

Physicochemical processes do not explain anomalous Au near roadsides

- ✓ While there has recently been academic discussion of using Gold for one of the catalysts in converters for lean-burning diesel engines, current high price of Gold compared to Pt, Pd, and Rh would restrict usage in such applications
- ✓ Certain high-priced racing spark plugs do use Gold-Palladium alloys in tips of their electrodes, but they would be installed in only a tiny percentage of total vehicles on roads and thus could not possibly account for anomalously high concentrations of Gold observed in roadside dust, soils, and plant tissues
- ✓ It is certainly possible that Gold is initially present as tiny impurities in Pt, Pd, and Rh catalyst metals before catalytic converters are being manufactured. However, even if this idea were true it could not possibly explain how some sampled locations show Gold concentrations that can exceed those of Pt, Pd, and/or Rh unless one invoked a mysterious *ad hoc* concentrating process that operates only on Gold after it is released via exhaust into environment
- ✓ Gold is extensively used with connectors found inside vehicular electronic systems. However, such connectors are always tightly enclosed within local protective structures. It is difficult to imagine very much of this Gold being released out into the external environment as long as structures are intact
- ✓ Prosaic processes do not explain data on anomalous concentrations of Gold

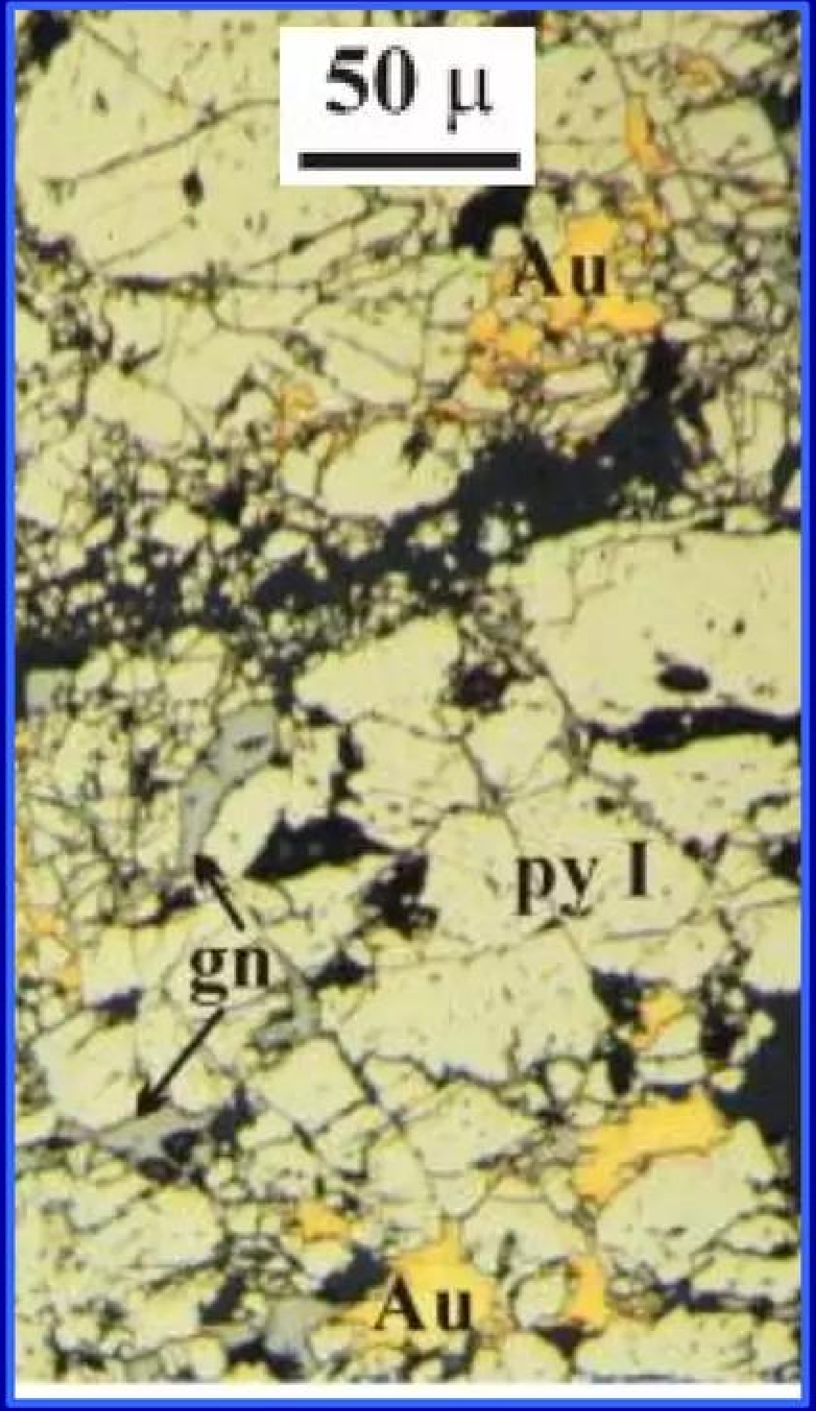
LENR production of Au from Pt can explain anomalous data

Neutron capture on ^{196}Pt produces unstable ^{197}Pt that β^- decays to ^{197}Au

Probable location of LENR processes in motor vehicles is the catalytic converter

- ✓ Data on PGE catalyst metals recovered, recycled, and refined from scrapped car and truck converters in U.S. reveals that for all three grades of recycled converter materials, Platinum comprises ~70% of catalysts present
- ✓ LENRs are possible in electric arc plasmas (sparks) found in combustion chambers. However, amounts of available W, Ir, and Pt in wear coatings and spark plugs that could serve as LENR neutron capture target elements are minuscule in comparison to amount available inside catalytic converters
- ✓ Gold has one stable isotope; only certain LENR nuclear transmutation paths are able to produce stable ^{197}Au. Most direct pathway to Au is via neutron capture on stable ^{196}Pt (natural abundance 25.3%) that transmutes it to unstable ^{197}Pt (half-life 19.9 hours) which rapidly β-decays to ^{197}Au
- ✓ If Gold is truly produced in vehicle catalytic converters via LENR transmutation processes then the ^{196}Pt pathway is our best candidate to explain anomalous Gold near roads

Diorite Gold ore thin-section magnified



Canada

Data suggests Gold being produced in catalytic converters

> “Nothing is too wonderful to be true,
> if it be consistent with the laws of Nature;
> and in such things as these experiments
> is the best test of such consistency.”

Michael Faraday

Laboratory journal entry #10,040
March 19, 1849

Other anomalies in Pt & Pd emitted from vehicle exhausts

Stable isotope abundances of Pt and Pd shift toward more neutron-rich

Platinum and Palladium emitted from catalytic converters is isotopically heavier

"Determination of Pt, Pd, and Rh by inductively coupled plasma sector field mass spectroscopy (ICP-SFMS) in size-classified urban aerosol samples"
K. Kanitsar et al. *Journal of Analytical Atomic Spectrometry* 18 pp. 239 - 246 (2003)
http://www.rsc.org/delivery/_ArticleLinking/DisplayArticleForFree.cfm?doi=b212218a&JournalCode=JA

"Novel matrix separation on-line pre-concentration procedure for accurate quantification of Palladium in environmental samples by isotope dilution inductively coupled plasma sector field mass spectrometry"
E. Rudolph et al. *Journal of Analytical Atomic Spectrometry* 21 pp. 1287 - 1293 (2006)
http://pubs.rsc.org/is/content/articlelanding/2006/ja/b604820j#!divAbstract

Very interesting papers by Kanitsar et al. (2003) and Rudolph et al. (2006) are cited above.

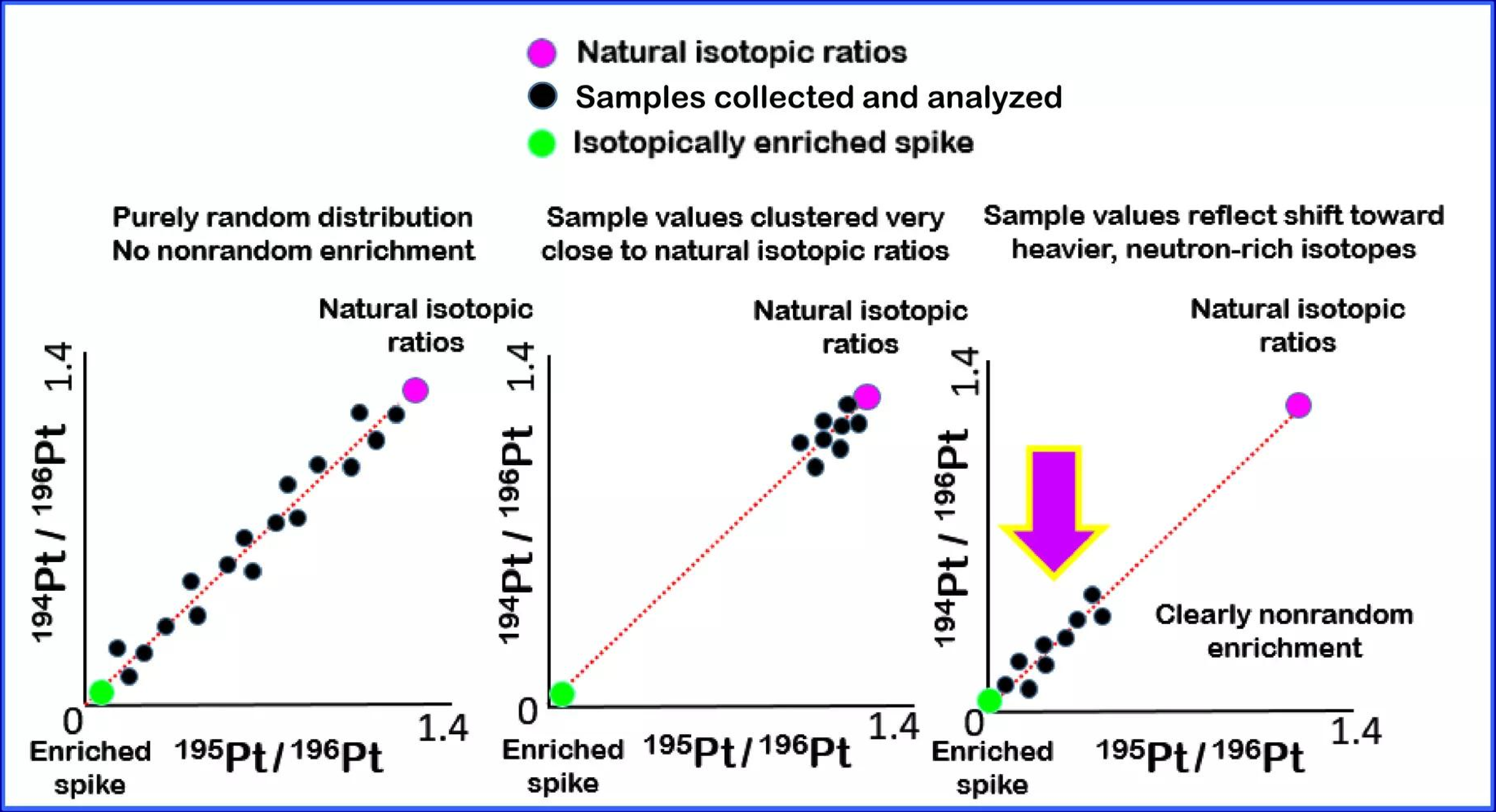
The purpose of 2003 Kanitsar et al. study was to measure "… Pt, Pd, and Rh concentration levels … in Viennese aerosol … emitted from car catalysts … urban aerosol was studied over a period of 1 month during summer 2002 in a heavy traffic area … Since Platinum group elements (PGE) are emitted from car catalysts as a result of mechanical processes, Pt, Pd and Rh were mainly found in the coarse fraction of urban aerosol."

Isotopic abundance ratio plots a la Kanitsar and Rudolph

Plot at left shows random enrichment; middle shows only natural ratios

Plot at right shows enhanced enrichment of heavier (more neutron-rich) isotopes

Idealized plots illustrate types of enrichment that could potentially occur

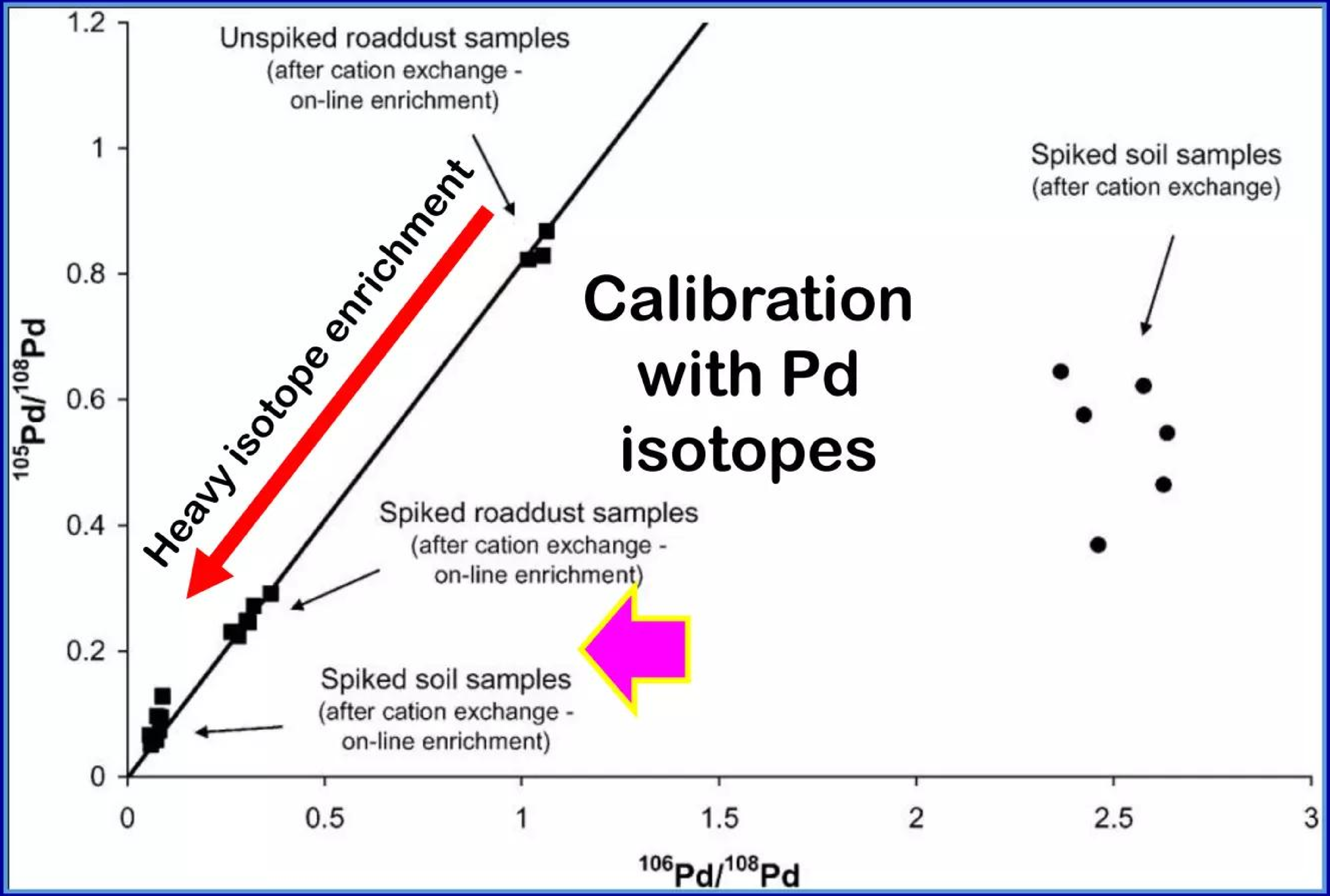


Rudolph et al. use same measurement technique as Kanitsar

Shows that data points for neutron rich samples will cluster near origin

Pt or Pd samples enriched in heavier isotopes will move closer toward origin

Fig. 2 Rudolph et al. (2006): in this illustrative example, only samples that were spiked with 98.25% ^{106}Pd cluster along the line nearer to the origin



Calibration with Pd isotopes

Other anomalies in Pt and Pd emitted in vehicle exhausts

Stable isotope abundances of Pt & Pd shifted toward more neutron-rich

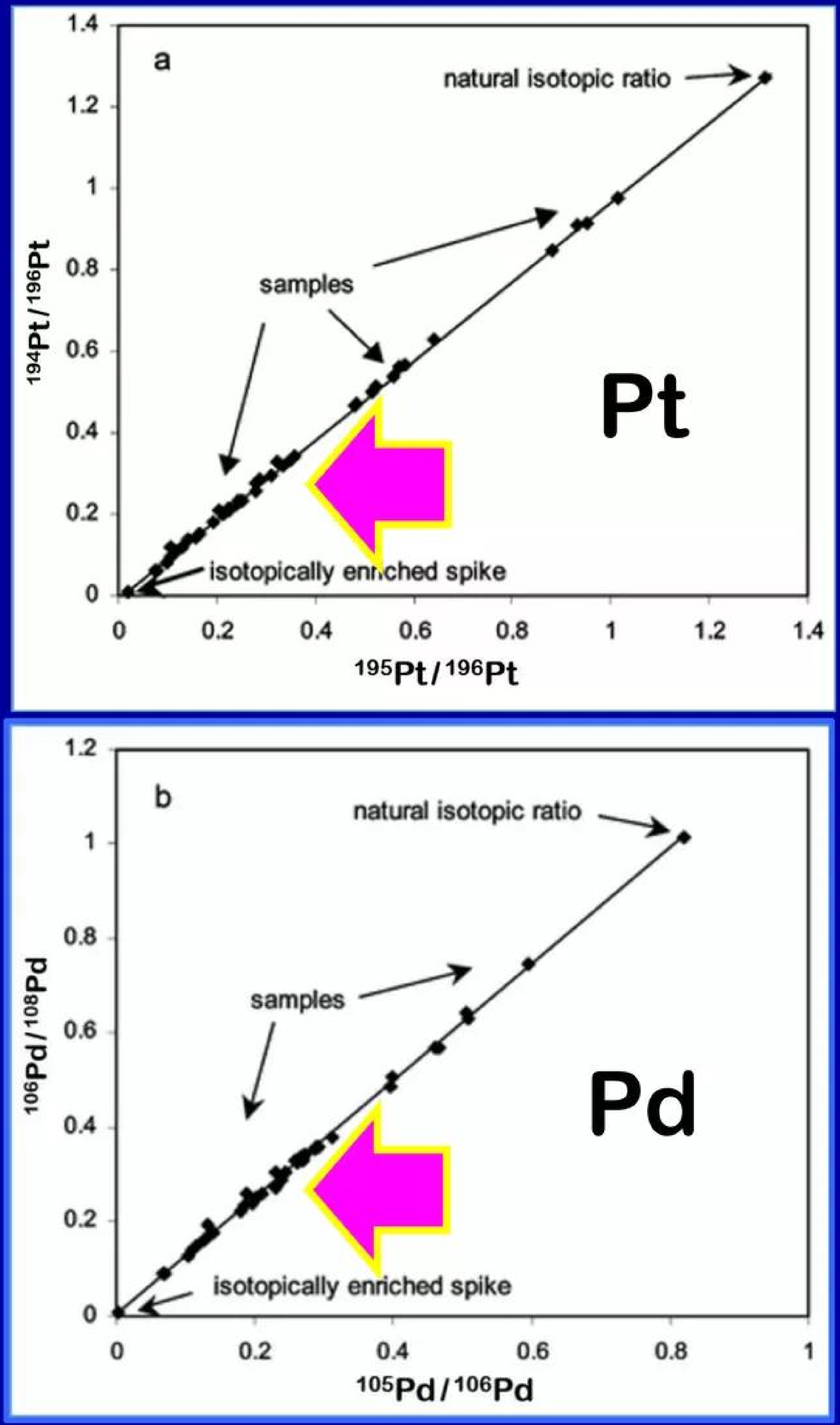
Platinum and Palladium emitted from catalytic converters is isotopically heavier

Heavy-isotope enrichment in samples

Of note is Fig. 1, where Kanitsar et al. plot values of ^{194}Pt/^{196}Pt vs. ^{195}Pt/^{196}Pt for field samples, which happen to fall along a straight line connecting an “isotopically enriched spike sample” (97.25% ^{196}Pt) with the x, y coordinate for the standard natural abundance ratios of these particular Pt isotopes. They then plot the same graph for Pd with ^{106}Pd/^{108}Pd vs. ^{105}Pd/^{108}Pd for field samples, which also fall neatly along a straight line connecting an “enriched spike sample” (98.25% ^{106}Pd) with the x, y coordinate for the standard natural abundance ratios of these Pd isotopes.

Values of field samples are not distributed randomly along the lines, nor are they just clustered close to the natural abundance values; are shifted toward heavier isotopes

Fig. 1 Kanitsar et al. plots



Other anomalies in Pt and Pd emitted in vehicle exhausts

Stable isotope abundances of Pt and Pd shift toward more neutron-rich

Platinum and Palladium emitted from catalytic converters is isotopically heavier

Platinum (Pt) has six stable isotopes: ^{190}Pt, ^{192}Pt, ^{194}Pt, ^{195}Pt, ^{196}Pt, ^{198}Pt
Neutron capture on certain Pt isotopes has tiny cross-section for producing Osmium

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

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

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

Other anomalies in Pt and Pd emitted in vehicle exhausts

Stable isotope abundances of Pt and Pd shift toward more neutron-rich

Platinum and Palladium emitted from catalytic converters is isotopically heavier

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

Comments:

- ✓ Of its six stable isotopes, ^{190}Pt has largest neutron capture cross-section (c-c-s) = 1.5 x 10^{2} barns (b) at thermal energies, then ^{195}Pt = ~28 b, and ^{192}Pt = ~2.0 b; other stable isotopes have much smaller capture cross-sections; again note that LENR ultralow energy neutron c-c-s can be >10^{3}x - 10^{6}x larger than $n_{thermal}$ c-c-s. Unsurprisingly, ^{190}Pt's natural abundance is the lowest of six stable isotopes because neutron capture c-s is so high
- ✓ All other things being equal, at low rates of LENR ULM neutron production no more than 1 - 2 neutrons may be captured per 'lucky' Pd atom located in or around a given LENR active site, there should be significant depletion of ^{190}Pt, which has huge neutron c-c-s. Ultralow energy neutron fluxes would have a strong tendency to *deplete* ^{192}Pt, ^{194}Pt and especially ^{195}Pt (nat. ab. 33.8% and capture c-s of 28 barns) and *progressively enrich* ^{196}Pt and ^{198}Pt. If virgin Platinum initially at natural isotopic abundances were exposed to LENR neutron fluxes, heavy isotope enrichment would be expected --- exactly as reported experimentally by Kanitsar et al. (2003)

Other anomalies in Pt and Pd emitted in vehicle exhausts

Stable isotope abundances of Pt and Pd shift toward more neutron-rich

Platinum and Palladium emitted from catalytic converters is isotopically heavier

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

- ✓ Presuming that we are not misinterpreting sample isotope data presented in Fig. 1 of Kanitsar et al. (2003), it appears that a decidedly nonrandom isotopic enrichment process took place in Pd and Pt found in small airborne particles emitted from motor vehicle exhausts
- ✓ Please recall we said that of the six stable isotopes, "^{105}Pd [22.33% nat. ab.] has the largest neutron capture cross-section of ~22 barns … All other things being equal, at low rates of LENR ultralow energy neutron production where only 1 - 2 neutrons are captured per Pd atom, there would be a tendency to *deplete* ^{105}Pd, ^{102}Pd and … *enrich* ^{106}Pd …" Such results are possible in condensed matter under the W-L theory and LENRs
- ✓ Lattice is unaware of any plausible chemical kinetic fractionation theories that could successfully explain the observed significant shifts toward heavier isotopies in emitted Pd and Pt. Furthermore, while some new *ad hoc* chemical fractionation processes could be proposed that also produce such results, the data of Kanitsar et al. can be satisfactorily explained by a green nuclear transmutation process, i.e., LENR low-energy neutron captures on Pd or Pt atoms in catalytic converters per W-L theory in condensed matter

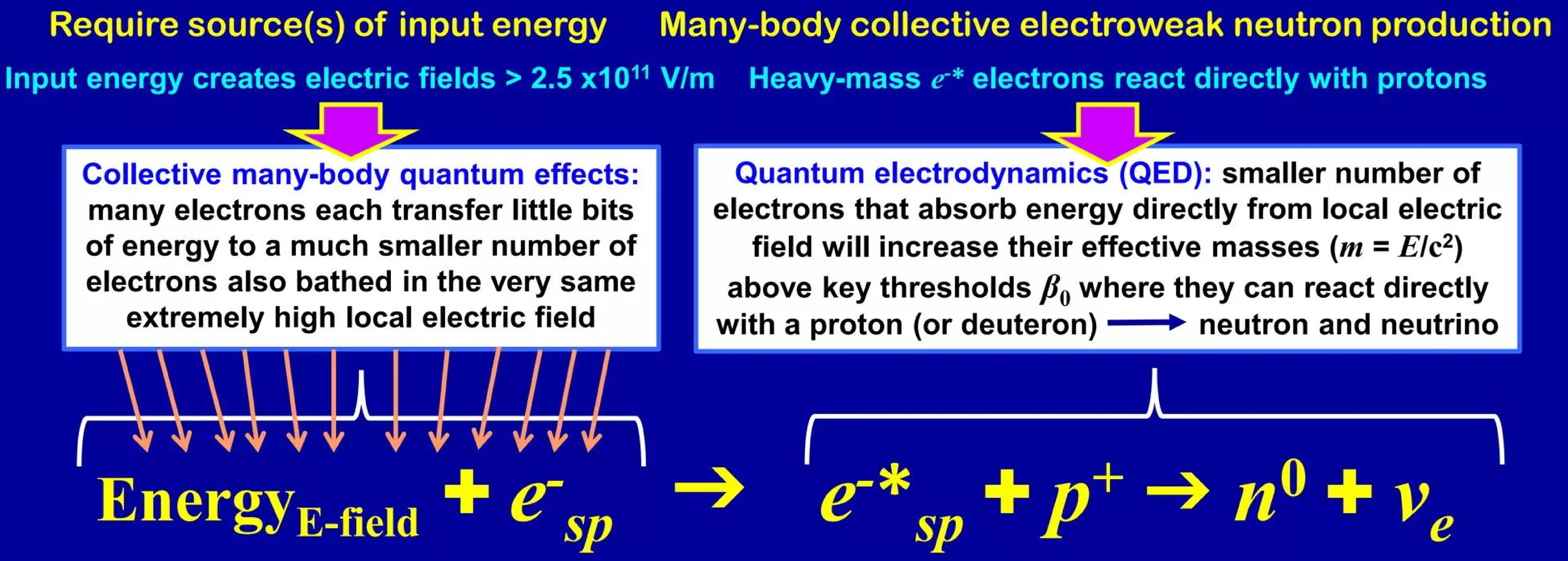
Platinum and Palladium isotopes shift in catalytic converters

Electroweak reaction in Widom-Larsen theory is simple

Protons or deuterons react directly with electrons to make neutrons

Need input energy source such as electricity to drive LENR neutron production

electrons + protons (Hydrogen) → neutrons + neutrinos (benign photons, fly into space)



Require source(s) of input energy

Input energy creates electric fields > 2.5 x10^{11} V/m

Collective many-body quantum effects: many electrons each transfer little bits of energy to a much smaller number of electrons also bathed in the very same extremely high local electric field

Many-body collective electroweak neutron production

Heavy-mass e^-* electrons react directly with protons

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 β_0 where they can react directly with a proton (or deuteron) → neutron and neutrino

$$\text{Energy}_{\text{E-field}} + e^-_{sp} \rightarrow e^{-*}_{sp} + p^+ \rightarrow n^0 + v_e$$

v_e neutrinos: ghostly unreactive photons that fly-off into space; n^0 neutrons capture on nearby atoms

Radiation-free LENR transmutation

Neutrons + capture targets → heavier elements + decay products

Neutrons induce nuclear transmutations that release enormous amounts of clean, CO_2-free heat

Electroweak neutron production has two distinct modes

Magnetic mode dominates in electric discharges: sparks, arcs, lightning

Production of neutrons from protons and electrons via electroweak catalysis:

Many-body collective effects in condensed matter and plasmas + input energy

$\mathrm{Energy}_{\text{E-field}} + e^{-}_{sp} \rightarrow e^{-*}_{sp} + p^{+} \rightarrow n + \nu_{e}$ [high electric fields on substrate surfaces]

$\mathrm{Energy}_{\text{B-field}} \rightarrow e^{-} + p^{+} \rightarrow lepton + X$ [plasmas inside cylindrical magnetic fields]

Collective electroweak production of neutrons on μ-scales on condensed matter substrates and via direct particle acceleration in magnetic fields of discharges

Transmutation of atoms that capture neutrons into other heavier isotopes/elements:

Both types of processes release nuclear binding energy (heat)

n + atom $(Z, A) \rightarrow (Z, A+1)$ [neutron capture on nearby atoms]

$(Z, A+1) \rightarrow (Z + 1, A+1) + e_{\beta}^{-} + \bar{\nu}_{e}$ [unstable products beta^{-} decay]

Commonly rapid β^{-} decays of unstable neutron-rich isotopic products

Appropriate input energy is required to produce neutrons

Catalytic converters can function as resonant electromagnetic cavities

Input energy is required to trigger LENRs: to create non-equilibrium conditions that enable nuclear-strength local E-fields which produce populations of heavy-mass e^{-*} electrons that react with many-body surface patches of p^{+}, d^{+}, or t^{+} to produce neutrons via $e^{-*} + p^{+} \rightarrow 1\ n$ or $e^{-*} + d^{+} \rightarrow 2\ n$, $e^{-*} + t^{+} \rightarrow 3\ n$ (energy cost = 0.78 MeV/neutron for H; 0.39 for D; 0.26 for T); includes (can combine sources):

- ✓ **Electrical currents** - i.e., an electron ‘beam’ of one sort or another can serve as a source of input energy for producing neutrons via $e + p$ electroweak reaction
- ✓ **Ion currents** - passing across a surface or an interface where SP electrons reside (i.e., an ion beam that can be comprised of protons, deuterons, tritons, and/or other types of charged ions); one method used for inputting energy is an ion flux caused by imposing a modest pressure gradient (Iwamura *et al.* 2002)
- ✓ **Incoherent and coherent electromagnetic (E-M) photon fluxes** - can be found in incoherent E-M radiation found in resonant electromagnetic cavities; with proper momentum coupling, SP electrons can also be directly energized with coherent laser beams emitting photons at appropriate resonant wavelengths
- ✓ **Organized magnetic fields with cylindrical geometries** - many-body collective magnetic LENR regime with direct acceleration of particles operates at very high electron/proton currents; includes organized and so-called dusty plasmas; scales-up to stellar flux tubes on stars with dimensions measured in kilometers

Electric discharges provide energy to create neutrons

Neutrons created on solid surfaces will have ultralow kinetic energies

Neutrons produced by direct particle acceleration in hot plasmas can be energetic

During electric discharges, electroweak neutron production via e + p reaction can simultaneously occur in complex, highly variable mixtures of three modes:

1. Nuclear-strength μ-scale local electric fields in condensed matter surfaces of electrodes. Neutrons mostly ultralow energy and local gamma emissions are directly converted into infrared photons (IR) by unreacted heavy electrons per W-L theory; virtually no emissions of MeV-energy gammas or neutrons. MeV energy betas (electrons) commonly emitted; sometimes MeV alpha particles
2. Nuclear-strength μ-scale local electric fields on surfaces of condensed matter particles embedded in discharge plasmas. These plasma-bathed particles --- typically with dimensions of nm to microns --- can either arise from ablation of electrode surfaces or were present in local gaseous environment and simply get trapped when discharge plasmas form. Neutrons made in this ~1. mode are mostly ultralow momentum; gammas are converted into IR by heavy electrons
3. Many-body collective *magnetic* effects dominate this mode. W-L-S mechanism operates via direct acceleration of charged particles (mainly electrons and protons) by electromagnetic fields within plasma channels. Neutron, proton, and electron energies can range from thermal up to tens of MeVs; produces energetic X-rays & gammas up to tens of MeVs; also energetic X particles

Electric discharges provide energy to create neutrons

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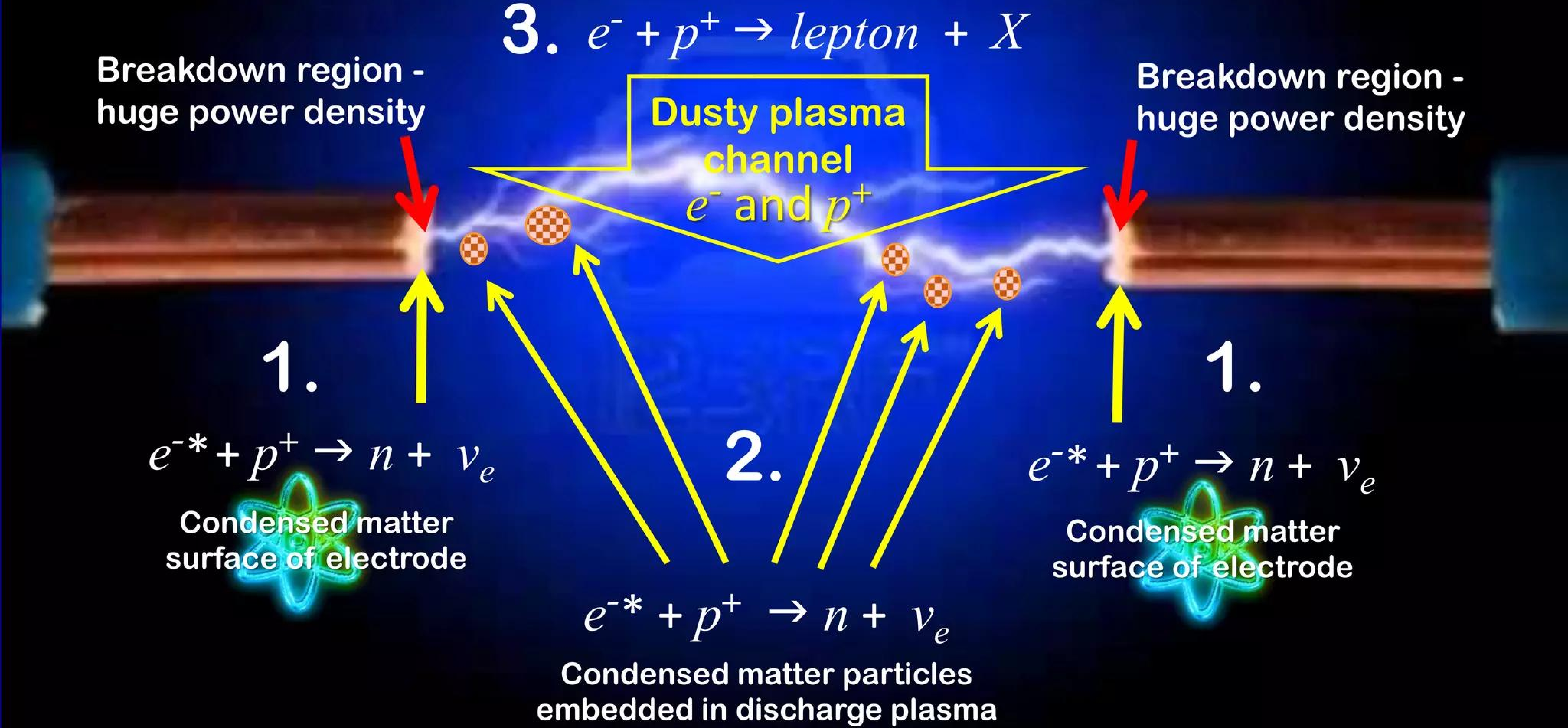


3. $e^- + p^+ \rightarrow lepton + X$

Breakdown region - huge power density

Dusty plasma channel

e^- and p^+

Breakdown region - huge power density

1. $e^{-*} + p^+ \rightarrow n + \nu_e$

Condensed matter surface of electrode

2. $e^{-*} + p^+ \rightarrow n + \nu_e$

Condensed matter particles embedded in discharge plasma

1. $e^{-*} + p^+ \rightarrow n + \nu_e$

Condensed matter surface of electrode

Summary of steps in Widom-Larsen theory of LENRs

5-step green process in sites occurs in 300 - 400 nanoseconds or less

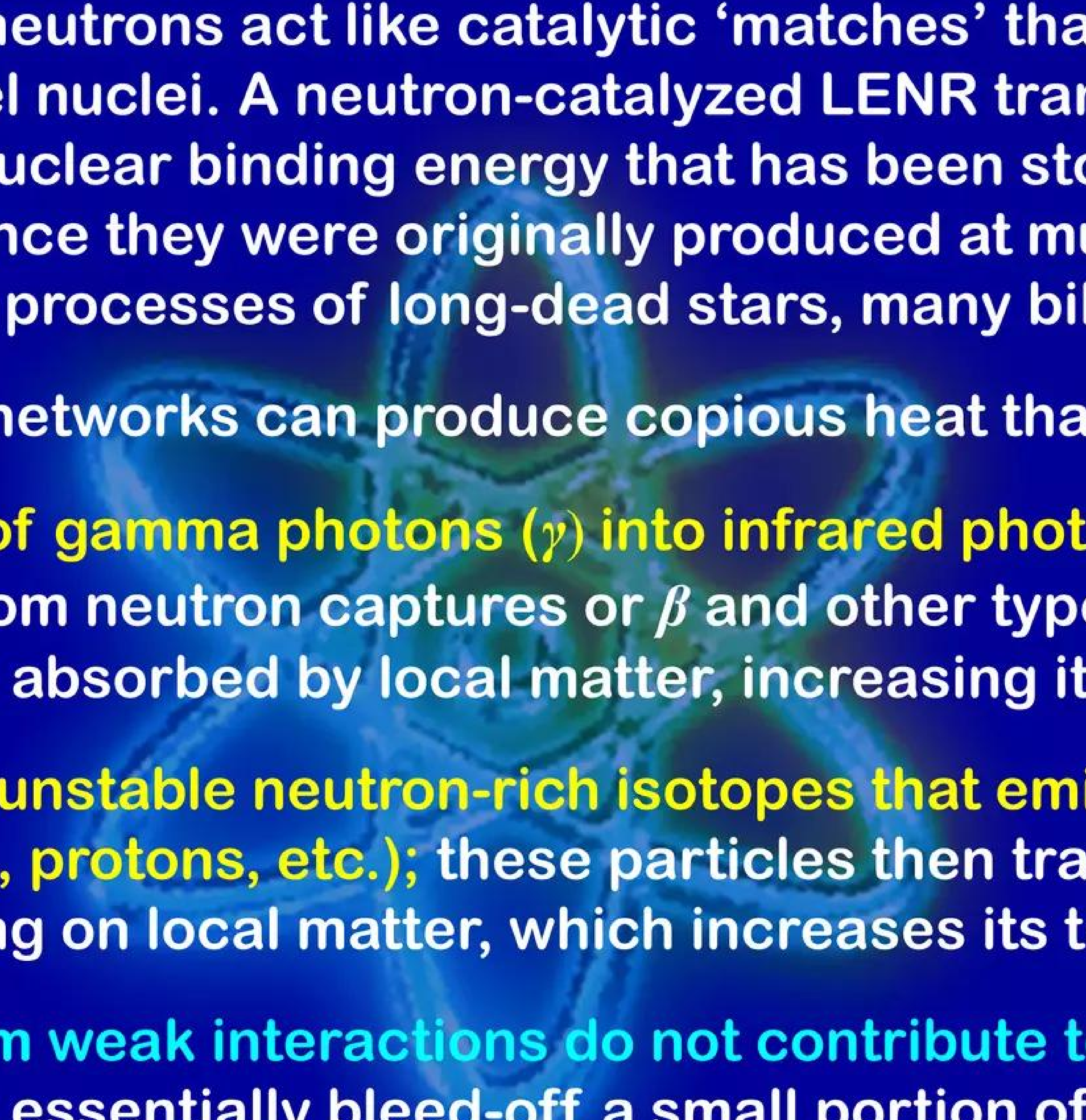
Collective many-body surface patches of protons can become LENR-active sites

1. Collectively oscillating, quantum mechanically entangled, many-body patches of Hydrogen (either +-charged protons or deuterons) will form spontaneously on metallic hydride surfaces or at certain types of interfaces, e.g. metal/oxide
2. Born-Oppenheimer approximation spontaneously breaks down, allows E-M coupling between local surface plasmon electrons and patch protons; application of input energy creates nuclear-strength local electric fields >2.5 x 10^{11} V/m - increases effective masses of surface plasmon electrons in patches
3. Heavy-mass surface plasmon electrons formed in many-body patches then react directly with electromagnetically interacting protons; process creates neutrons and neutrinos via many-body collective electroweak $e + p$ reaction
4. Neutrons collectively created in patch have ultralow kinetic energies and are all absorbed locally by nearby atoms - no dangerous energetic neutron fluxes escape apparatus; any locally produced or incident gammas are converted directly into safe infrared photons (heat) by unreacted heavy electrons (Lattice patent US# 7,893,414 B2) - no hard MeV-energy gamma emissions
5. Transmutation of elements and formation of craters at active sites begins

Release of nuclear binding energy produces usable heat

Several different mechanisms produce clean heat in LENR-active sites

Widom-Larsen explains what generates calorimetrically measured excess heat



- ✓ Conceptually, LENR neutrons act like catalytic ‘matches’ that are used to ‘light the logs’ of target fuel nuclei. A neutron-catalyzed LENR transmutation network operates to release nuclear binding energy that has been stored and locked away in nuclei ‘fuel logs’ since they were originally produced at multi-million degrees in fiery nucleosynthetic processes of long-dead stars, many billions of years ago
- ✓ LENR transmutation networks can produce copious heat that comes mainly from:
  - Direct conversion of gamma photons (γ) into infrared photons (IR) by heavy electrons; e.g., γ from neutron captures or β and other types of decays. IR is then scattered and absorbed by local matter, increasing its temperature (heat)
  - Nuclear decays of unstable neutron-rich isotopes that emit energetic particles (e.g., betas, alphas, protons, etc.); these particles then transfer their kinetic energy by scattering on local matter, which increases its temperature (heat)
- ✓ Neutrino photons from weak interactions do not contribute to any production of excess heat; they will essentially bleed-off a small portion of released nuclear binding energy outward into space; unavoidable neutrino emissions are part of the energetic cost of obtaining energy releases in LENR networks from β^- decays

W-L theory explains creation of LENR-active sites

Needed to produce neutrons that induce transmutation of elements

Hydrogen (protons or deuterons) and heavy-mass electrons are key reactants

- ✓ Substantial quantities of Hydrogen isotopes must be brought into intimate contact with fully-H-loaded metallic hydride-forming metals (or non-metals like Se); e.g., Palladium, Platinum, Rhodium, Nickel, Titanium , Tungsten, etc. Please note that collectively oscillating, 2-D surface plasmon (SP) electrons are intrinsically present and cover the surfaces of such metals. At full lattice loading (saturation) of Hydrogenous isotopes, many-body, collectively oscillating island-like LENR active sites comprised of protons p^+, deuterons d^+, or tritons t^+ will form spontaneously at random locations on surfaces
- ✓ Or, delocalized collectively oscillating π electrons comprising outer covering surfaces of fullerenes, graphene, benzene, and polycyclic aromatic hydrocarbon (PAH) molecules behave identically to SPs; when such molecules are hydrogenated, they create many-body, collectively oscillating, entangled quantum systems that per W-L theory are functionally equivalent molecular analogues of metal hydrides. In this case, LENRs are triggered on aromatic rings; strong tendency to transmute ring Carbons
- ✓ Born-Oppenheimer approximation breaks down in LENR active sites composed of nearly homogenous collections of collectively oscillating p^+, d^+, and/or t^+ ions; enables E-M coupling between nearby SP or π electrons and hydrogen ions at active sites and creates nuclear-strength local electric fields > 2 x 10^{11} V/m. Effective masses of electrons in such E-fields are increased to multiple of an electron at rest ($e \rightarrow e^*$) determined by required ~simultaneous energy input(s); called “mass renormalization”

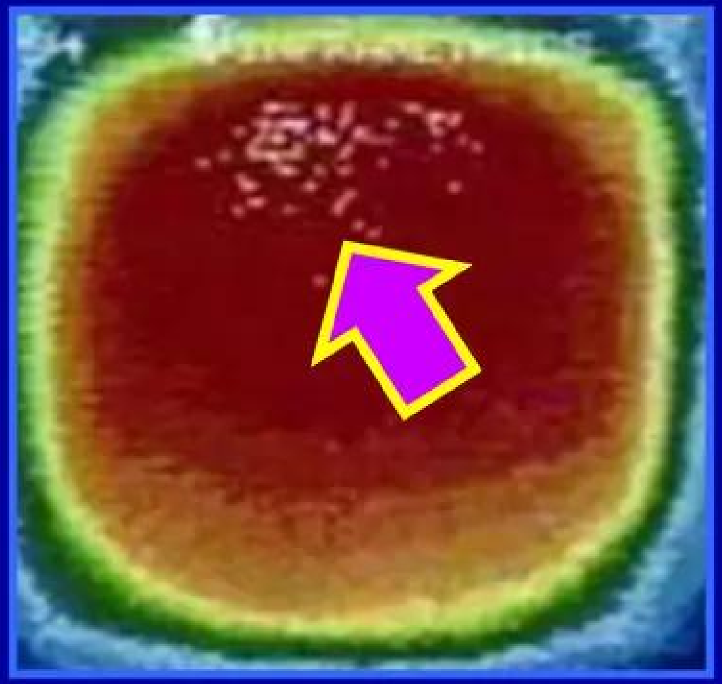
Widom-Larsen provides description for LENR-active sites

Size of these active sites ranges from 2 nanometers up to ~100^{+} microns

Active sites have limited lifetimes before being destroyed by fast nuclear heating

- ✓ Per Widom-Larsen theory LENRs occur in localized micron-scale LENR-active sites on ~planar surfaces: at certain types of interfaces\; or curved surfaces of various shaped nanoparticles
- ✓ Tiny LENR-active sites live for less than ~300 - 400 nanoseconds before being destroyed by intense heat; local peak temps range from 4,000 - 6,000º C; LENR-active sites spontaneously reform under right conditions in well-engineered LENR thermal devices
- ✓ Microscopic 100-micron LENR hotspot can release as much as several Watts of heat in < 400 nanoseconds; create crater-like features on surfaces that are visible in SEM images and show evidence for flash-boiling of both precious & refractory metals
- ✓ Peak local LENR power density in microscopic LENR-active sites can hit > 1.0 x 10^{21} Joules/sec·m^3 during brief lifetimes
- ✓ Control macroscopic-scale temperatures in LENR systems by tightly regulating total input energy and/or total area/volumetric densities of LENR-active sites present in the reaction chambers

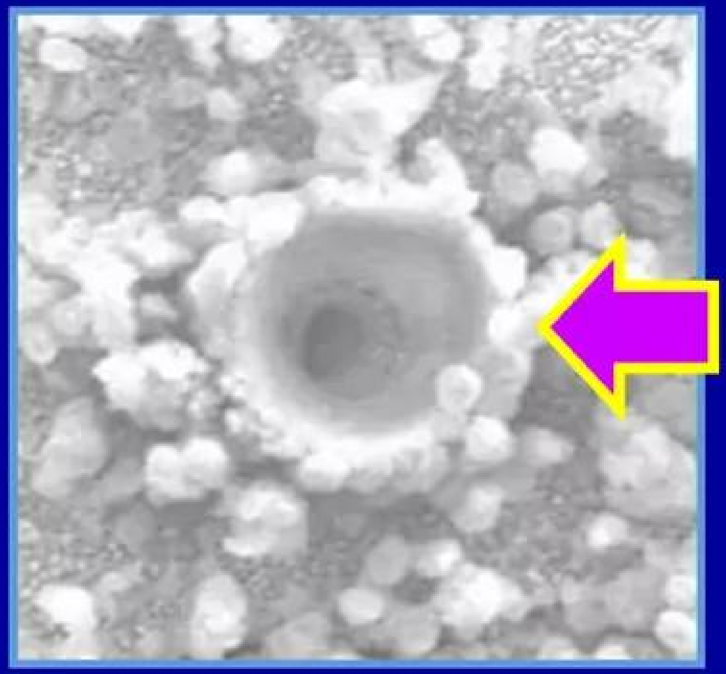
LENR hotspots on Pd cathode
Infrared video of LENR hotspots



Credit: P. Boss, U.S. Navy

http://www.youtube.com/watch?v=OUVmOQXBS68

100 μ LENR crater in Palladium
Electrochemical LENR cell



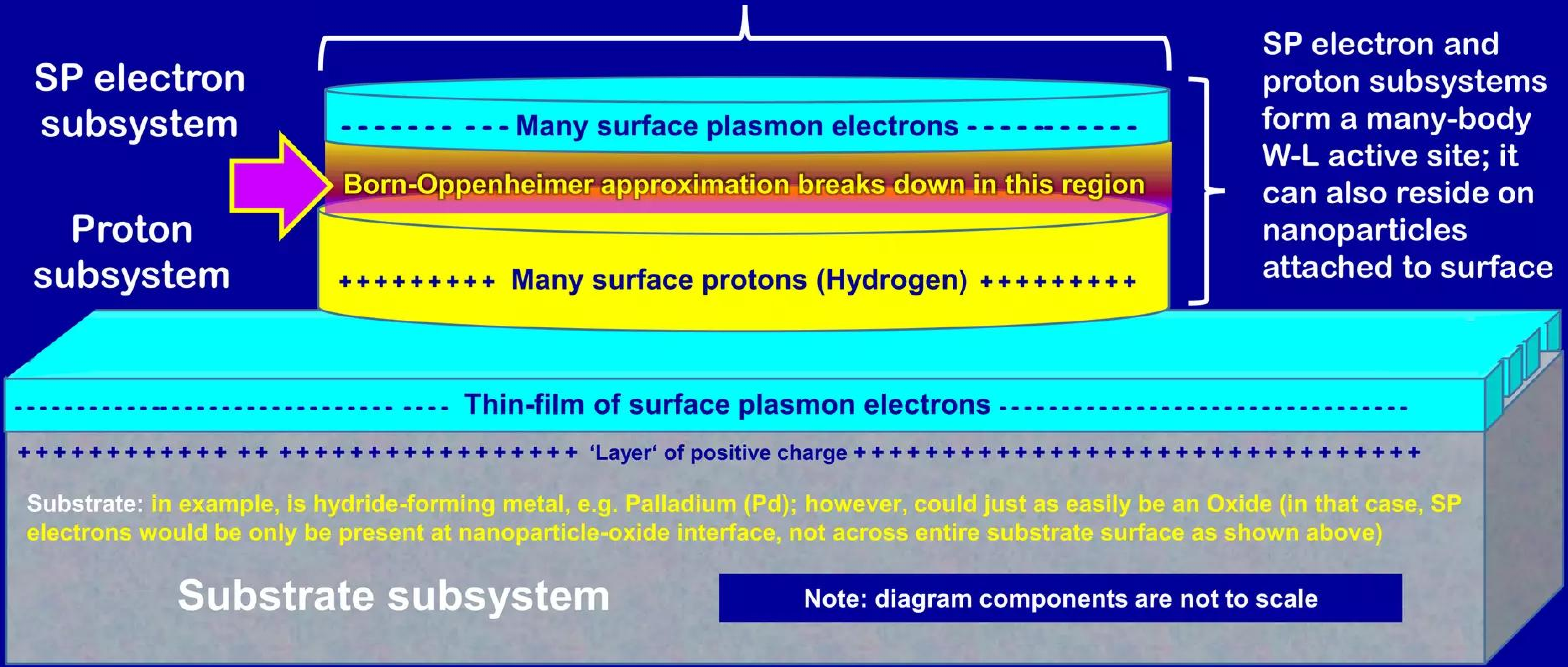
Credit: P. Boss, U.S. Navy

W-L concept of a microscopic LENR-active surface site

Comprised of many-body patches of protons and electrons on surface

SP electrons and protons oscillate collectively and are mutually Q-M entangled

Diameters of many-body active sites randomly range from several *nm* up to ~ 100^+ microns



Input energy creates high electric fields in LENR active sites

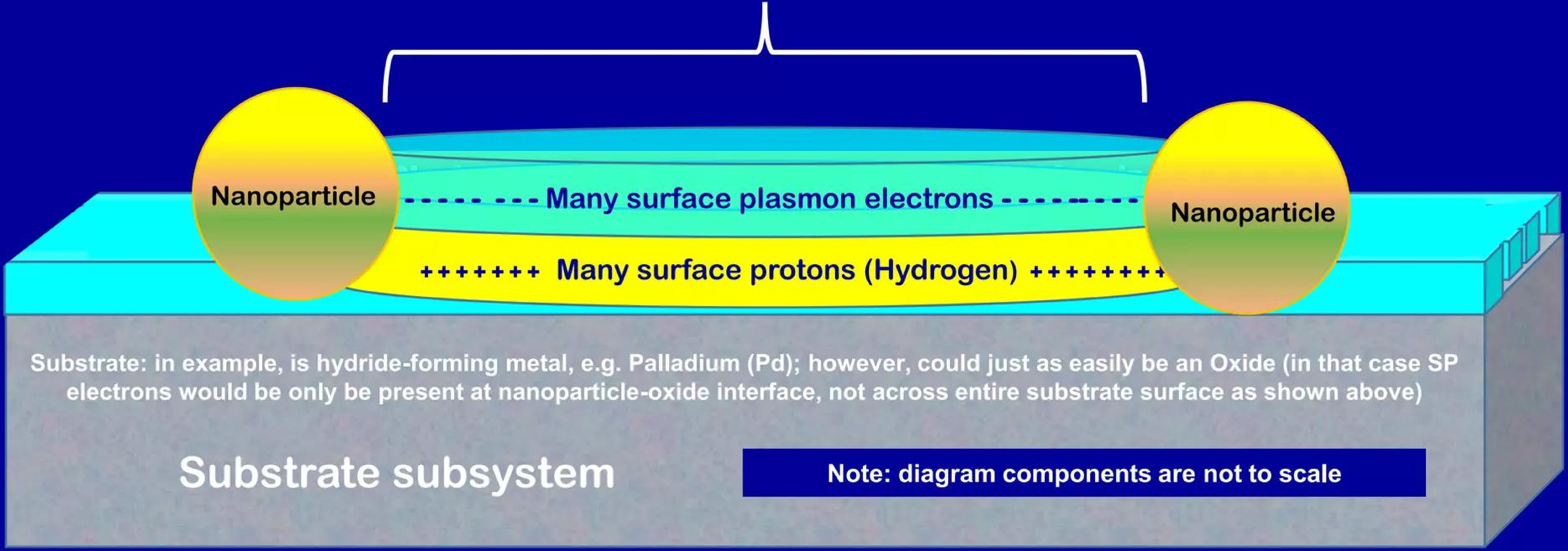
Born-Oppenheimer breakdown enables nuclear-strength local E-field

Huge electric field increase effective masses of some patch SP electrons

Correct input energies create huge local E-fields > 2.5 x 10^{11} V/m between adjacent nanoparticles

Input energy$_{\text{E-field}}$ + $e^{-}_{sp} \rightarrow e^{-*}_{sp} + p^{+} \rightarrow n + \nu_e$ [condensed matter surfaces]

Single nascent LENR-active site



Substrate: in example, is hydride-forming metal, e.g. Palladium (Pd); however, could just as easily be an Oxide (in that case SP electrons would be only be present at nanoparticle-oxide interface, not across entire substrate surface as shown above)

Substrate subsystem

Note: diagram components are not to scale

LENRs occur in microscopic active sites found on surfaces

Many-body collections of protons and electrons form spontaneously

Ultralow energy neutrons produced & captured close to LENR-active sites

After being produced, neutrons capture on targets in/around active sites

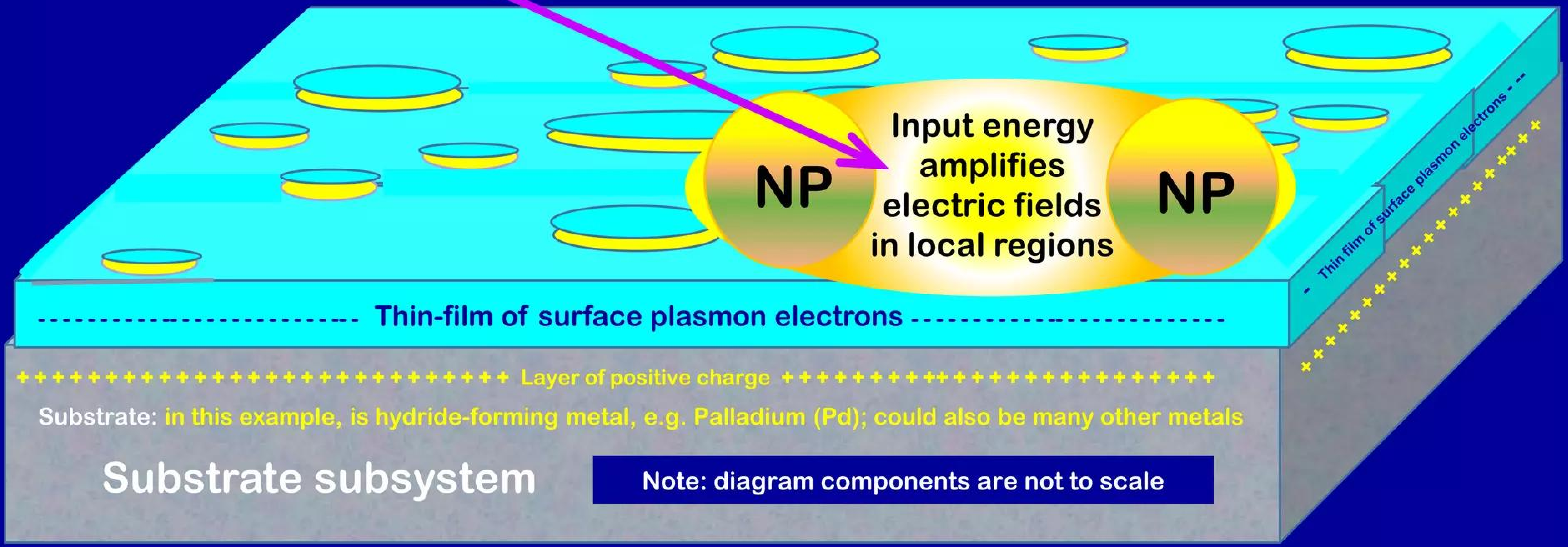
Intense heating in LENR-active sites will form μ-scale event craters on substrate surfaces

$n + (Z, A) \rightarrow (Z, A+1)$ [neutrons capture on nearby target atoms]

$(Z, A+1) \rightarrow (Z + 1, A+1) + e_{\beta}^{-} + \nu_e$ [beta^{-} decay]

Often followed by β^{-} decays of neutron-rich intermediate isotopic products

● = Metallic nanoparticle (NP)

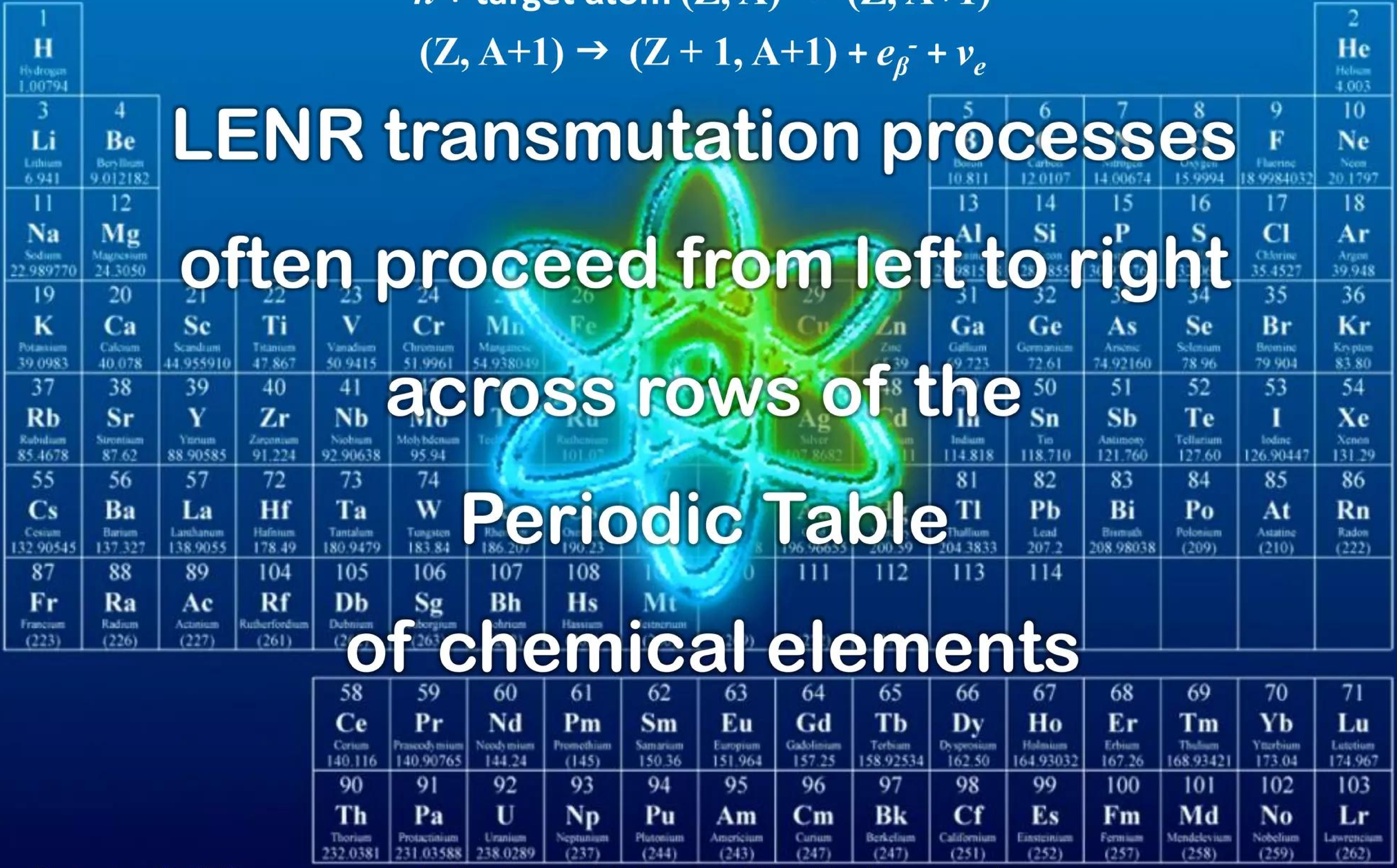


Neutrons are charge-neutral; atoms readily absorb them

Capture of neutrons by atoms will transmute them into other isotopes

$$n + \text{target atom } (Z, A) \rightarrow (Z, A+1)$$

$$(Z, A+1) \rightarrow (Z + 1, A+1) + e_{\beta}^{-} + \nu_e$$

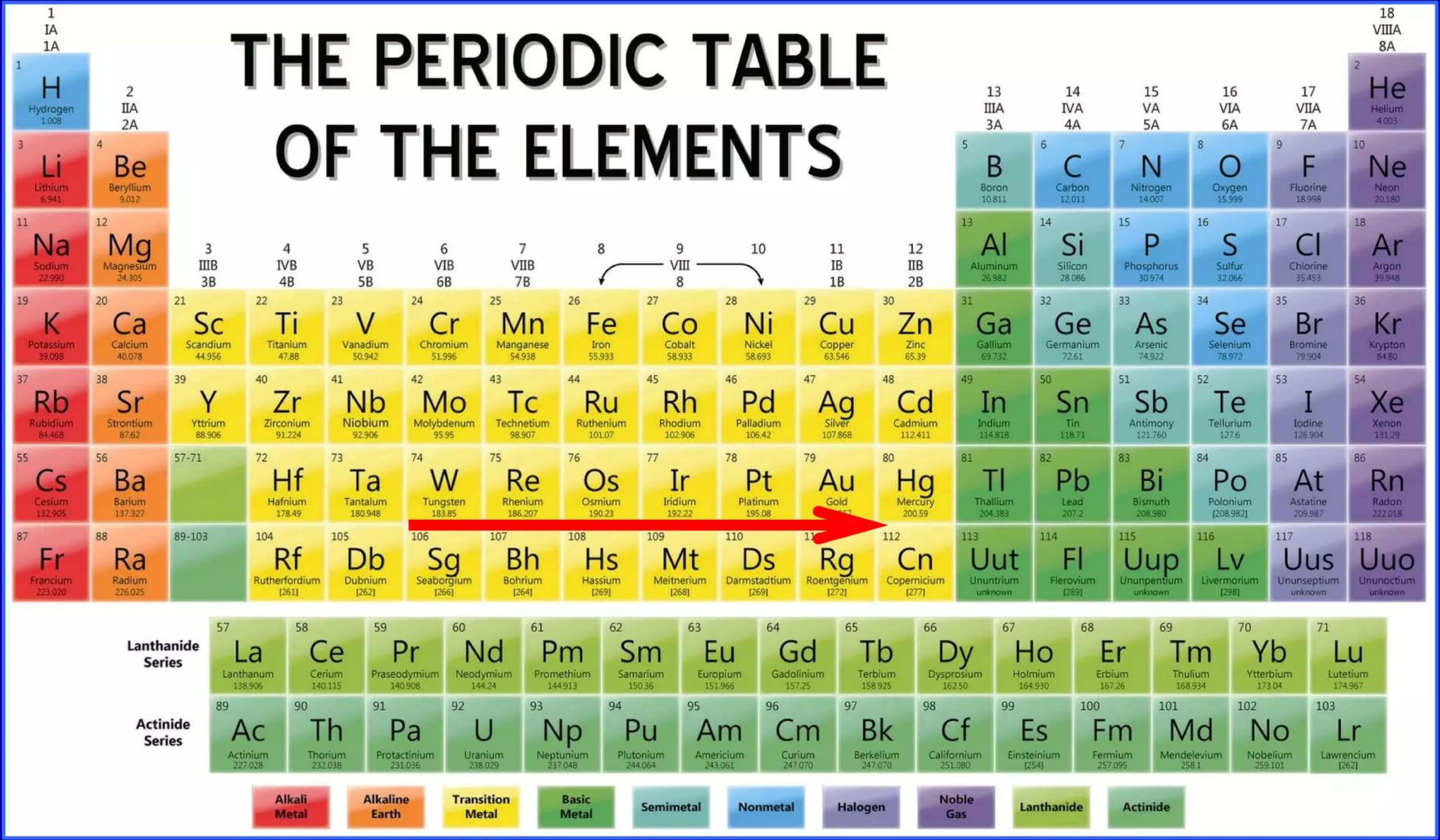


LENR transmutation processes often proceed from left to right across rows of the Periodic Table of chemical elements

LENR transmutations traverse rows from left-to-right

Neutron capture by elements transmutes them into different elements

Tungsten (W) → Rhenium → Osmium → Iridium → Platinum → Gold (Au)



THE PERIODIC TABLE OF THE ELEMENTS

1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.972	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold [illegible]	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	11 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

Lanthanide Series	57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

LENR nucleosynthetic networks can transmute elements

Legend

Neutron captures proceed from left to right denoted by green horizontal arrow; Q-value of capture reaction (MeV) is above or below horizontal arrow. →

Beta$^-$ (β^-) decays proceed from top to bottom; denoted with bright blue vertical arrow pointing down with Q-value (MeV) in blue either to left or right; beta$^+$ (β^+) decays are denoted with yellow arrow pointing upward to row above ↓ ↑

Alpha decays indicated with orange arrows, proceed mostly from right to left at angle with its Q-value (MeV) located on either side of process arrow. ↖

Electron captures (e.c.) shown by purple vertical arrow; Q-value at left or right. ↑

Except where specifically listed because branching cross-section is significant, beta-delayed decays not shown; BR means "branching ratio" if >1 decay alternative

When known, half-lives are shown as "HL = xx". Stable and quasi-stable isotopes (i.e., those with half-lives > or equal to 10^7 years) indicated by green boxes; unstable isotopes are denoted by purplish boxes; those with half-lives of < 1 day are in yellow

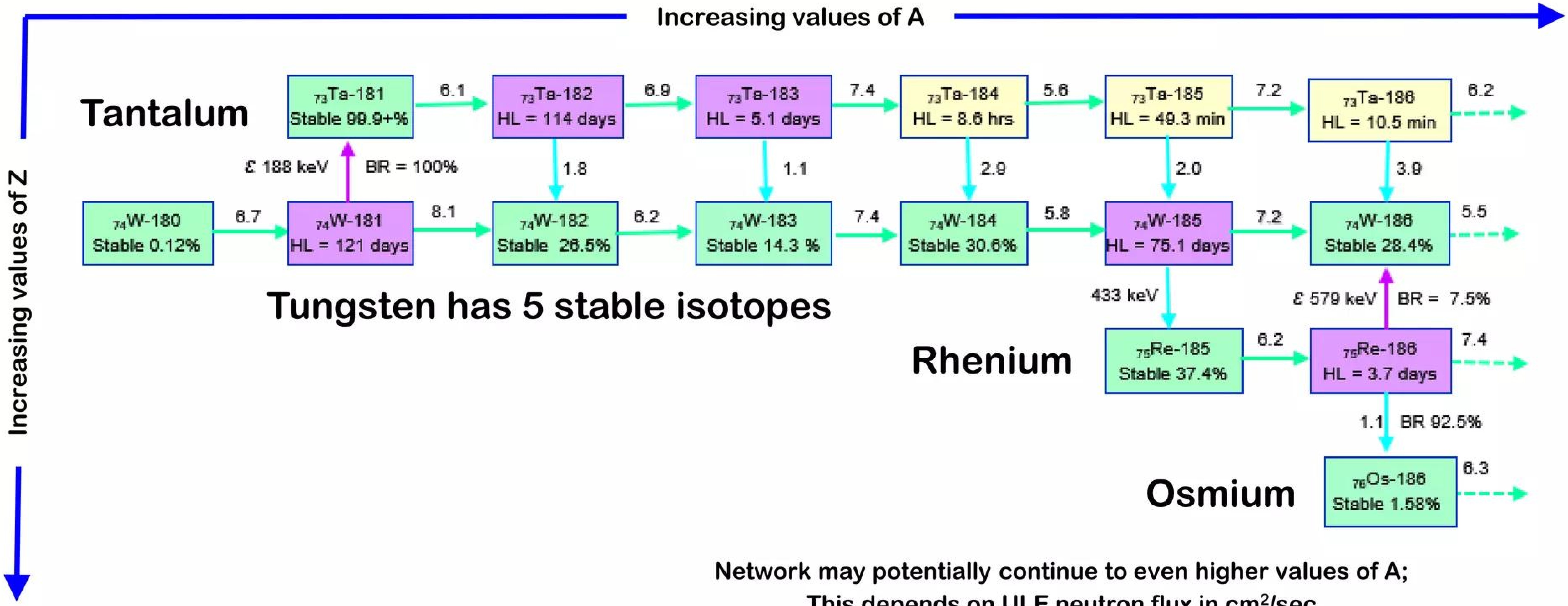
Natural terrestrial abundances for stable isotopes indicated with % symbol

LENR nucleosynthetic network can transmute W into Au

Network proceeds with combination of neutron captures and beta decays

Tungsten (W) → Rhenium → Osmium → Iridium → Platinum → Gold (Au)

Start LENR process with stable isotopes of pure Tungsten (W) metal



Increasing values of A

Increasing values of Z

Tantalum

$_{73}$Ta-181 Stable 99.9+% → 6.1 → $_{73}$Ta-182 HL = 114 days → 6.9 → $_{73}$Ta-183 HL = 5.1 days → 7.4 → $_{73}$Ta-184 HL = 8.6 hrs → 5.6 → $_{73}$Ta-185 HL = 49.3 min → 7.2 → $_{73}$Ta-186 HL = 10.5 min → 6.2

£ 188 keV BR = 100%

1.8

1.1

2.9

2.0

3.9

$_{74}$W-180 Stable 0.12% → 6.7 → $_{74}$W-181 HL = 121 days → 8.1 → $_{74}$W-182 Stable 26.5% → 6.2 → $_{74}$W-183 Stable 14.3 % → 7.4 → $_{74}$W-184 Stable 30.6% → 5.8 → $_{74}$W-185 HL = 75.1 days → 7.2 → $_{74}$W-186 Stable 28.4% → 5.5

Tungsten has 5 stable isotopes

433 keV

£ 579 keV BR = 7.5%

Rhenium

$_{75}$Re-185 Stable 37.4% → 6.2 → $_{75}$Re-186 HL = 3.7 days → 7.4

1.1 BR 92.5%

Osmium

$_{76}$Os-186 Stable 1.58% → 6.3

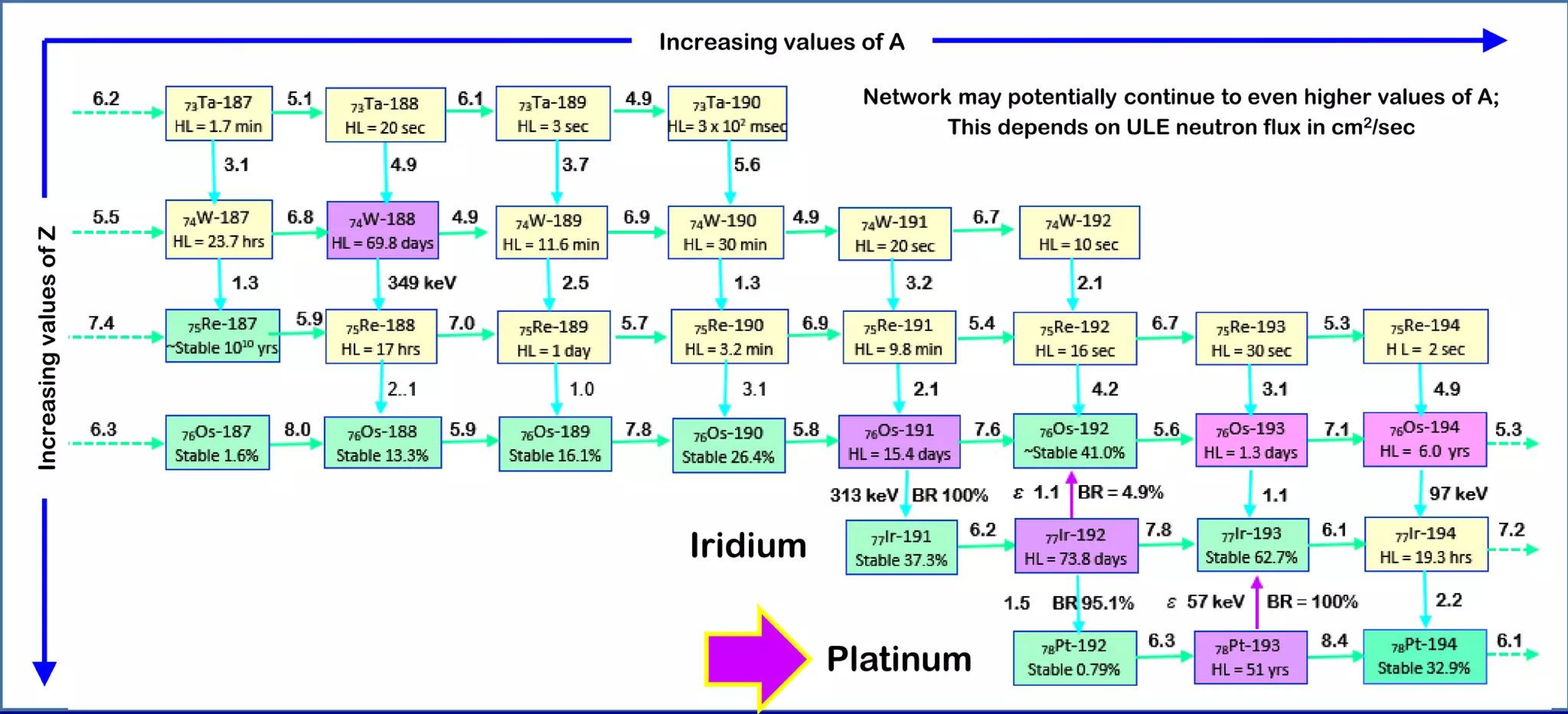
Network may potentially continue to even higher values of A;
This depends on ULE neutron flux in cm^2/sec

Note: certain isotopes have small cross-sections for alpha decay upon capturing one neutron. To improve legibility and reduce visual clutter, these are not shown on this transmutation network diagram

LENR nucleosynthetic network can transmute W into Au

Osmium also produced via α-decay of Pt isotopes after neutron capture

Tungsten (W) → Rhenium → Osmium → Iridium → Platinum → Gold (Au)



Increasing values of A

Increasing values of Z

Network may potentially continue to even higher values of A;
This depends on ULE neutron flux in cm²/sec

6.2 → $_{73}$Ta-187 HL = 1.7 min → 5.1 → $_{73}$Ta-188 HL = 20 sec → 6.1 → $_{73}$Ta-189 HL = 3 sec → 4.9 → $_{73}$Ta-190 HL= 3 x 10^2 msec

3.1 4.9 3.7 5.6

5.5 → $_{74}$W-187 HL = 23.7 hrs → 6.8 → $_{74}$W-188 HL = 69.8 days → 4.9 → $_{74}$W-189 HL = 11.6 min → 6.9 → $_{74}$W-190 HL = 30 min → 4.9 → $_{74}$W-191 HL = 20 sec → 6.7 → $_{74}$W-192 HL = 10 sec

1.3 349 keV 2.5 1.3 3.2 2.1

7.4 → $_{75}$Re-187 ~Stable 10^{10} yrs → 5.9 → $_{75}$Re-188 HL = 17 hrs → 7.0 → $_{75}$Re-189 HL = 1 day → 5.7 → $_{75}$Re-190 HL = 3.2 min → 6.9 → $_{75}$Re-191 HL = 9.8 min → 5.4 → $_{75}$Re-192 HL = 16 sec → 6.7 → $_{75}$Re-193 HL = 30 sec → 5.3 → $_{75}$Re-194 H L = 2 sec

2..1 1.0 3.1 2.1 4.2 3.1 4.9

6.3 → $_{76}$Os-187 Stable 1.6% → 8.0 → $_{76}$Os-188 Stable 13.3% → 5.9 → $_{76}$Os-189 Stable 16.1% → 7.8 → $_{76}$Os-190 Stable 26.4% → 5.8 → $_{76}$Os-191 HL = 15.4 days → 7.6 → $_{76}$Os-192 ~Stable 41.0% → 5.6 → $_{76}$Os-193 HL = 1.3 days → 7.1 → $_{76}$Os-194 HL = 6.0 yrs → 5.3

313 keV BR 100% ε 1.1 BR = 4.9% 1.1 97 keV

Iridium

$_{77}$Ir-191 Stable 37.3% → 6.2 → $_{77}$Ir-192 HL = 73.8 days → 7.8 → $_{77}$Ir-193 Stable 62.7% → 6.1 → $_{77}$Ir-194 HL = 19.3 hrs → 7.2

1.5 BR 95.1% ε 57 keV BR = 100% 2.2

Platinum

$_{78}$Pt-192 Stable 0.79% → 6.3 → $_{78}$Pt-193 HL = 51 yrs → 8.4 → $_{78}$Pt-194 Stable 32.9% → 6.1

Note: certain isotopes have small cross-sections for alpha decay upon capturing one neutron. To improve legibility and reduce visual clutter, these are not shown on this transmutation network diagram

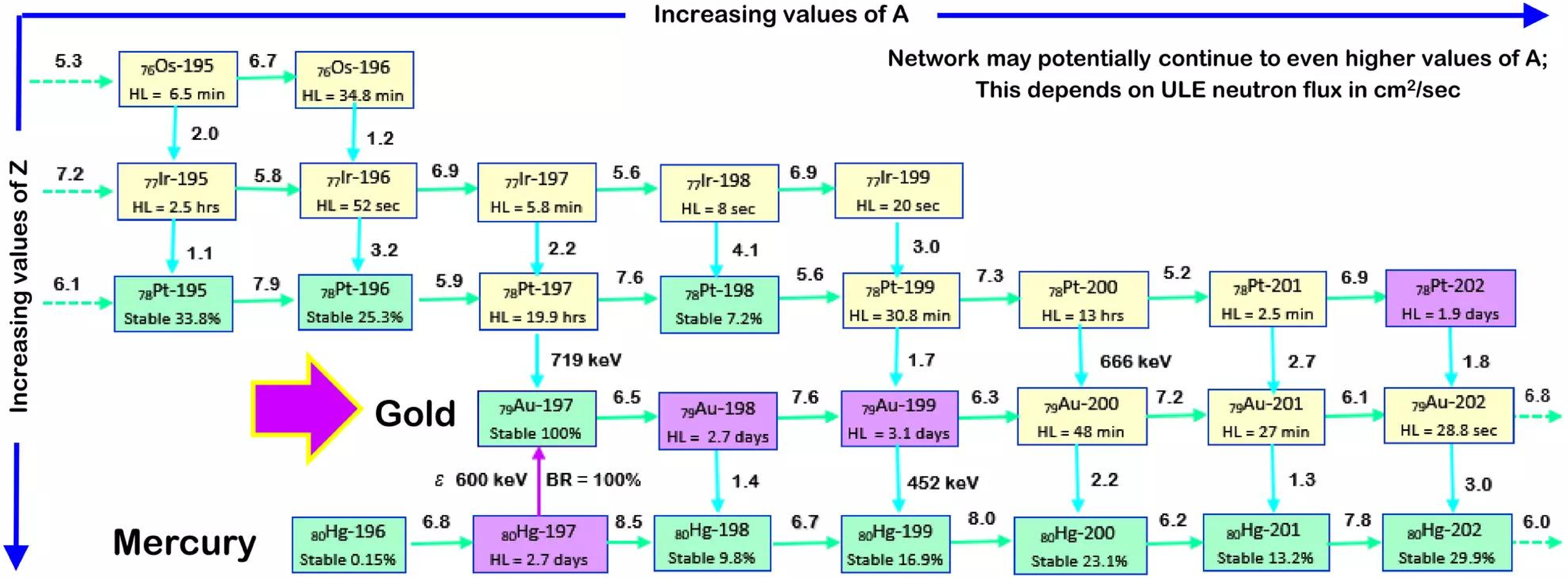
LENR nucleosynthetic network can transmute W into Au

Transmutation network also produces Rhenium, Iridium, and Mercury

Tungsten (W) → Rhenium → Osmium → Iridium → Platinum → Gold (Au)

Increasing values of A

Network may potentially continue to even higher values of A; This depends on ULE neutron flux in cm^2/sec

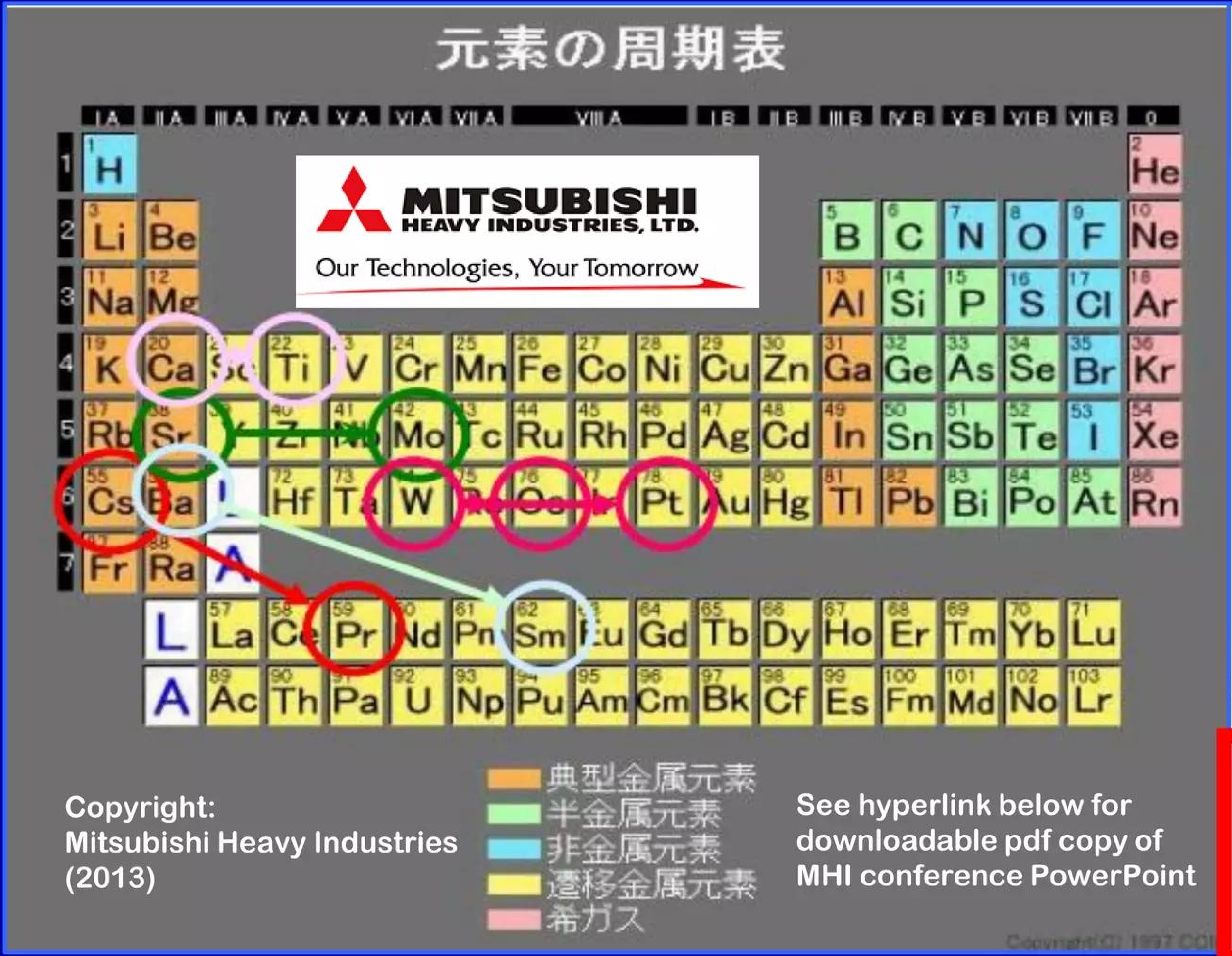


Note: certain isotopes have small cross-sections for alpha decay upon capturing one neutron. To improve legibility and reduce visual clutter, these are not shown on this transmutation network diagram

Mitsubishi Heavy Industries transmuted W to Os and Pt

Utilized apparatus that functioned as resonant electromagnetic cavity

All MHI's data is explained by Widom-Larsen with neutron captures and *β* decays



Copyright:
Mitsubishi Heavy Industries
(2013)

See hyperlink below for
downloadable pdf copy of
MHI conference PowerPoint

$$^{133}_{55}Cs \rightarrow {}^{141}_{59}Pr$$

$$^{88}_{38}Sr \rightarrow {}^{96}_{42}Mo$$

$$^{138}_{56}Ba \rightarrow {}^{150}_{62}Sm$$

$$^{137}_{56}Ba \rightarrow {}^{149}_{62}Sm$$

$$^{44}_{20}Ca \rightarrow {}^{48}_{22}Ti$$

$$^{184}_{74}W \rightarrow {}^{188}_{76}Os$$

$$^{182}_{74}W \rightarrow {}^{190}_{78}Pt$$

https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/36792/RecentAdvancesDeuteriumPermeationPresentation.pdf?sequence=1

Toyota repeated Mitsubishi's LENR transmutation of Cs → Pr

Apparatus utilized functioned as resonant electromagnetic LENR cavity

Element/isotope quantities vary on μ-scale because LENR active sites are tiny

"Inductively coupled plasma mass spectrometry study on the increase in the amount of Pr atoms for Cs-ion-implanted Pd/CaO multilayer complex with Deuterium permeation"
T. Hioki et al. *Japanese Journal of Applied Physics* 52 pp. 107301-1 to 107301-8 (2013)

http://iopscience.iop.org/1347-4065/52/10R/107301/

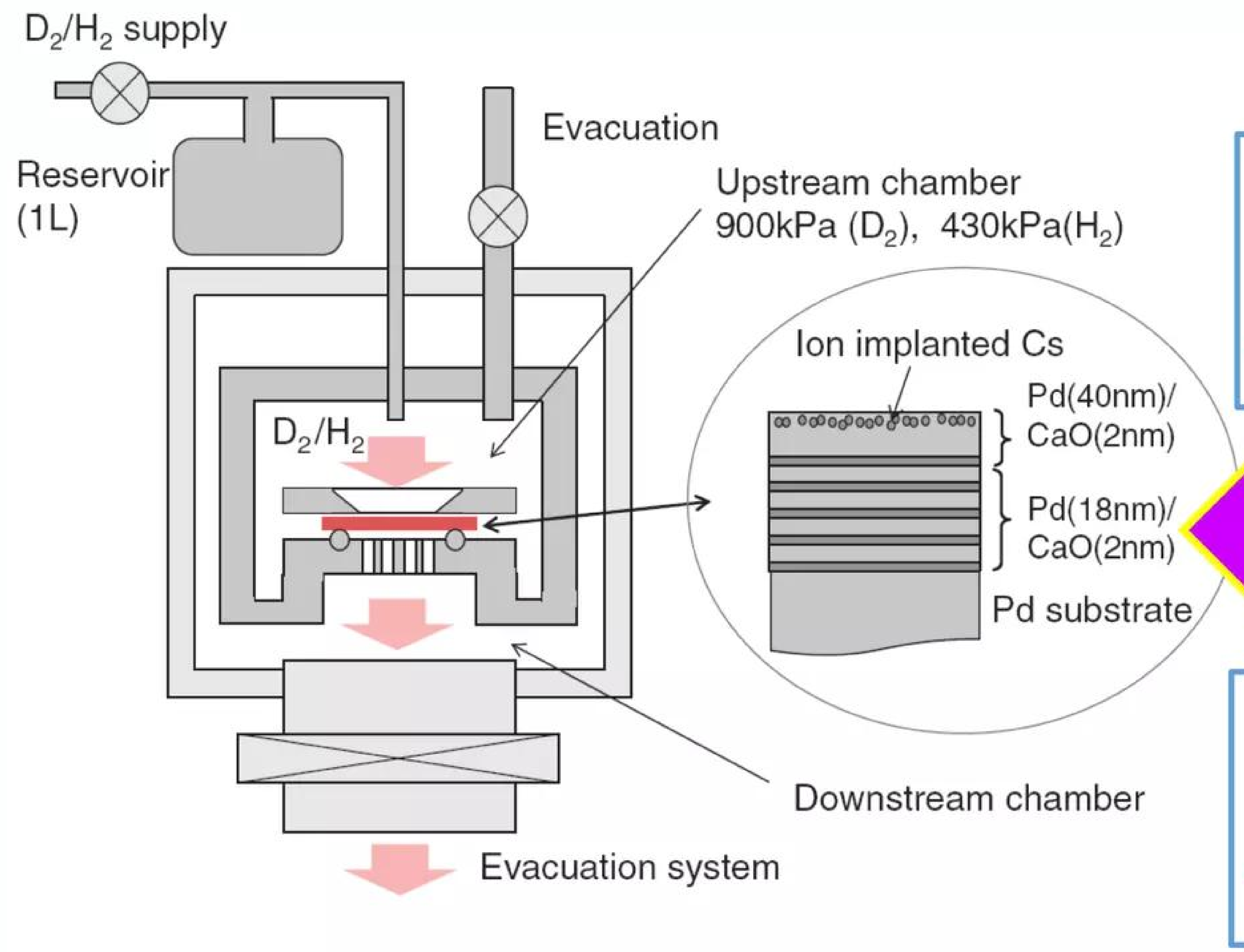


Fig. 1. (Color) Schematics of deuterium (/hydrogen) permeation system and Cs-ion-implanted Pd/CaO multilayer complex.

Figs. 1 and 3 reproduced from *JJAP* (2013) paper by T. Hioki *et al.*

TOYOTA

TEM

MITSUBISHI

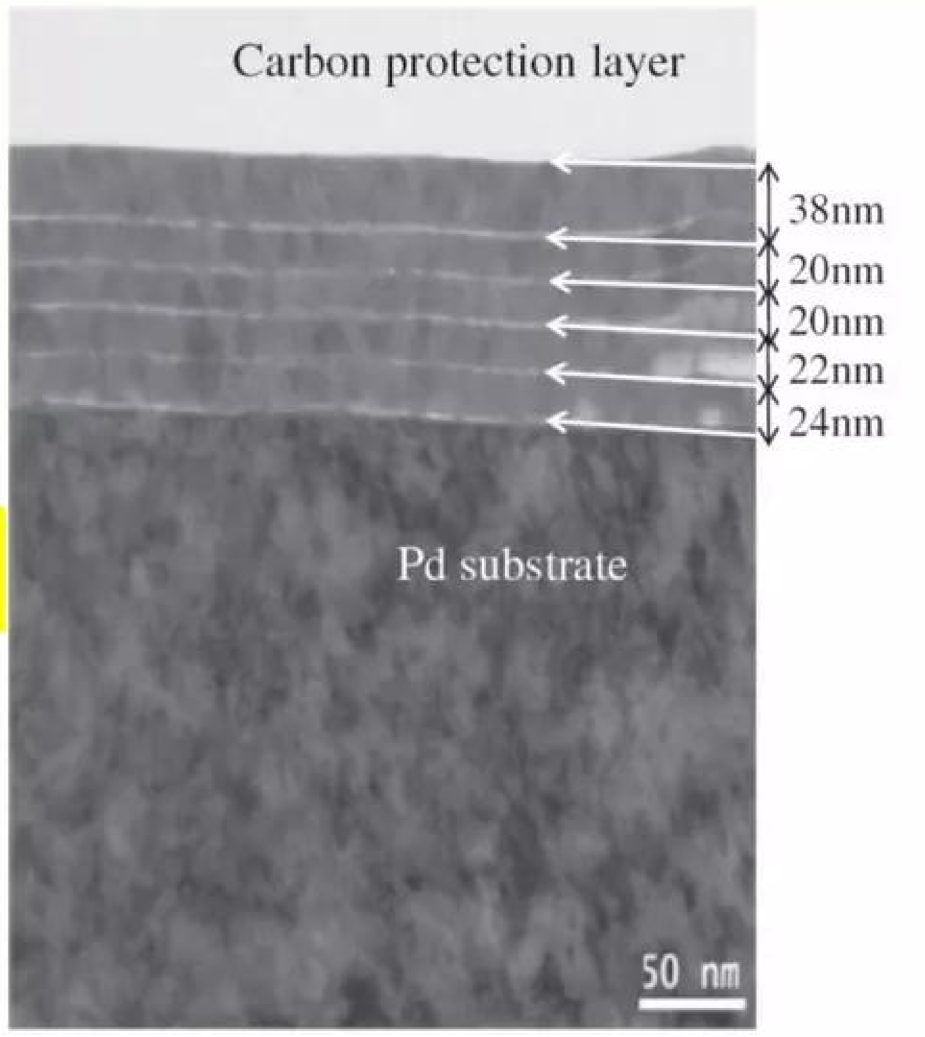


Fig. 3. Cross-sectional TEM view of the Pd/CaO multilayer complex.

Condensed matter LENR-active sites size from 2 nm to ~100μ

LENRs create heterogeneous elemental compositions on μ length-scales

Mitsubishi Heavy Industries has observed this effect while transmuting Cs ➔ Pr

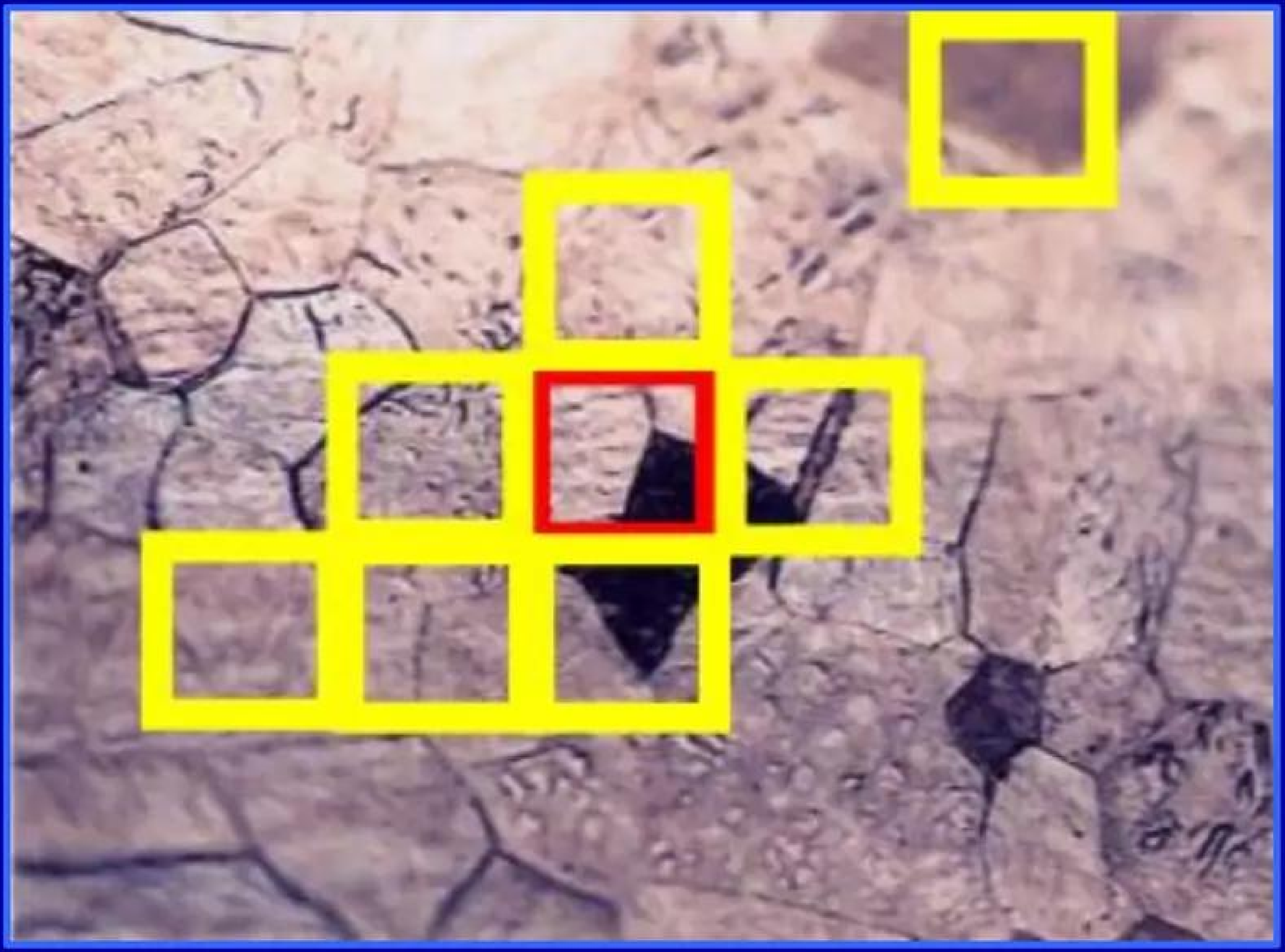
Experimental apparatus in these studies functioned as resonant electromagnetic cavity

$$^{133}_{55}Cs \rightarrow {}^{141}_{59}\mathrm{Pr}$$

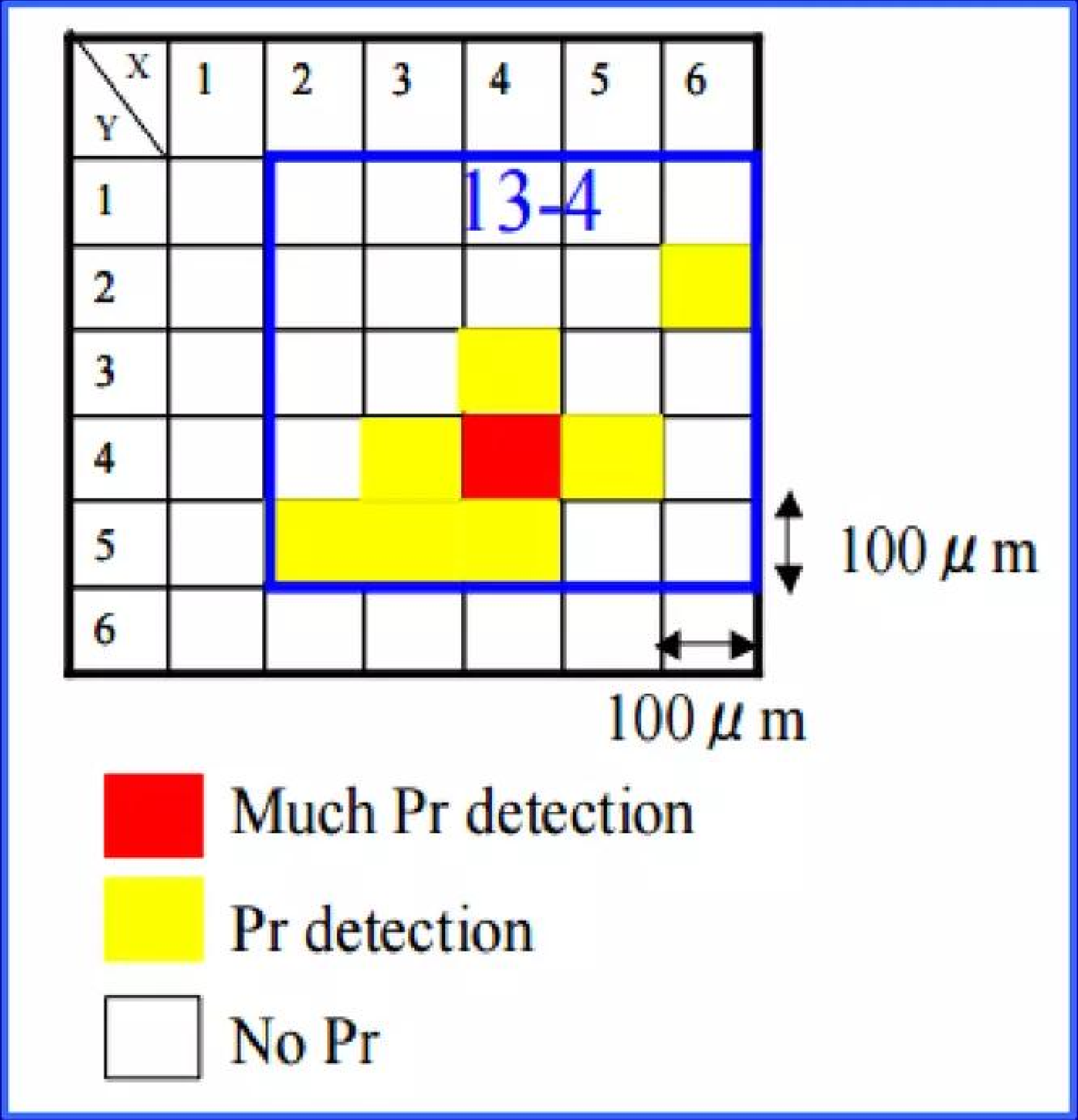
MITSUBISHI HEAVY INDUSTRIES, LTD.
Our Technologies, Your Tomorrow

Implanted Cesium ↓ Praseodymium

Surface of thin-film Pd/oxide heterostructure after experiment



Credit: Mitsubishi Heavy Industries



Y \ X	1	2	3	4	5	6
1	☐	☐	☐	☐	☐	☐
2	☐	☐	☐	☐	☐	🟨
3	☐	☐	☐	🟨	☐	☐
4	☐	☐	🟨	🟥	🟨	☐
5	☐	🟨	🟨	🟨	☐	☐
6	☐	☐	☐	☐	☐	☐

🟥 Much Pr detection
🟨 Pr detection
☐ No Pr

See Slide #44 in the following Mitsubishi PowerPoint conference presentation (2013):

http://tinyurl.com/zcr3azt

Osmium is unexpectedly being emitted in vehicular exhaust

Few industrial uses; many believe is impurity in Platinum group metals

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

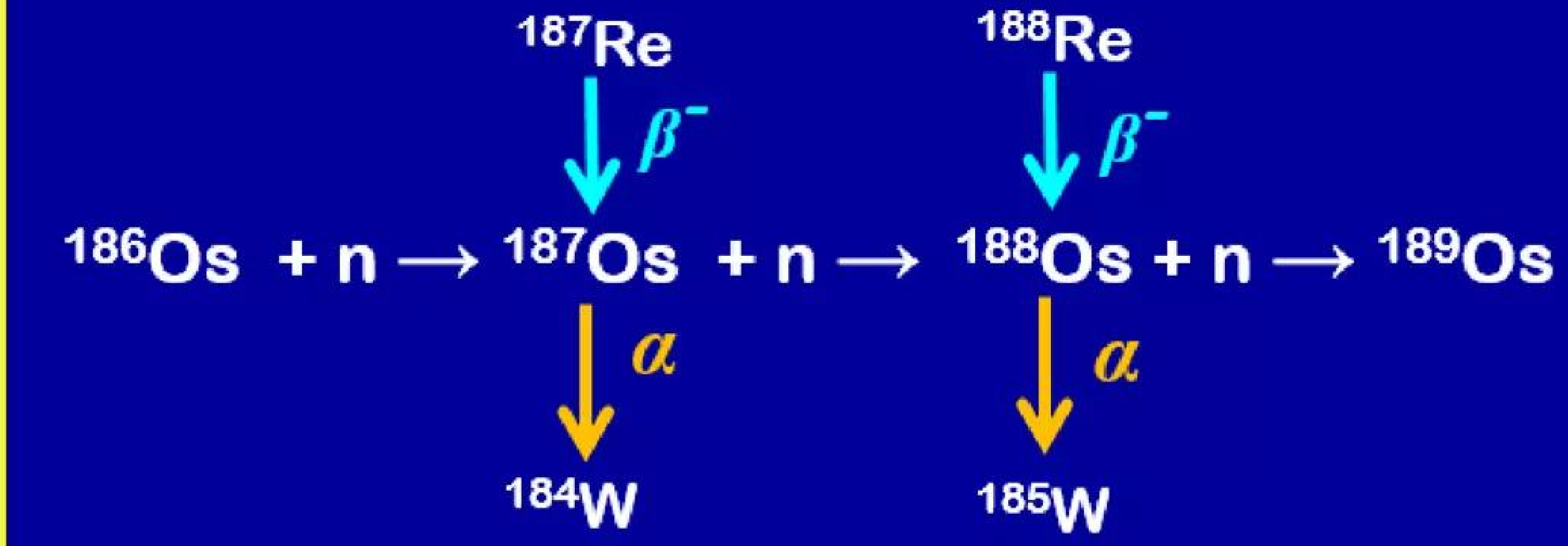
- ✓ Natural abundances of stable Osmium isotopes are as follows: ^{184}Os = 0.020%; ^{186}Os = 1.58%; ^{187}Os = 1.6%; ^{188}Os = 13.3% ; ^{189}Os = 16.1%; ^{190}Os = 26.4%; and ^{192}Os = 41.0%
- ✓ ^{185}Os - unstable, h.l. = 93.6 days, decays via electron capture into stable ^{185}Re – Rhenium, nat.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

LENR transmutation network can alter ^{187}Os/^{188}Os ratio

Measured value for ratio can vary greatly depending on reaction rates

- ✓ As explained by Shirey & Walker (1998), the ^{187}Os/^{188}Os ratio is widely measured and utilized in various types of environmental isotopic studies. Scientists making such measurements assume that: (a) ^{188}Os is not being presently produced via nucleosynthetic processes anywhere on earth or its immediate environs; and, (b) the *only* source of newly produced atoms of ^{187}Os in the terrestrial environment is radiogenic β^- decay of ^{187}Re to ^{187}Os
- ✓ These assumptions will be violated in operating catalytic converters that are functioning as resonant electromagnetic cavities. According to W-L theory of LENRs, it is quite possible that some or all of following possible LENR nuclear transmutation pathways could be occurring simultaneously at very low rates in μ-scale active sites on surfaces inside catalytic converters and in high-heat industrial processes (e.g. smelting) wherein Hydrogen moieties are present:

Measured ^{187}Os/^{188}Os ratio could vary greatly on either macroscopic or microscopic length-scales depending on the relative rates for each of these three different types of competing nuclear reactions



C. Chen et al. measure $^{187}Os/^{188}Os$ in many environments

Qi et al. report great variability at different locations in 3 Chinese cities

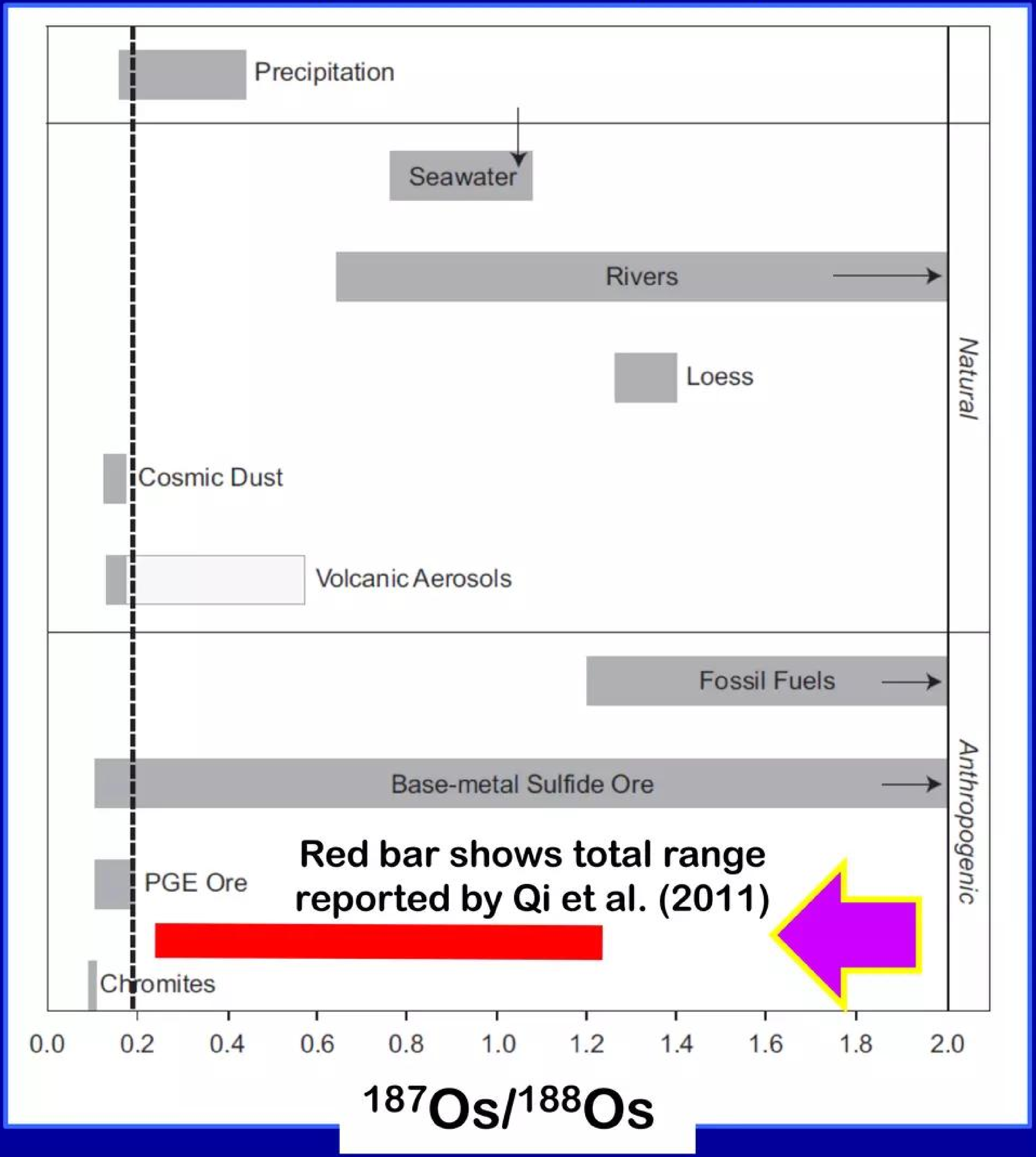
http://www.pnas.org/content/106/19/7724.full.pdf

"Anthropogenic Osmium in rain and snow reveals global-scale atmospheric contamination"
C. Chen et al.
PNAS 106 pp. 7724 - 7728 (2009)

Fig. 1. "Comparison of the Os isotope ratios of potential atmospheric sources with values measured in precipitation. Dashed line represents the unradiogenic endmember estimated from the y-intercept of the mixing line (Fig. 2)."

Note: range of measured values for the $^{187}Os/^{188}Os$ ratio in different environments and materials begins at ~ .10 ("unradiogenic") and extends up to maximum of 2.0 Ratio values of ~ 1.0 and higher are considered to be "radiogenic"

Fig. 1 Chen et al. (2009)



Red bar shows total range reported by Qi et al. (2011)

Poirier & Gariepy measure Osmium isotopes in converters

Recycled catalyst metals: higher ppt Osmium concentration vs. pristine

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

https://www.researchgate.net/publication/7697491_Isotopic_Signature_and_Impact_of_Car_Catalysts_on_the_Anthropogenic_Osmium_Budget

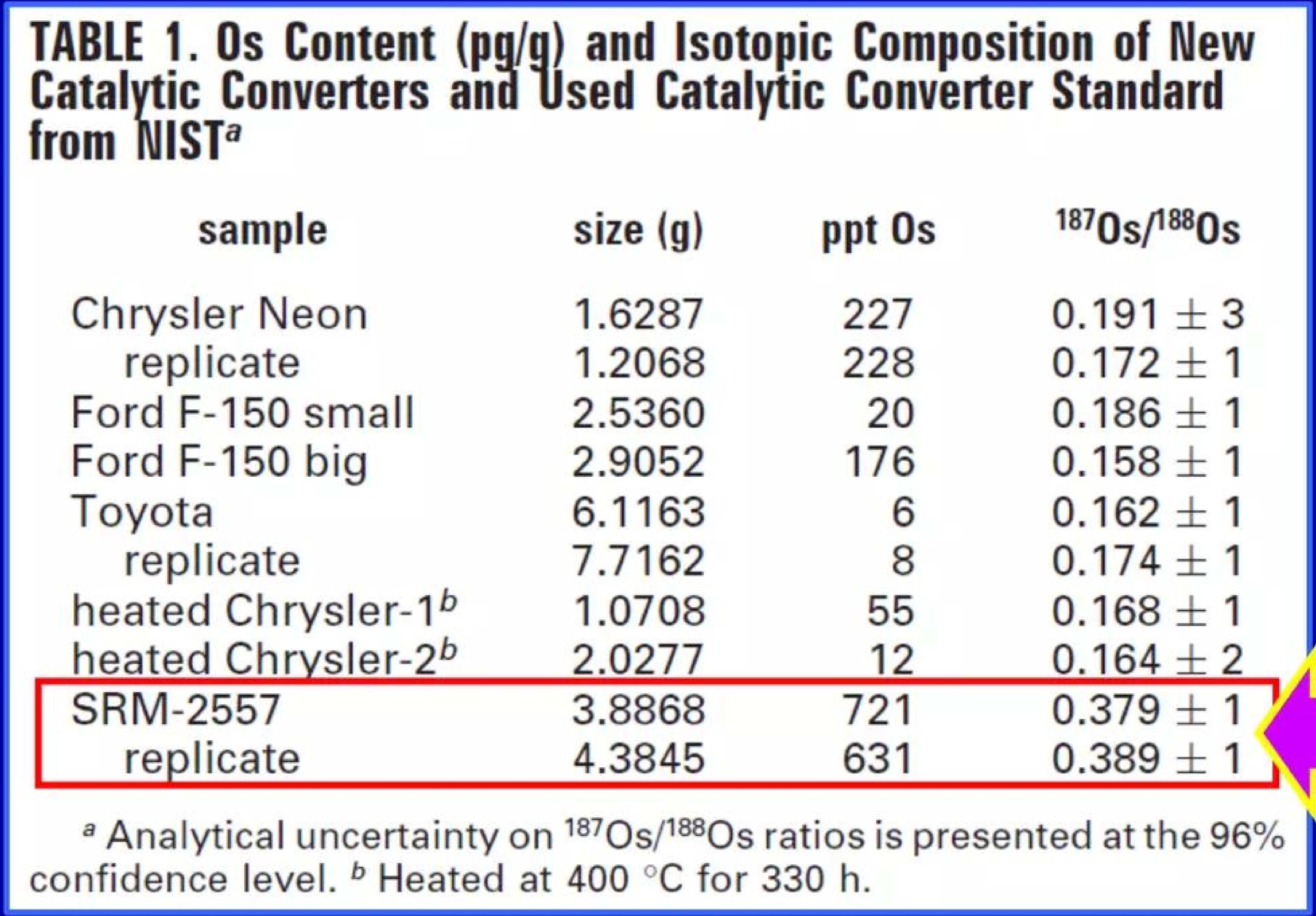


TABLE 1. Os Content (pg/g) and Isotopic Composition of New Catalytic Converters and Used Catalytic Converter Standard from NIST[a]

sample	size (g)	ppt Os	^{187}Os/^{188}Os
Chrysler Neon	1.6287	227	0.191 ± 3
replicate	1.2068	228	0.172 ± 1
Ford F-150 small	2.5360	20	0.186 ± 1
Ford F-150 big	2.9052	176	0.158 ± 1
Toyota	6.1163	6	0.162 ± 1
replicate	7.7162	8	0.174 ± 1
heated Chrysler-1[b]	1.0708	55	0.168 ± 1
heated Chrysler-2[b]	2.0277	12	0.164 ± 2
SRM-2557	3.8868	721	0.379 ± 1
replicate	4.3845	631	0.389 ± 1

[a] Analytical uncertainty on ^{187}Os/^{188}Os ratios is presented at the 96% confidence level. [b] Heated at 400 °C for 330 h.

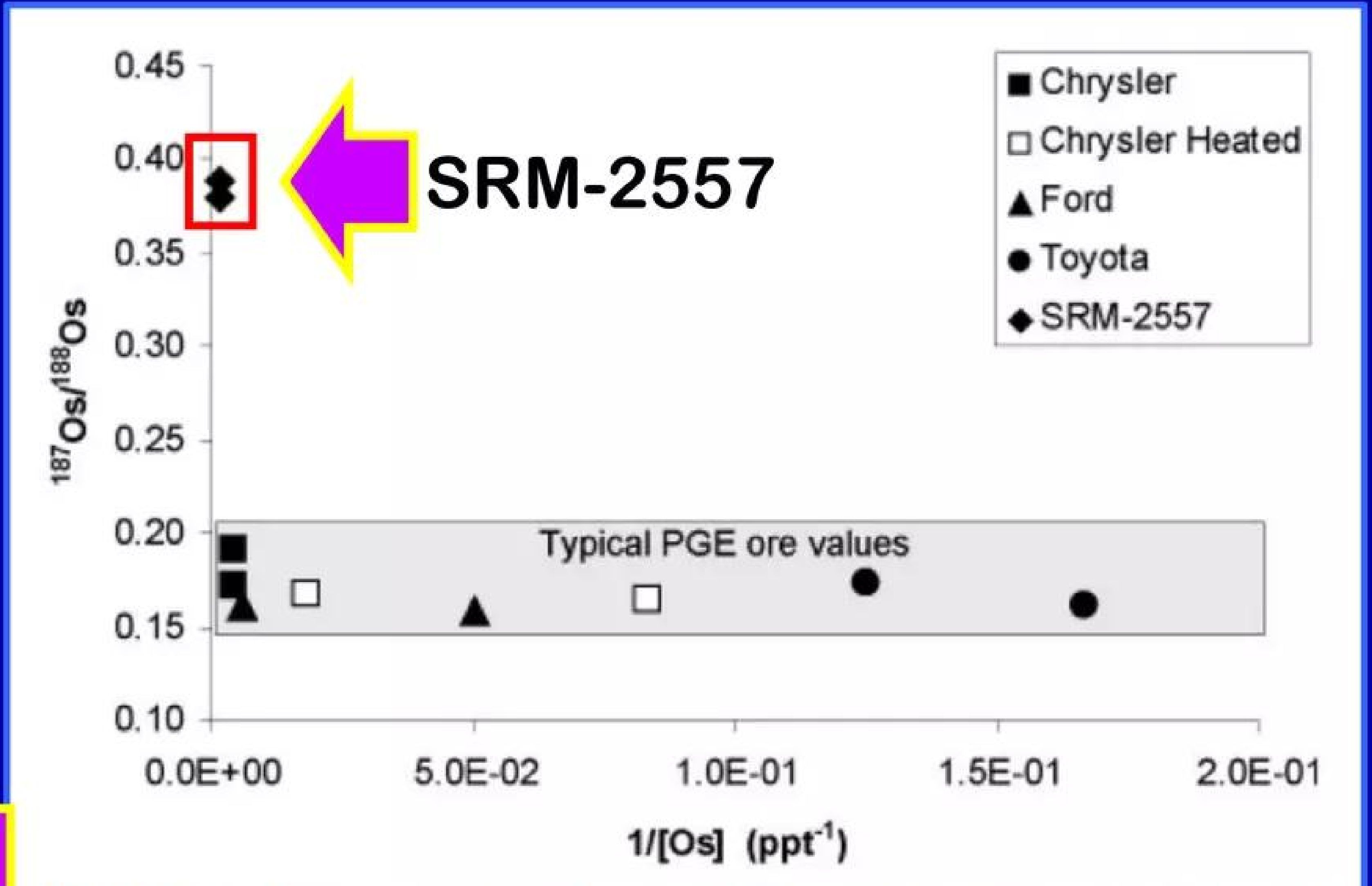


FIGURE 1. Inverse of osmium content and isotopic signature of new car catalysts, heated catalysts, and catalysts standard SRM-2557.

Note especially: SRM-2557 is a monolithic catalyst standard prepared and distributed by U.S. National Institute of Standards and Technology (NIST). Was made solely from *used* recycled catalytic converter materials that were recovered and refined by Inco Ltd.

Poirier & Gariepy measure Osmium isotopes in converters

SRM-2557 recycled catalyst metals had *higher* concentration of Osmium

Was unexpected result caused by "contamination" or by LENR production of Os?

In catalytic converters any Osmium exposed O_2 will produce volatile OsO_4 b.p. 105 °C

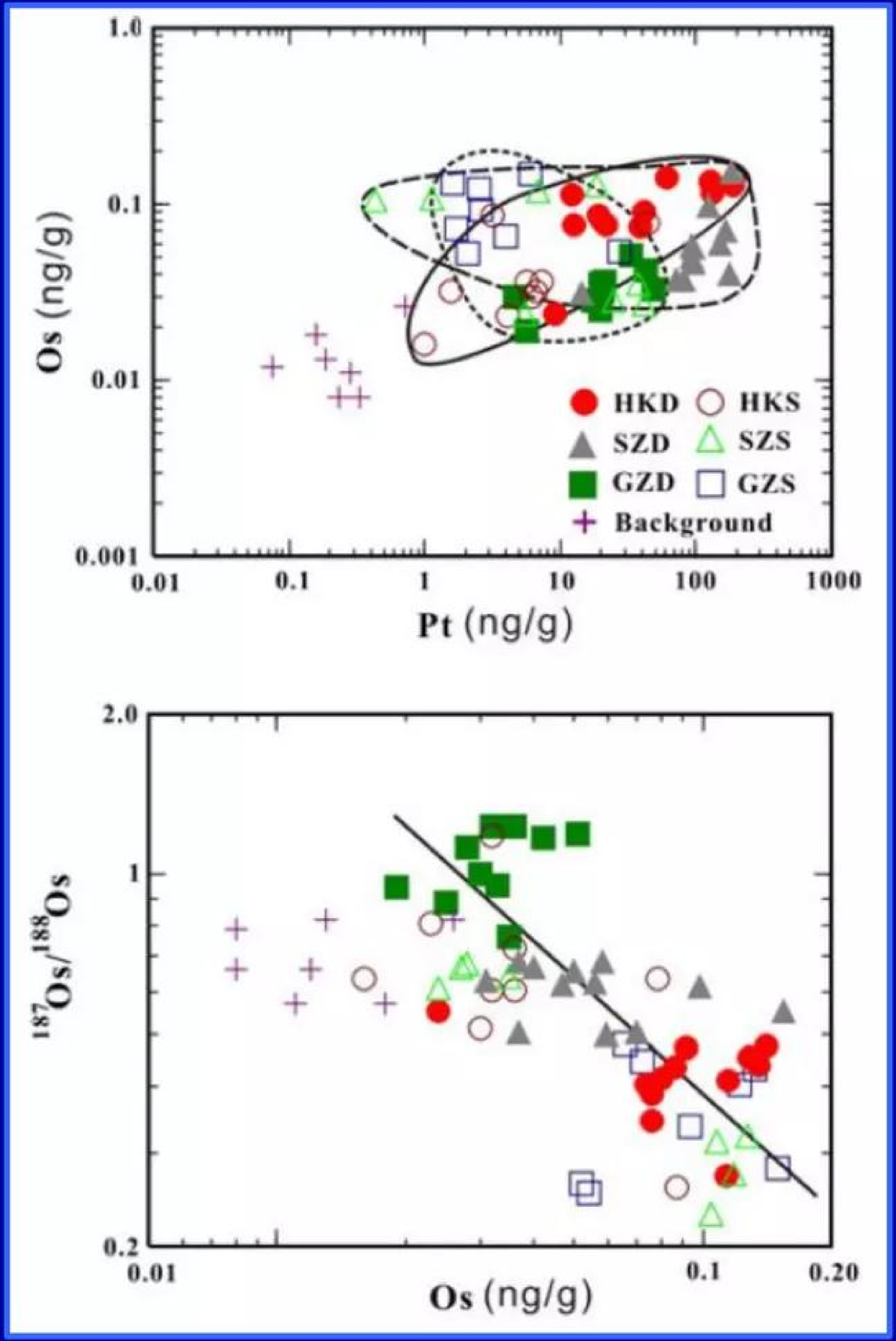
- ✓ "We present the first direct Os concentrations and isotopic measurements of catalytic converters for major automobile brands to test the assumption that car catalysts release Os with a distinct signature in the environment. The analysis of four new catalytic converters yields similar low $^{187}Os/^{188}Os$ ratios (0.1 - 0.2), suggesting a similar source for the PGM. The Os concentrations measured are in the ppt range (6 - 228 ppt)."
- ✓ Poirier & Gariepy's (2005) measured $^{187}Os/^{188}Os$ ratios in four new (unused pristine) catalytic converters, obtaining values of 0.16 - 0.19; their numbers are later cited by Chen et al. (2007). Poirier & Gariepy (2005) further state that, "We show that Os loss from catalysts as volatile OsO_4 [b.p. = 105 °C] is important at car catalyst operating temperatures." They then go on to make a very important statement, "The NIST car catalyst standard (SRM-2557, made from recycled used catalysts) yields higher concentrations (up to 721 ppt Os) and a more radiogenic isotopic composition (approximately 0.38), perhaps indicative of Os contamination during its preparation." Maybe it wasn't contamination. Perhaps LENRs?

Extraordinary Os isotopic variability in catalytic converters

Very difficult to explain magnitude of variation with chemical fractionation

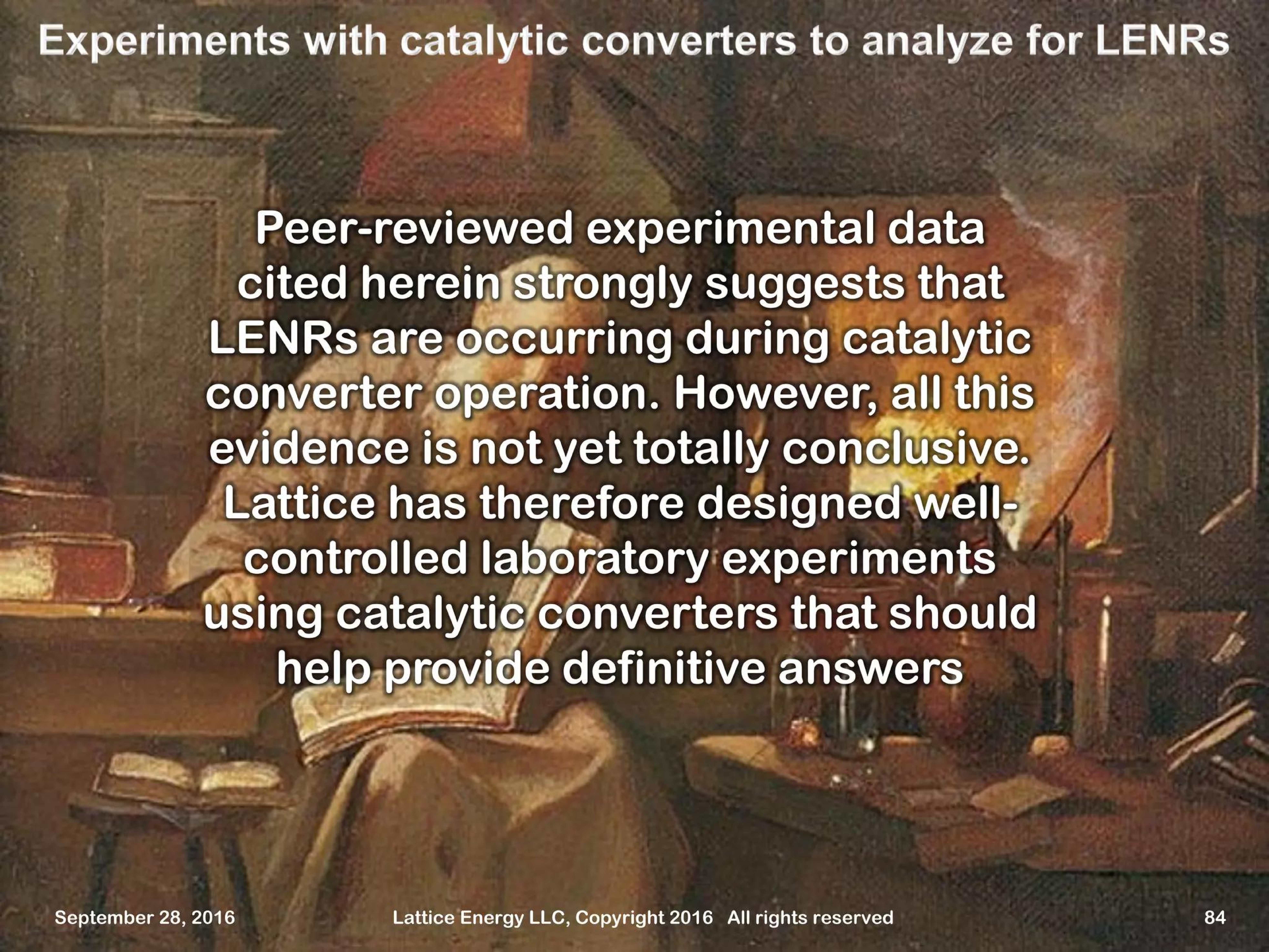
- ✓ In three Chinese cities, per Qi et al. (2011) value of $^{187}Os/^{188}Os$ isotope ratio ranges from 0.23 up to 1.23 which spans over 50% of entire global range of such variability as reported in Fig. 1 of Chen et al. (2009). Observed values of the $^{187}Os/^{188}Os$ ratio thus vary by factor of ~5x (500%) across three cities; within one city (Shenzhen) the range is ~400%. Stable isotopic variation is normally expressed in per mil δ notation, which means parts-per-thousand shifts in isotopes
- ✓ Os isotope ratios observed to change by huge 4x - 5x over distances on the order of miles; this magnitude would not be expected from chemical fractionation, even though phase change from Os metal to OsO_4 gas
- ✓ Poirier & Gariepy (2005) reported NIST car catalyst standard (SRM-2557, made solely from recycled used catalysts) yielded higher Os concentrations (up to 721 ppt) and more radiogenic isotopic composition (~0.38) compared to using pristine virgin catalyst metals. Since chemical processes cannot explain this result they attributed excess Osmium seen to contamination. However, it could be explained by Os production from other elements via LENRs during converter operation

Fig. 4 from Qi et al. (2011)
Os conc. vs. Pt conc. and
Os conc. vs. $^{187}Os/^{188}Os$ ratio



Osmium produced & isotopes shifted in catalytic converters

Experiments with catalytic converters to analyze for LENRs



Peer-reviewed experimental data cited herein strongly suggests that LENRs are occurring during catalytic converter operation. However, all this evidence is not yet totally conclusive. Lattice has therefore designed well-controlled laboratory experiments using catalytic converters that should help provide definitive answers

Experiments with catalytic converters to analyze for LENRs

Design experiments to measure elements/isotopes in inputs and outputs

Tight control of parameters and closure on mass balances should provide answer

1. Begin with a brand new (unused) computer-controlled, gasoline-powered automobile engine with certified Gold-free spark plugs, chassis, drive train, wheels, and tires (no body) on a test bed where it can be run and varying loads put on the engine as if it were actually being driven on the highway
2. Altogether, treat engine, exhaust system, and catalytic converter as if they were a closed system. It has measurable inputs that can be isotopically characterized and sampled: air (gaseous), gasoline (liquid), and lubricants (liquid). Measured outputs that will be analyzed are whatever elements/isotopes may be present in catalytic converter in solid form at the beginning and end of an experiment, as well as whatever gaseous and particulate matter is emitted and periodically sampled beyond the exhaust pipe
3. Specially construct two types of otherwise identical three-way catalytic converters (TWCs) containing customary commercial amounts and ratios of Pd, Pt, and Rh and washcoat: (a) standard honeycomb ceramic 'monolith' support structure; and (b) stainless steel honeycomb support structure (there will be a total of four TWCs)
4. When preparing washcoat with its Pd, Pt, and Rh particles, make certain that all catalyst metals used are 99^{+} % pure and certified 'virgin'; i.e., they have come directly from a miner/refiner, e.g., Johnson-Matthey, Tanaka Metals, and have *never* previously been recycled or used in catalytic converters or other industrial processes (we now have 2 ceramic TWCs and 2 stainless steel; one of each will be set aside as a control)

Experiments with catalytic converters to analyze for LENRs

Design experiments to measure elements/isotopes in inputs and outputs

Tight control of parameters and closure on mass balances should provide answer

5. Exhaustively characterize all elements/isotopes present inside catalytic converters at the beginning of a experiment with whatever mass spectroscopy techniques are needed to accomplish that goal. If possible, purchase one lot of fuel and lubricants that will be enough for all of the experiments and characterize them prior to starting
6. With whatever mass spectroscopy techniques are needed, exhaustively analyze periodic samples of input air and exhaust emissions (gaseous and particulate) to characterize all elements/isotopes present to whatever degree is technologically feasible; idea here is to be able to see whether elements are created or disappeared and to be able to measure isotopic shifts that may have occurred in stable elements
7. Run each of two experiments for total of 5,000 engine operating hours. At the very end of each experiment, remove the TWC, tear it apart, and exhaustively analyze the elements/isotopes in it to whatever degree is technologically possible. It would be highly desirable to also be able to use a Cameca nanoSIMS 50 to perform before-and-after mass spectroscopy measurements on small nanoparticulate samples collected from inner working surfaces of catalytic converters during experiments
8. If measurements with effectively closed mass balances demonstrate that elements *not* initially present in significant quantities at beginning of converter operation are detected at the conclusion of experiments, and/or are accompanied by very large isotopic shifts, it would be direct, indisputable evidence for LENR transmutations

Working with Lattice

Partnering on commercialization and consulting on certain subjects

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

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

- ✓ 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 fee-based consulting. This separate work covers subjects such as: micron-scale, many-body collective quantum effects in condensed matter; Lithium-ion battery safety engineering issues including minimizing risks for occurrence of thermal runaways; and development of ultra-high-temperature superconductors. Additional areas of expertise include: long-term strategic implications of LENRs for high cap-ex long term investments in power generation technology; energy storage technologies; and LENR impact on vehicle exhaust emissions. Will consult on these subjects as long as it does not involve disclosing Lattice proprietary engineering details relating to developing LENR power generation systems

Publications about the Widom-Larsen theory of LENRs

Index provides comprehensive guide to available online information

"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

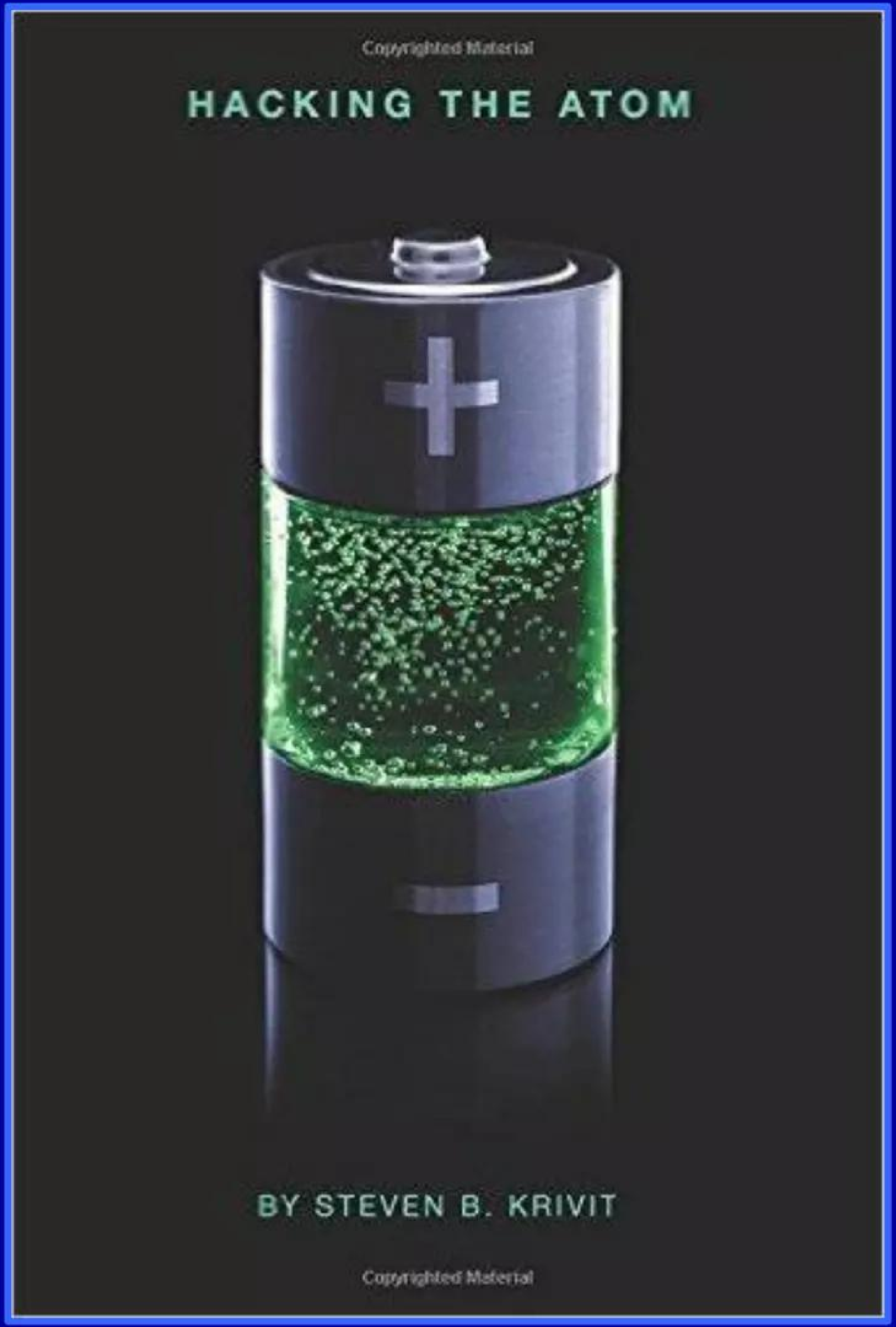
"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen (author's copy)
Pramana - Journal of Physics 75 pp. 617 - 637 (2010)
http://www.slideshare.net/lewisglarsen/srivastava-widom-and-larsenprimer-for-electroweak-induced-low-energy-nuclear-reactionspramana-oct-2010

"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

"Index to key concepts and documents" all hyperlinks in document are 'live'
v. #21 updated and revised through Sept. 7, 2015
L. Larsen, Lattice Energy LLC, May 28, 2013 [133 slides] download is enabled
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-hyperlinked-index-to-documents-re-widomlarsen-theory-and-lenrs-september-7-2015

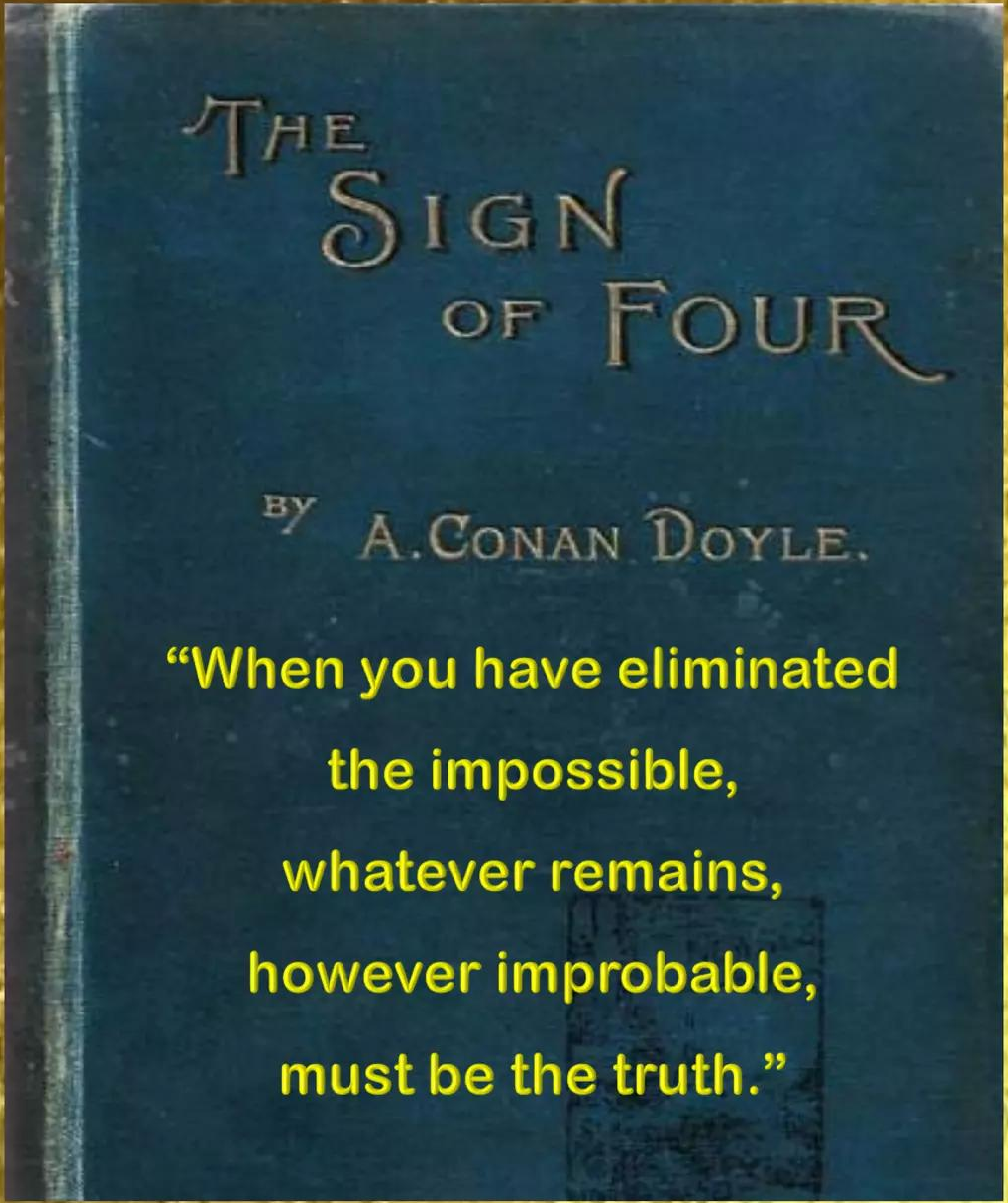
Steven Krivit’s new book about LENRs “Hacking the Atom”

https://www.amazon.com/dp/0996886451



“Hacking the Atom”
“Explorations in nuclear research” (Volume 1)
Steven B. Krivit
Michael J. Ravnitzky, ed.
Cynthia Goldstein, ed.
Mat Nieuwenhoven, ed.
Pacific Oaks Press, San Rafael, CA
September 1, 2016 (484 pages)
Sold now on Amazon.com
Paperback US$16.00; hardcover US$48.00
Electronic versions to follow shortly

Lattice Energy LLC



“When you have eliminated
the impossible,
whatever remains,
however improbable,
must be the truth.”