

TSC Jitterbug Fusion of D in Pd NanoClusters

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Abstract:

Graphic Cover summarizes TSC Fusion of D in 147-atom Palladium Clusters; Jitterbug Icosa - Cubocta - Icosa Transformation reloading D into Pd Clusters; and Zeolite Steam Engine utilizing Fusion Energy.

The body of the paper gives details of the Pd - D TSC Jitterbug Fusion Process:

Clusters of Palladium atoms have two basic structures:
Icosahedral and Cuboctahedral

1 - Icosahedon <-> Cuboctahedron Jitterbug Transformation

2 - Pd clusters with absorbed Deuterium have two states:
Icosahedral ground state
Cuboctahedral metastable state

3 - Tetrahedral Symmetric Condensation (TSC) in Icosahedral Pd-D produces Fusion.

4 - Icosahedra TSC Fusion Triggers Jitterbug to Cuboctahedra.

5 - Cuboctahedra reload TSC sites and Jitterbug back to Icosahedra

6 - Repeat the Cycle:

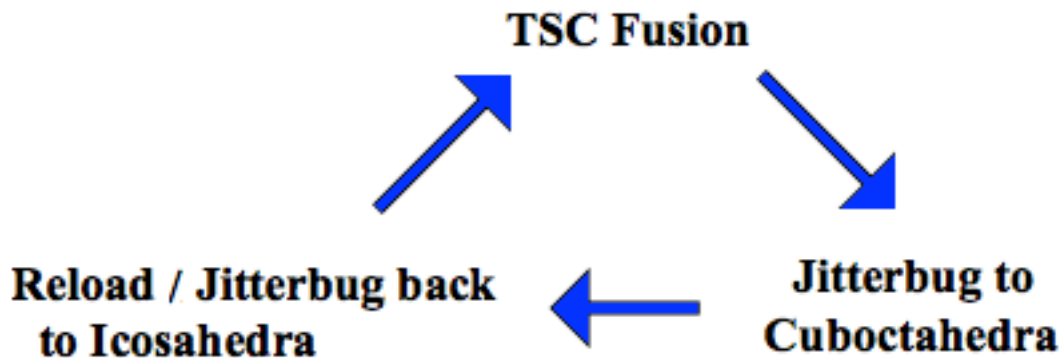


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Deuterium Fusion Energy

D = Deuterium = Heavy Hydrogen nucleus has 1 Neutron + 1 Proton

D + D has 2 Neutrons + 2 Protons

He = Helium nucleus also has 2 Neutrons + 2 Protons

BUT

(using Einstein's $E = mc^2$)

D+D is heavier than He by 23.8 MeV

(where 1 MeV of energy = about 2 x mass of electron)

so

Fusion of D+D to He produces Energy

How much Energy ?

Earth's Oceans contain a lot of Water, most of which is H₂O = HHO

where H = Hydrogen nucleus = 1 Proton

but

0.015% = about 1 part per 7,000 of Earth's Ocean Water is D₂O = DDO

D₂O can be extracted by processes such as distillation and chemical exchange.

If 1 / 1,000 of the Earth Ocean D₂O were used for Fusion of D+D to He

the Energy would be enough to sustain

10 billion people consuming energy at the level of 1985 USA

for 2,000,000 years

How much would it Cost ?

The energy equivalent of a gallon of D₂O is about equal to 300,000 gallons of fuel oil.

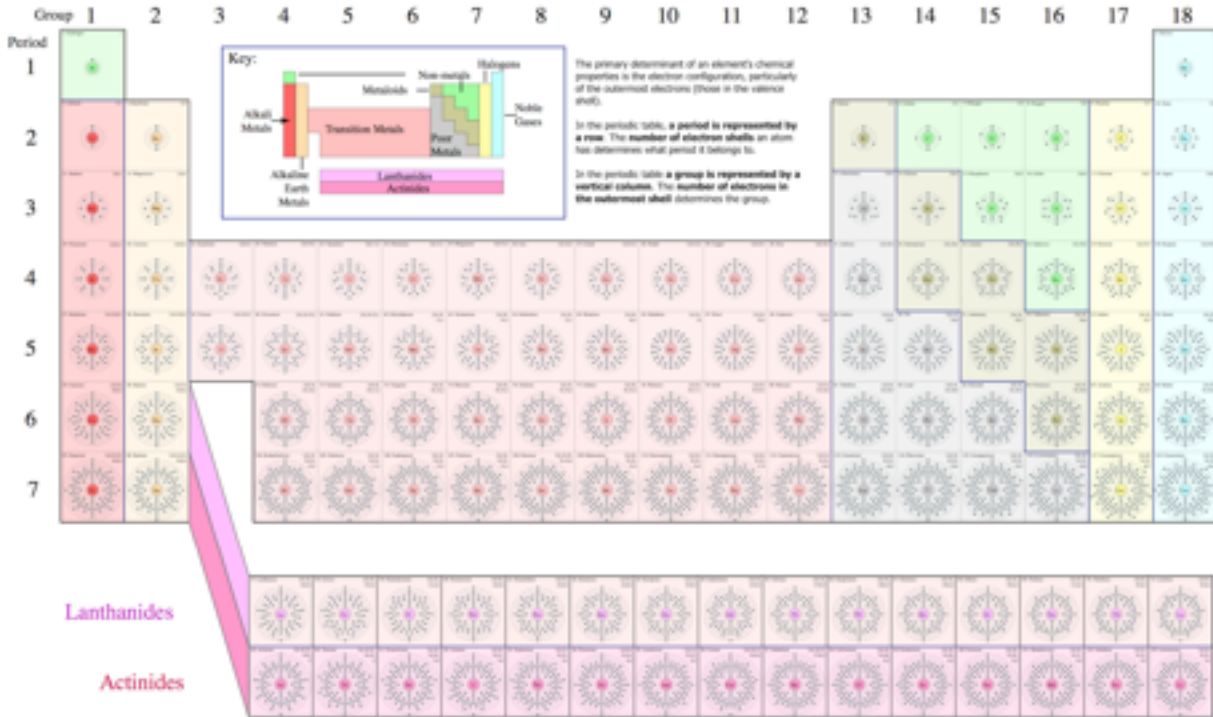
You can buy a liter of D₂O for about \$1,000

which is about 1 cent per gallon of oil (energy equivalent).

Palladium Electron Shells

Wikipedia says (I added the red material specifically about Palladium): “...

Periodic Table Of Elements Showing Electron Shells



... Each s subshell holds at most 2 electrons
 Each p subshell holds at most 6 electrons
 Each d subshell holds at most 10 electrons
 Each f subshell holds at most 14 electrons
 Each g subshell holds at most 18 electrons ...

Shell name	Subshell name	Subshell max electrons	Shell max electrons
K	1s	2	2
	2s	2	
L	2p	6	2 + 6 = 8
	3s	2	
M	3p	6	2 + 6 + 10 = 18
	3d	10	
N	4s	2	2 + 6 + 10 + 14 = 32
	4p	6	
	4d	10	
	4f	14	

Palladium

2

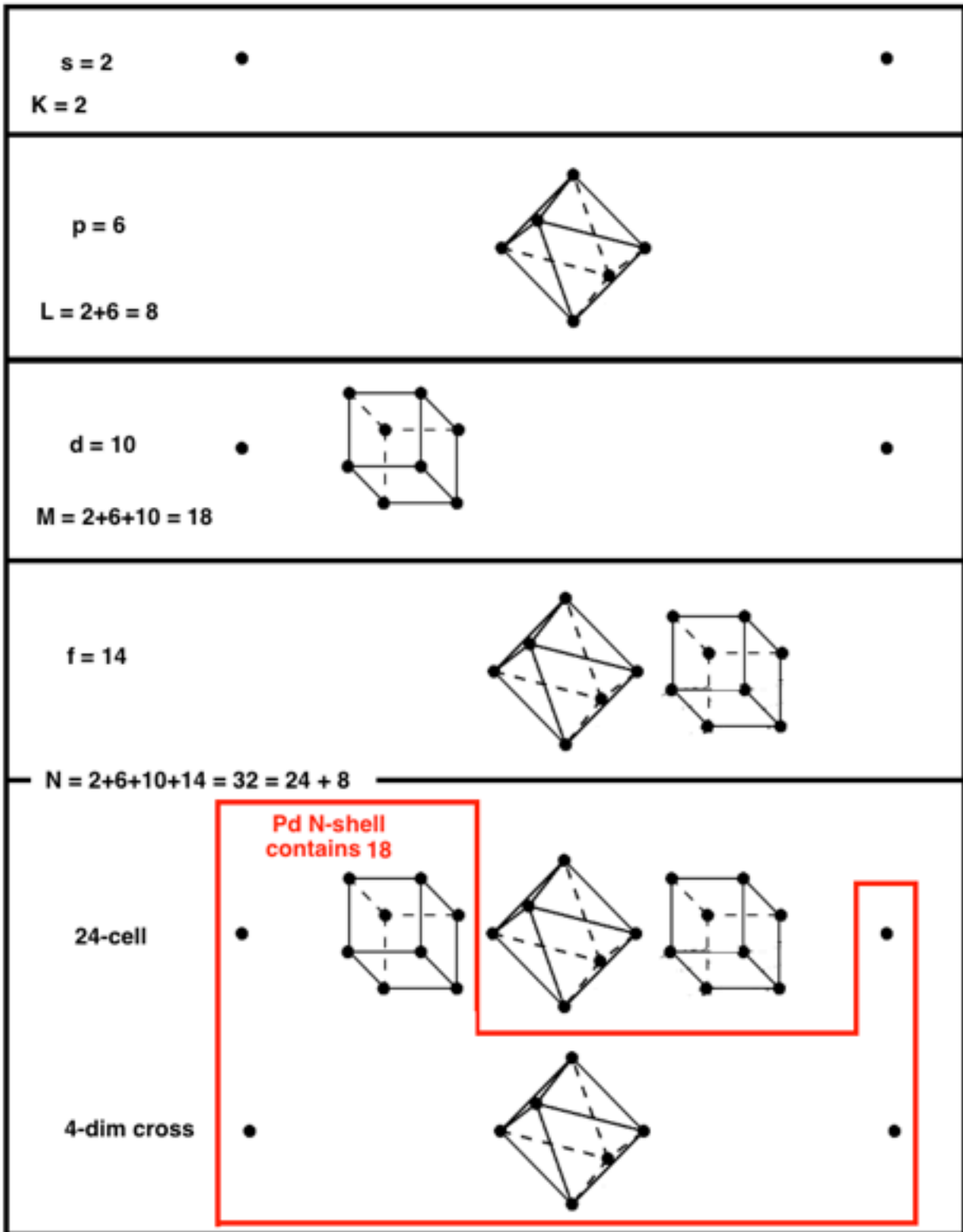
2+6 = 8

2+6+10 = 18

2+6+10 = 18



... palladium (atomic number 46) has no electrons in the fifth shell, unlike other atoms with lower atomic number ...”



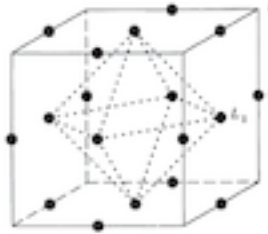
(24-cell image from John Baez review of "On Quaternions and Octonions" by Conway and Smith)

Geometrically:

2 of the First Shell correspond to the Root Vectors of $B_1 = \text{Spin}(3)$

8 of the Second Shell correspond to the Root Vectors of $B_2 = \text{Spin}(5)$

18 of the Third Shell correspond to the Root Vectors of $B_3 = \text{Spin}(7)$



(image from Representation Theory by Fulton and Harris)

The B_3 Root Vectors live in 3-dim space, which is where Element Electron Shells live.

32 of the Fourth Shell correspond to the Root Vectors of $B_4 = \text{Spin}(9)$

Palladium is the only element whose outer shell has more electrons than the 8 electrons of noble gases beyond Helium.

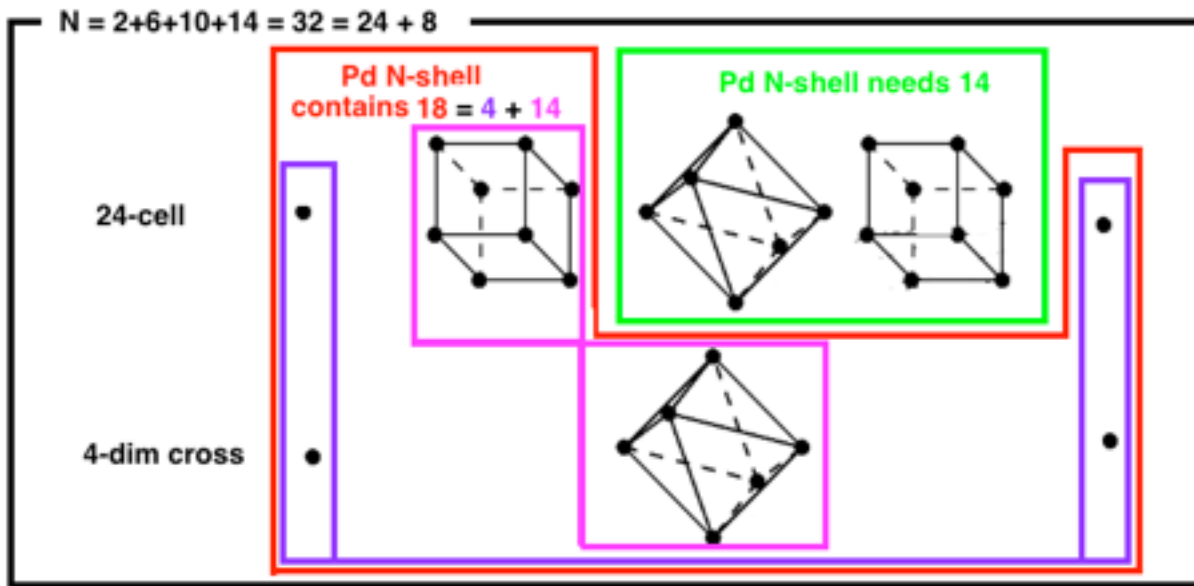
The 18 electrons in the outer shell of Palladium replicate the full state of the Third Shell (M shell).

How do the Palladium atoms in a cluster interact with each other ?

The interaction is primarily through the outer shell of electrons (N-shell for Palladium).

A full N-shell has $s + p + d + f = 2 + 6 + 10 + 14 = 32$ electrons.

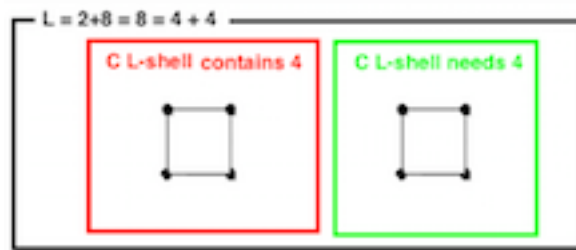
Palladium N-shell has $2 + 6 + 10 = 18$ electrons and “holes” to receive 14 electrons:



Each Palladium atom has 14 N-shell electrons that every other Pd atom needs.

Further,
each Palladium atom has 4 N-shell electrons that can interact
with 4 electrons of 4 Deuterium atoms absorbed into a Pd cluster,
helping them to participate in a Schwinger coherent quantum state for TSC Fusion.

Compare the outer shell (L-shell) of Carbon:

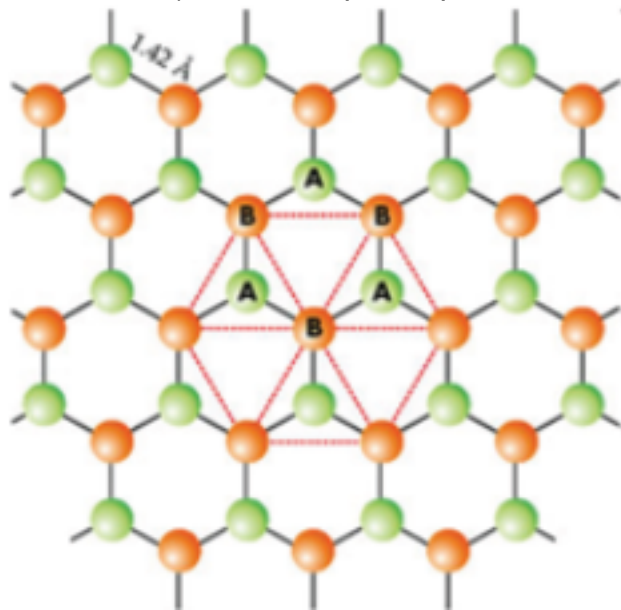


The useful chemistry of Carbon (graphite, diamond, buckyballs, graphene, organics) is due to the fact that each Carbon atom has the 4 L-shell electrons that every other Carbon atom needs.

If each Carbon atom is connected to 4 other Carbon atoms then the result is a 3-dim Diamond Packing with Tetrahedron Vertex Figure.

However, Diamond is only a metastable state. Graphene is a stable state.

P. B. Allen and B. K. Nikolic, in University of Delaware PHYS 824: Introduction to Nanophysics - Electronic band structure of graphene, said: "... Band structure of graphene ... originates from orbital hosting the fourth valence electron. The bands which correspond to the dispersion of bonding and antibonding molecular orbital (constructed from orbitals on two carbon atoms) are called pi and pi* bands ...



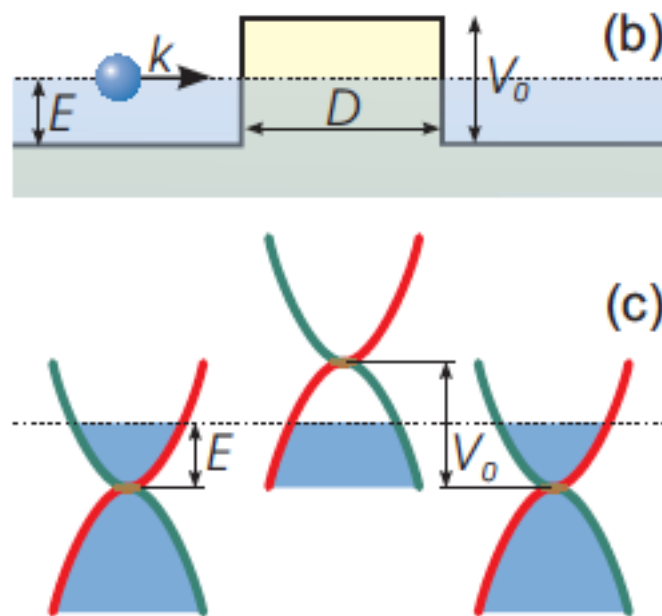
The honeycomb lattice of graphene ... is not a Bravais lattice. Instead, it can be viewed as bipartite lattice composed of two interpenetrating triangular sublattices ... the single-particle electron states are ... two classes, called sigma and pi.

The even sigma states are derived from carbon s and px , py orbitals (i.e., their hybridized sp² orbitals ...),

while **the odd pi states are derived from carbon pz orbitals** ... electron and hole states in graphene should be interconnected, exhibiting properties analogous to the

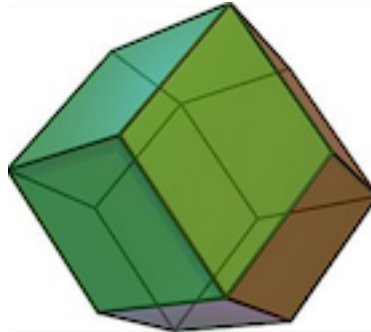
charge-conjugation symmetry in quantum electrodynamics ... because graphene low-energy quasiparticles have to be described by two-component wave functions ... which are needed to define the relative contributions of the A and B sublattices in the quasiparticles make-up. The two-component description for graphene is very similar to the [Dirac Equation] spinor wave functions in QED...”.

I. Katsnelson, K. S. Novoselov & A. K. Geim, in Chiral tunnelling and the Klein paradox in graphene (arXiv cond-mat/0604323), said: The ... Klein paradox - unimpeded penetration of relativistic particles through high and wide potential barriers - ... can be tested ... using electrostatic barriers in single- and bi-layer graphene. Due to the chiral nature of their quasiparticles, quantum tunnelling ... becomes ... qualitatively different from ... normal, non-relativistic electrons. ...



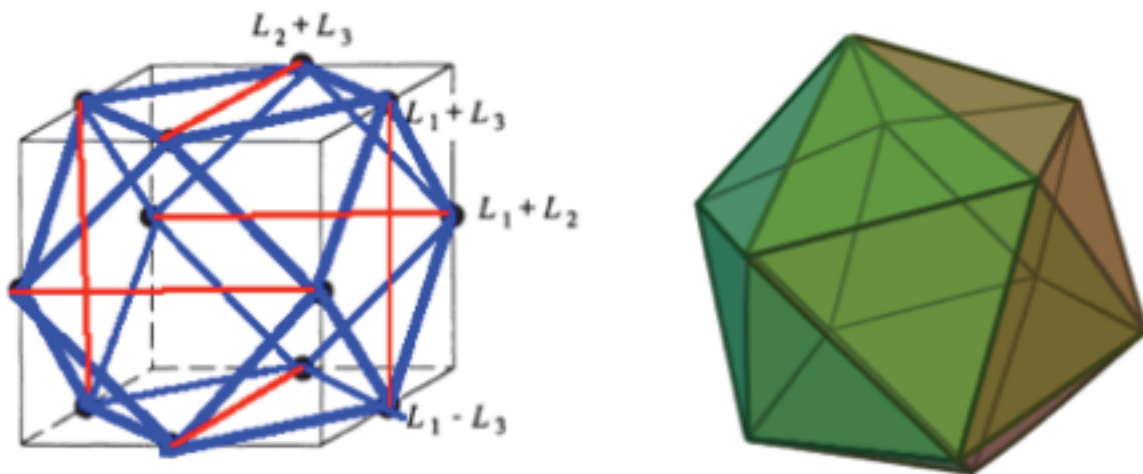
... Tunnelling through a potential barrier in graphene: ... (b) ... diagrams ... show the positions of the Fermi energy E across such a barrier. The Fermi level (dotted lines) lies in the conduction band outside the barrier and the valence band inside it. The blue filled areas indicate occupied states. The pseudospin ... is parallel (antiparallel) to the direction of motion of electrons (holes), which also ... keeps a fixed direction along the red and green branches of the electronic spectrum. (c) - Low-energy spectrum for quasiparticles in **bilayer graphene**. The spectrum is isotropic and, despite its parabolicity, also originates from the intersection of energy bands formed by equivalent sublattices, which ensures charge conjugation, similar to ... single-layer graphene. ... charge carriers in bilayer graphene ... are massive quasiparticles with a finite density of states at zero energy, similar to conventional nonrelativistic electrons. On the other hand, these quasiparticles are also chiral and described by spinor wavefunctions, similar to relativistic particles or quasiparticles in single-layer graphene ... the origin of the unusual energy spectrum can be traced to the crystal lattice of bilayer graphene with four equivalent sublattices. ... **the relevant QED-like effects appear to be more pronounced in bilayer graphene ...**”.

If each Palladium atom is connected to 14 other Palladium atoms then the result is a 3-dim FCC Lattice with Rhombic Dodecahedron Vertex Figure



However, it may be that the Rhombic Dodecahedron FCC Lattice is only metastable and

more stable state may be based on its dual, the Cuboctahedron

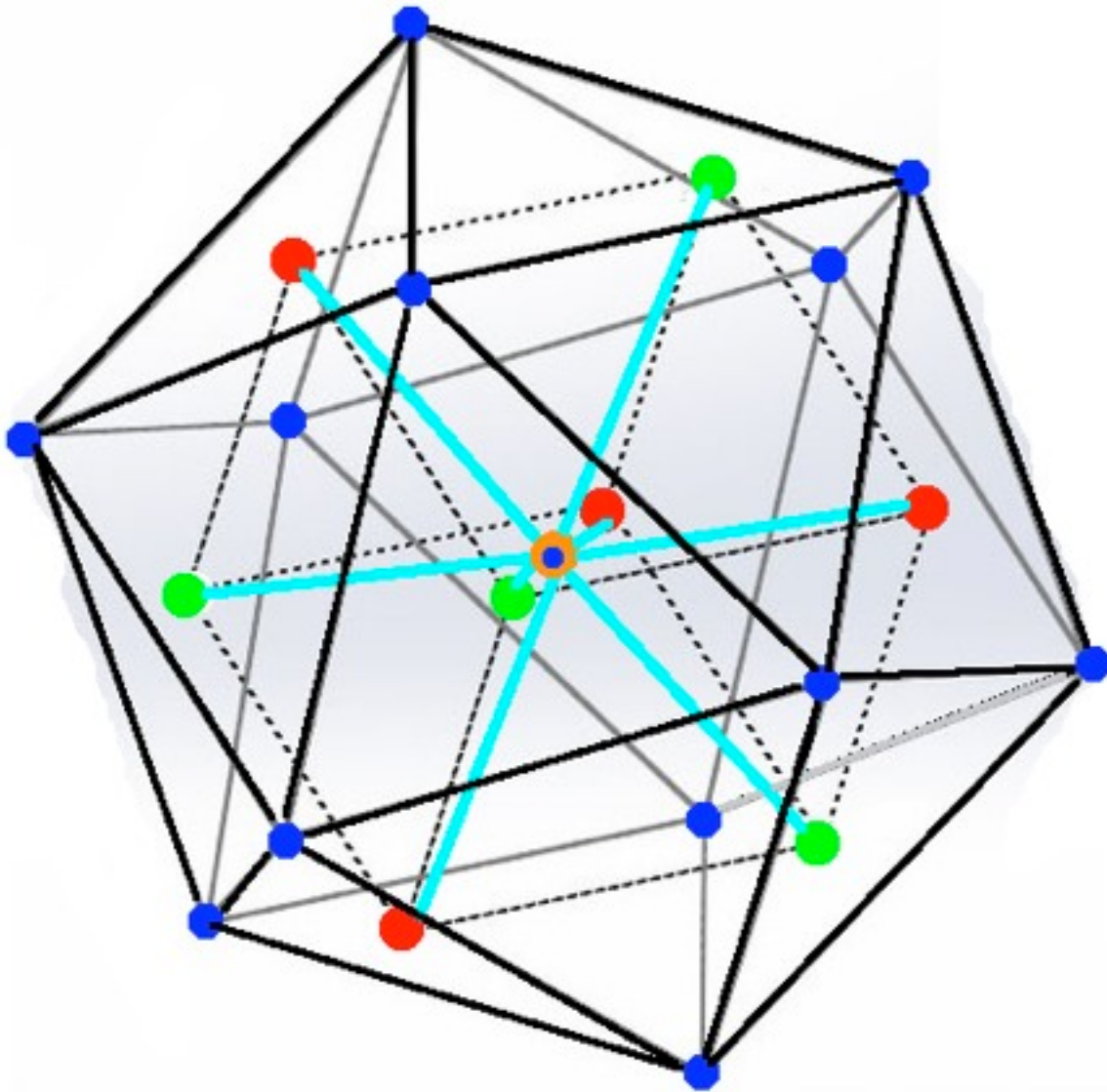


which can transform by Jitterbug Transformation into an Icosahedron.

Just as Graphene directly uses 3 of the 4 Carbon electrons
the Cuboctahedron / Icosahedron directly uses 12 of the 14 Palladium electrons.

Just as the 4th Carbon valence electron in Bilayer Graphene produces a Dirac Fermion band with Klein Paradox Tunneling through Potential Barriers
the $14 - 12 = 2$ Palladium valence electrons produce a **Dirac Fermion band** which, using Klein Paradox Tunneling through Potential Barriers, enable TSC Fusion of Deuterium in Palladium Cluster structures.

The $18-14 = 4$ Palladium electrons are used by the central Palladium atom of the Icosahedral TSC Fusion configuration to attract 4 Deuterium nuclei to the central TSC Fusion site.



(blue = Pd , red = D nuclei , green = D electrons , cyan = TSC Fusion paths, orange = TSC Fusion site)

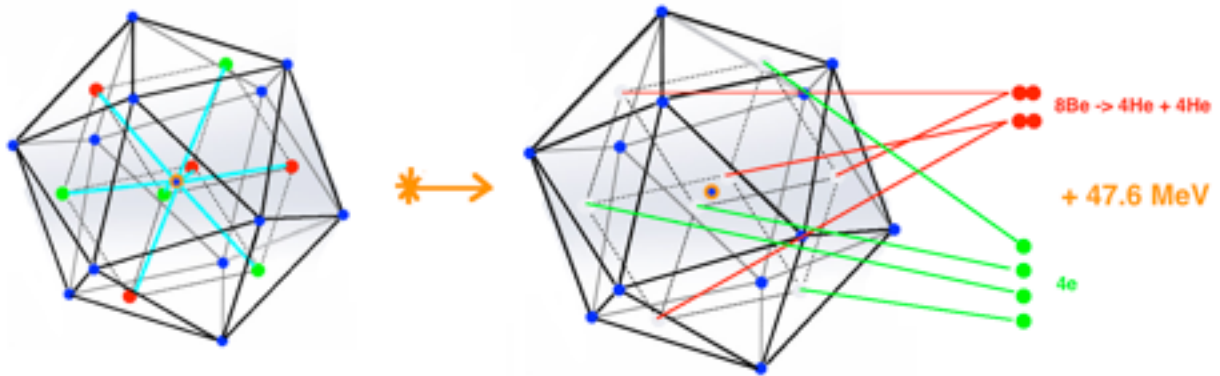
In the other Palladium atoms, the $18-14 = 4$ electrons help position and guide the Deuterium nuclei and electrons in the TSC condensation process whereby they move to the icosahedron center for TSC Fusion of the 4 Deuterium nuclei.

Can D+D to He Fusion be done without High Energy for Hot Fusion ?

Arata and Zhang, and SRI, and Iraj Parchamazad have observed heat from Palladium nanoclusters exposed to Deuterium gas which heat seems to me to be due to TSC Fusion of Deuterium nuclei.

Akito Takahashi developed a Tetrahedral Symmetric Condensate (TSC) model for fusion $D+D+D+D \rightarrow 8Be \rightarrow 4He + 4He + 47.6 \text{ MeV}$ in Pd atomic clusters.

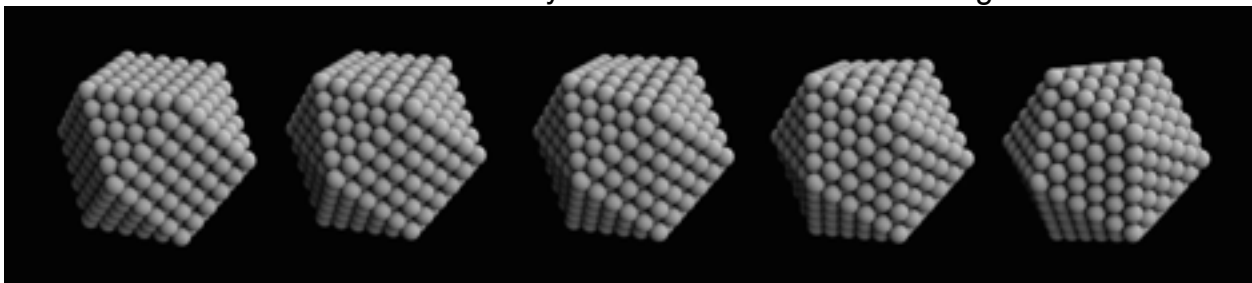
13-atom Palladium icosahedra within an Icosahedral Ground State 147-atom Pd Cluster can absorb 4 Deuterium atoms whose nuclei can produce TSC Fusion heat

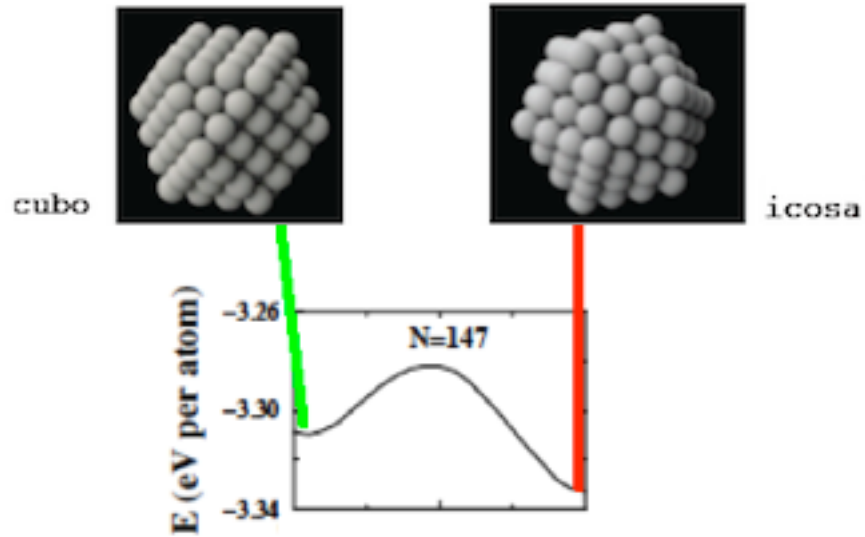


The 4 Deuterium nuclei (red) and 4 electrons (green) form a coherent quantum state that collapses to the center of a 13-atom icosahedral configuration of Pd atoms (blue) without interference from Pd electrons because **Pd is the only element that has an 18-electron outer shell.**

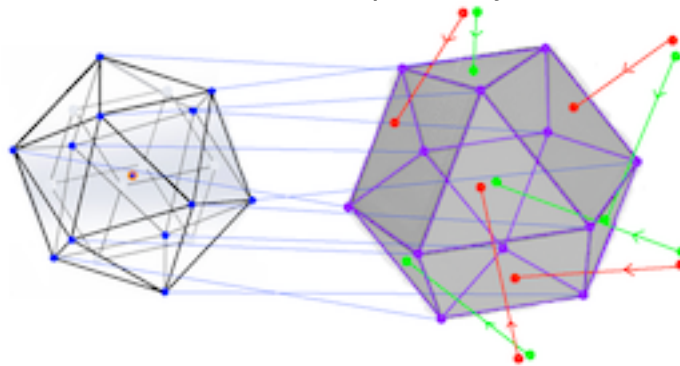


A cluster of 147 Palladium atoms which has two states, an Cuboctahedral Metastable State and an Icosahedral Ground State, that can transform into each other by a Buckminster Fuller Jitterbug Transformation

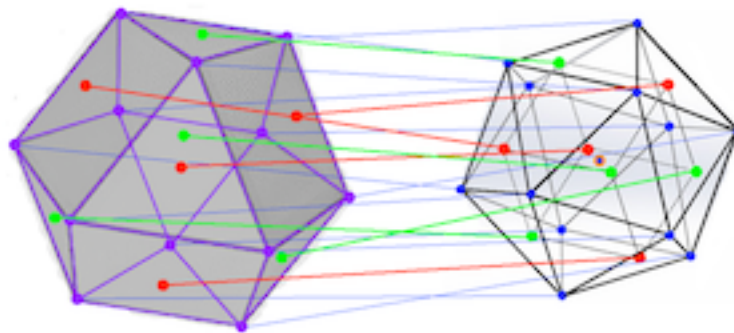




The heated Palladium cluster expands by Jitterbug to a Cuboctahedral Metastable State and the Fused Deuterium nuclei are replaced by new Deuterium from the gas

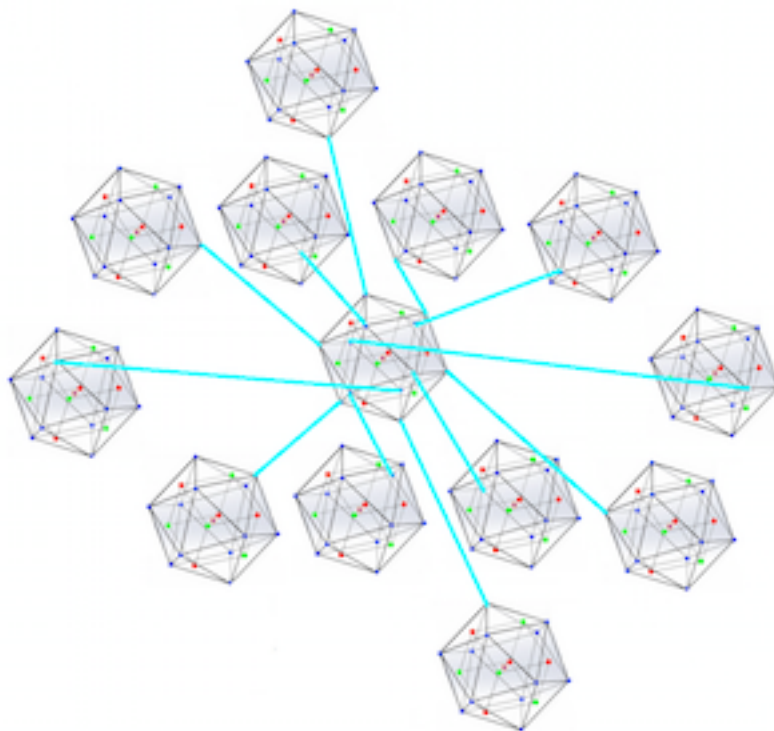


The Cuboctahedral Metastable state, loaded with the new Deuterium, collapses by Jitterbug back to the Icosahedral Ground State



Then a new TSC Fusion occurs, and the cycle repeats as long as there is Deuterium "ammunition" to fuel the Fusion.

There are 13 such 13-atom icosahedra within a 147-atom Pd Cluster (diameter 1.5 nm)



12 of which have outer faces on its outer boundary.

Structure of Palladium Clusters

There are two basic structures that are Jitterbug Transforms of each other:

Icosahedral and Cuboctahedral

n = number of shells

N = number of Pd atom vertices

d = diameter of icosahedral configuration in nm

C = number of cells in icosahedral phase

CT = number of tetrahedral cells in icosahedral phase

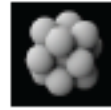
CO = number of octahedral cells in icosahedral phase

n	N	d	C = CT + CO
0	1	0.27	0 = 0 + 0
1	13	0.70	20 = 20 + 0
2	55	1.13	100 = 80 + 20
3	147	1.56	280 = 200 + 80
4	309	2.00	(icosa and cubo images not shown)

icosahedral   cuboctahedral



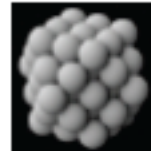
icosahedral



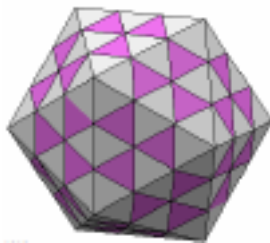
cuboctahedral



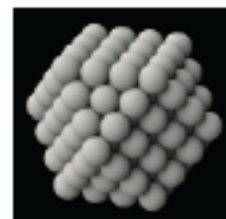
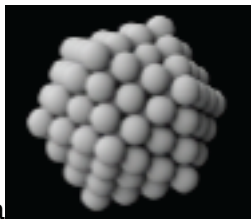
icosa



cubo



icosa

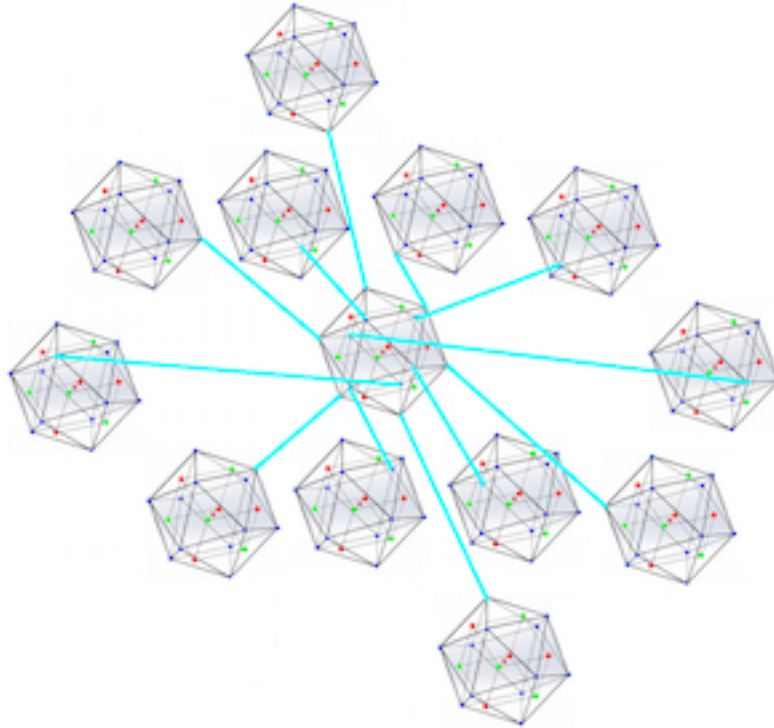


cubo

(Images from: Polyhedral Clusters by Lord et al; Frank and Kasper in Acta Cryst. 11 (1958) 184-190; Mackay in Acta Cryst. 15 (1962) 1916-1918; vimeo.com/27662398 by Yan Liang (L2XY2) August 2011. Data for n, N, and d from Shtaya-Suleiman dissertation Gottingen 2003.)

How many TSC Fusion sites are in a 147-atom Pd cluster ?

The icosahedral 147-atom ground state has 12 exterior icosahedra and a central icosahedron with 12 interior vertices which are the innermost vertices of 12 exterior TSC Fusion site icosahedra

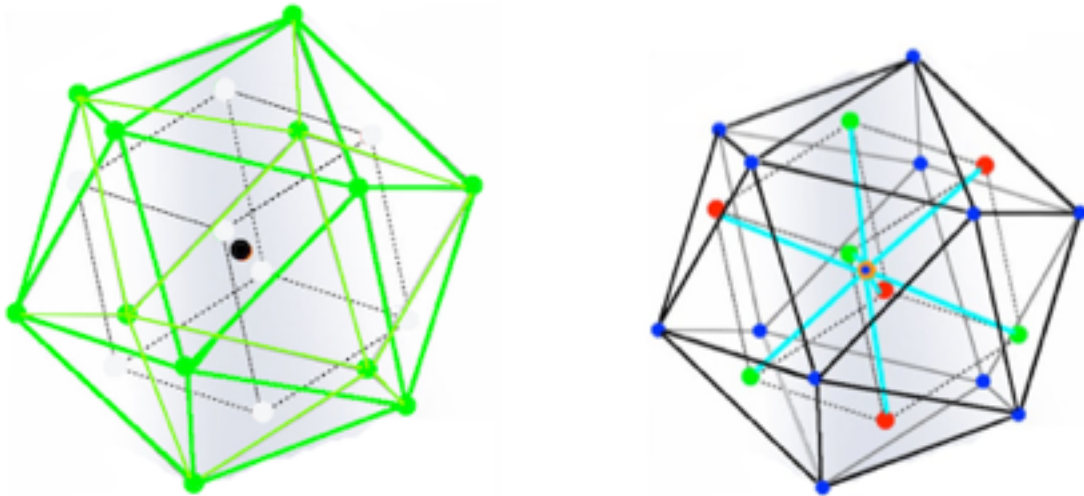


There are 13 TSC Fusion sites (12 are exterior) in each 147-atom Pd Cluster.

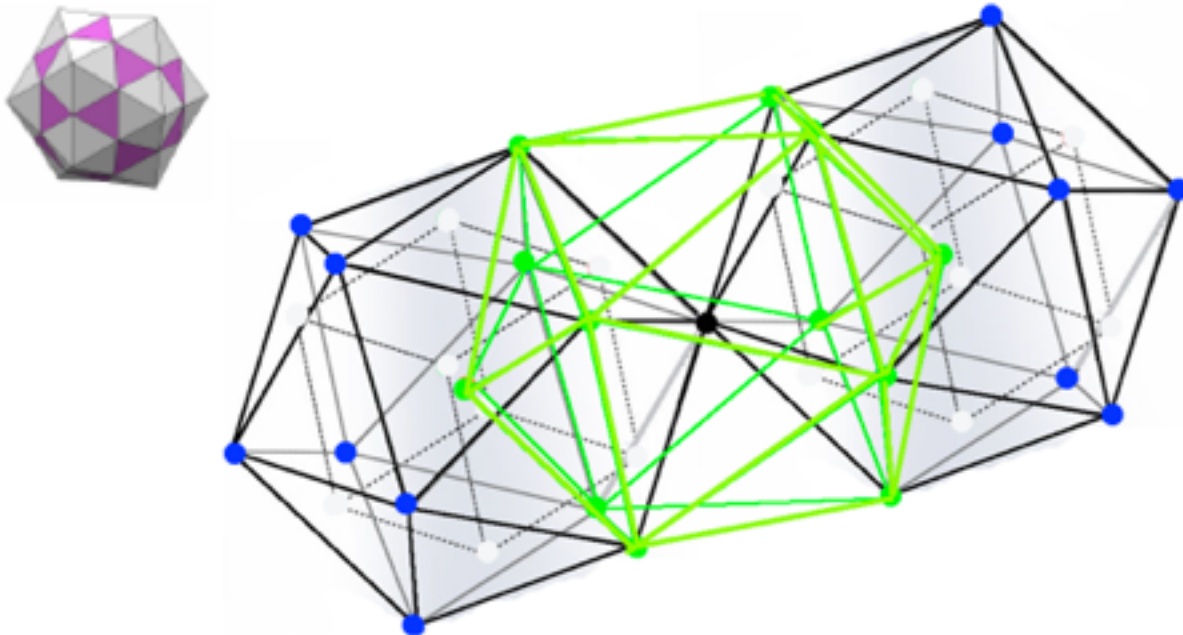
The 147-atom cluster is made up of a single central Palladium atom surrounded by 3 layers of Pd atoms:

Layer 1 = central 1 (black) + 12 icosahedral (green) = 13 vertices and 20 tetrahedral cells

It is a single icosahedron configuration that allows TSC fusion of 4 Deuterium nuclei (red dots) screened by their 4 electrons (green dots) condensing along symmetrical paths (cyan lines) to fusion at the center

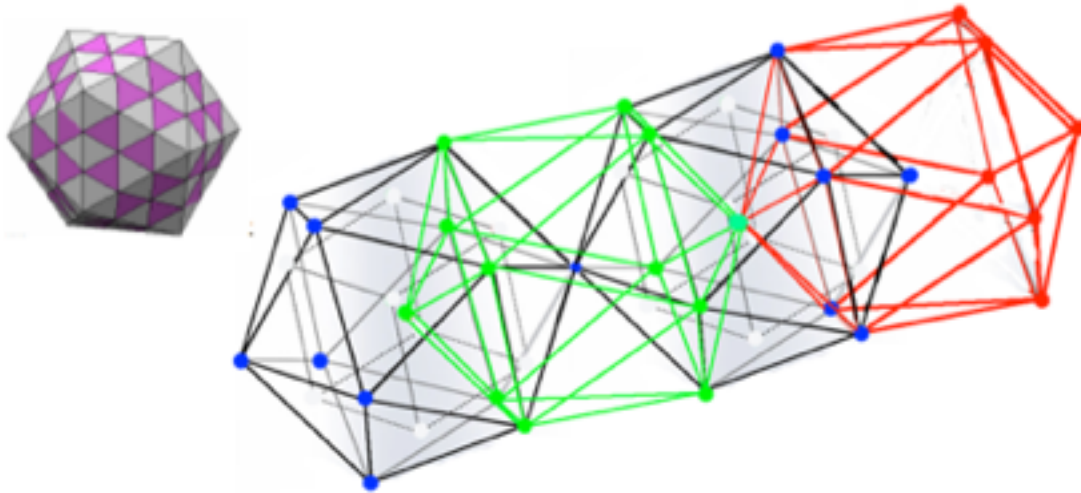


Layer 2 adds 42 vertices (blue) for total of 55 and 60 tetrahedral + 20 cuboctahedral cells for total 80 tetra + 20 cubo = 100

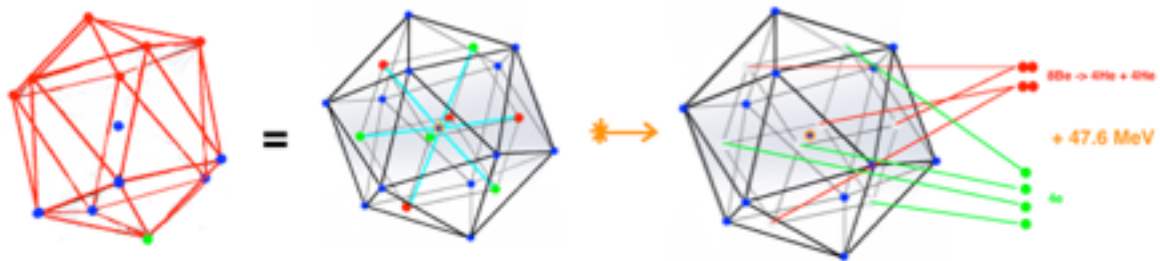


It is a configuration of 2 TSC fusion icosahedra sharing the central vertex with the remaining 55 - (26-1) = 30 vertices in 3 10-vertex bands

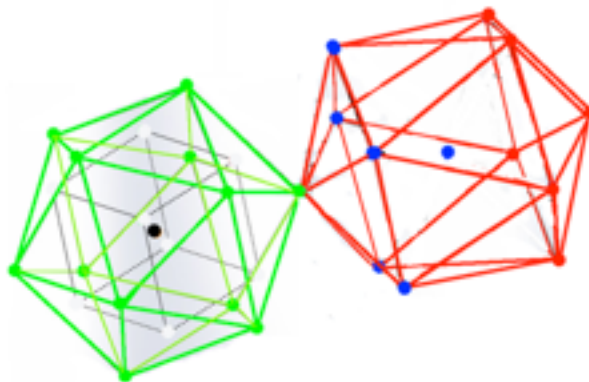
Layer 3 adds 92 vertices (red) for total of 147
 and 120 tetrahedral + 60 cuboctahedral cells for total 200 tetra + 80 cubo = 280



It is a configuration of 12 TSC fusion icosahedra

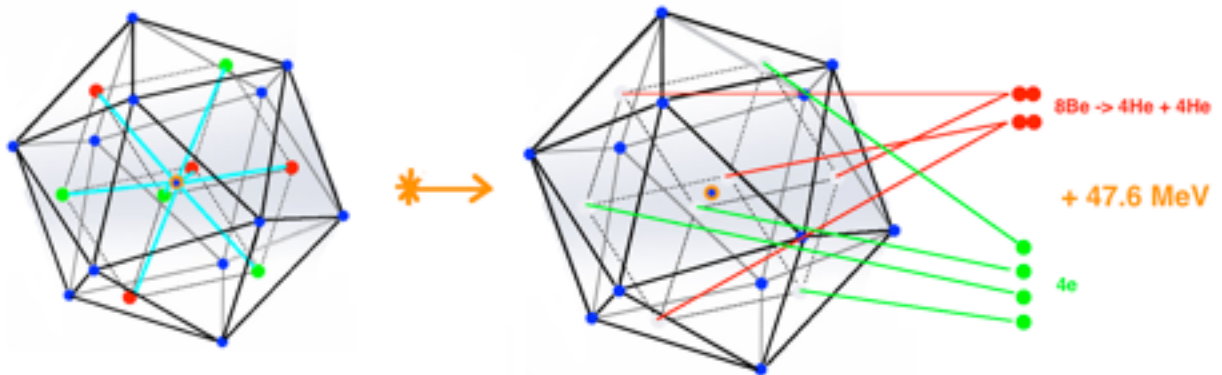


each of which shares a vertex with one of the 12 vertices of the Layer 1 icosahedron.

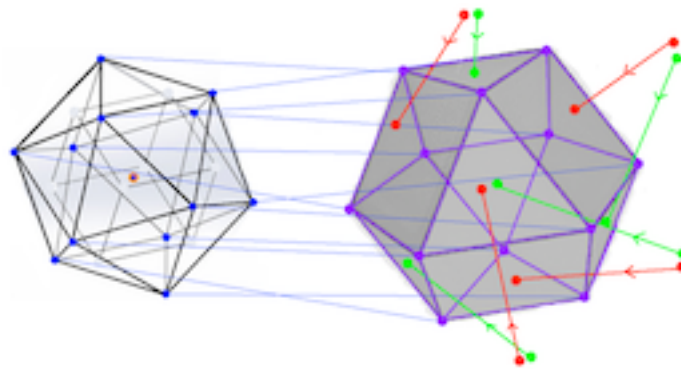


so that the entire 3-layer 147-atom configuration has 13 TSC fusion icosahedra:
 12 outer icosahedra and 1 central icosahedron.
 The 13 TSC configurations have $13 \times 13 = 169$ vertices but
 24 vertices are shared between an outer and the central TSC
 and $5 \times 12 = 60$ vertices are shared between two outer TSC
 so $169 - 24/2 - 60/2 = 127$ of the 147 vertices are in the 13 TSC
 The remaining $147 - 127 = 20$ vertices outside the 13 TSC are
 at the centers of the triangle faces of the entire 147-atom icosahedron.

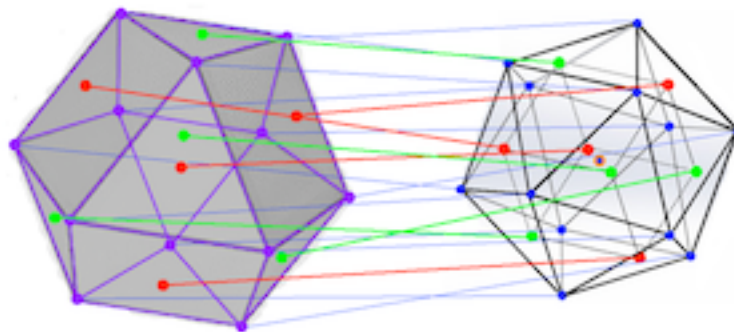
Each of the 13 TSC fusion icosahedra is capable of TSC fusion if it has absorbed 4 Deuterium nuclei + electrons:



The heated Palladium cluster expands by Jitterbug to Cubocta Metastable State
 The Fused Deuterium nuclei can be replaced by ambient Deuterium.
 Replacement is easier for the 12 outer TSC configurations than for the 1 central TSC configuration which is not directly exposed to ambient D gas

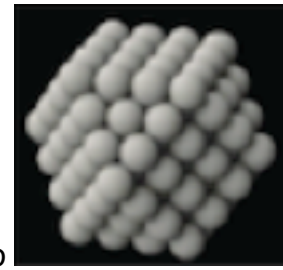


The Cubocta Metastable state, loaded with the new Deuterium, collapses by Jitterbug back to the Icosa Ground State

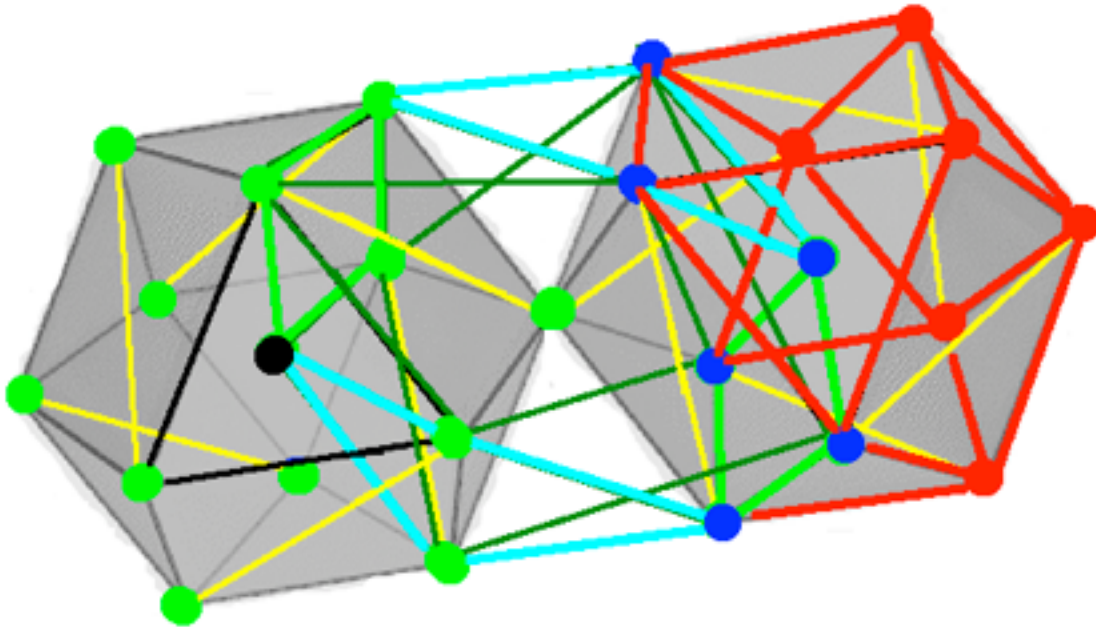


Then a new TSC Fusion occurs and the cycle repeats.

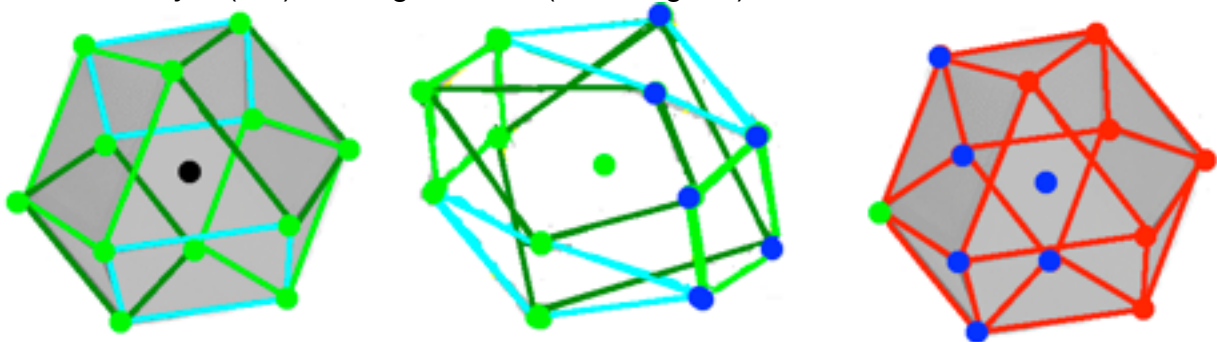
147-atom Cuboctahedral Geometry



The 147-atom 3-layer icosah structure goes to a 3-layer cuboctahedral structure by Jitterbug transformation of all 147 atoms.



Like the icosah case, in the cubo case there is a central (black) vertex surrounded by 12 (green) cubo-configured vertices and a second layer (blue) forming an intermediate (distorted) cuboctahedron and a third layer (red) forming an outer (more regular) cuboctahedron.



In the cubo case, there are also 12 outer TSC Jitterbug cuboctahedra plus a single central TSC Jitterbug cuboctahedron, so Jitterbug transformation of the entire 147-atom Pd cluster works consistently with individual Jitterbug transformations of the 13 TSC icosahedra and TSC Jitterbug cuboctahedra.

How do the Icosahedral Clusters grow to 147 atoms ?

Eric A. Lord, Alan L. Mackay, and S. Ranganathan say in "New Geometries for New Materials" (Cambridge 2006):
"... The Mackay icosahedron is obtained by packing tetrahedra and octahedra around an icosahedron [12 vertices +1 center = 13 vertices]...
if an octahedron is placed on every face of an icosahedron, the angular gap between neighboring octahedra can be closed by a very small deformation, to bring them into face contact [12 + 20 x (6-3)/2 = 42 vertices]...



... The concave regions of the resulting polyhedron can be filled by five-rings of tetrahedra [42 + 12 + 1 center = 55 vertices]...



... The [55]-atom Mackay cluster ...[triangles: dark = octahedra; light = tetrahedra]...
The process can be continued ...[with octahedra on each of the 12x5 = 60 outer cell faces of 5-rings thus adding 60 x (2/2 + 1/3) = 80 vertices and creating 2 TSC Fusion structures sharing a central vertex.
This also creates concave places for 30 pairs of tetrahedra adding no vertices plus 12 tetra-5-rings adding 12 vertices for a total of 54+80+12 + 1 center = 147.



147-atom cluster

has 12+1 = 13 TSC Fusion sites]..."

Lord et al use 12, 54, and 146 atoms for Mackay clusters
while Liang uses 13, 55, and 147 atoms.

The difference is whether or not the center vertex is counted, that is,
not so much a real physical difference but a difference in math convention.

What about more than 147 atoms ?

As more layers are added, the deformations of tetrahedra and octahedra accumulate and eventually destabilize the structures necessary for Jitterbug and TSC Fusion. The next Mackay cluster beyond 147 atoms has $147+162 = 309$ atoms.

Barretau, Desjonqueres, and Spanjaard in Eur. Phys. J. D. 11 (2000) 395-402 say:

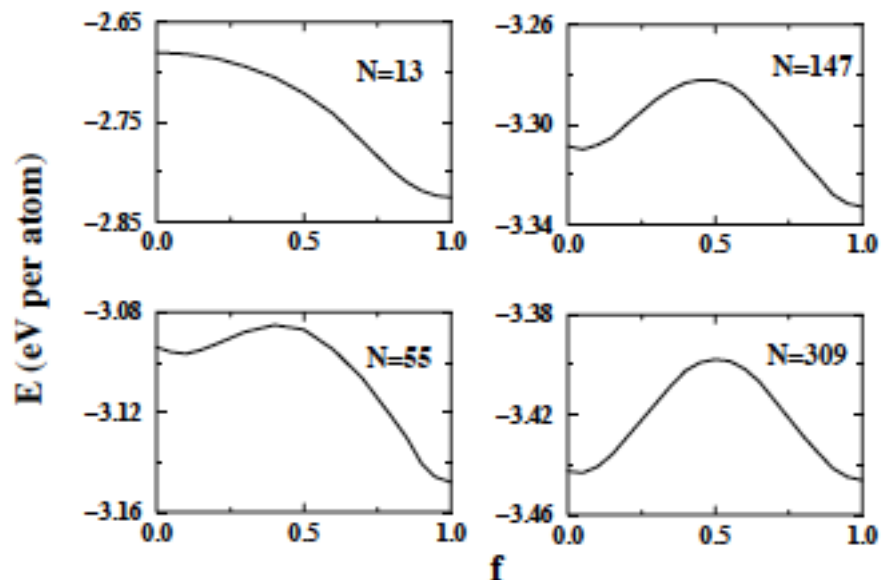
“... the icosahedron is the preferred structure at small sizes, and the critical size at which the relative stability becomes favorable to cuboctahedrons is $N = 561$ for PdN clusters ...[for which]...

For $N = 13$ the cuboctahedron is ... unstable.

For $N = 55, 147,$ and 309 atoms the cuboctahedron is metastable and slightly distorted. Its transformation to a perfect icosahedral structure needs an activation energy of 12 meV for $N = 55,$ 28 meV for $N = 147$ and 45 meV for $N = 309.$

The activation energies involved in the inverse transformation are 61 meV for $N = 55,$ 51 meV for $N = 147$ and 48 meV for $N = 309.$

...[compare 47.6 MeV for each TSC Fusion event]...



... The evolution of the potential energy profile of homogeneously relaxed ... PdN clusters during the Mackay [Jitterbug] transformation for increasing values of N . f is a fraction of the displacements ... $f = 0$ and 1 correspond to the ... cuboctahedron and icosahedron, respectively ...”.

$N = 309$ is disfavored for TSC-Jitterbug Fusion with respect to $N = 147$ for two reasons:

energy levels are too close for rapid Jitterbug cubocta to icosah transition

$N = 309$ Pd Cluster is too large (2 nm) to fit through 1.5 nm expanded Sodium Zeolite Y pore

It seems that **147 atoms is optimal for TSC fusion.**

How many D atoms can live in a 147-atom Pd cluster ?

F. Calvo and A. Carre say in Nanotechnology 17 (2006) 1292–1299

"Structural transitions and stabilization of palladium nanoparticles upon hydrogenation":

"... Cuboctahedra ...[and]... icosahedra ... contain exactly the same number of atoms. ...

In the case of ... the 147-atom Pd cluster ... the favoured structure in the pure metal is the three-layer icosahedron.

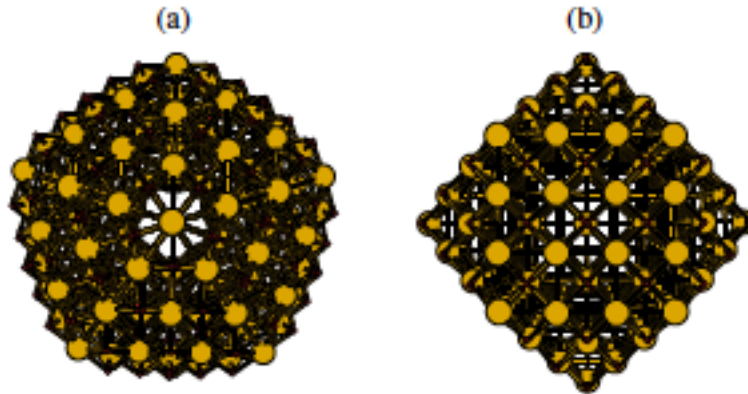


Figure 1. Palladium clusters fully loaded with hydrogen.

(a) $\text{Pd}_{147}\text{H}_{200}$, I_h symmetry; (b) $\text{Pd}_{147}\text{H}_{164}$, O_h symmetry.

Since the minimum full load for Icosa or Cubocta Pd/Ni 147-atom clusters is 164 D/H atoms, no more than 3 cycles of full TSC fusion

(each consuming 56 D/H nuclei) can occur without replenishment of D/H from the surroundings of the clusters (such as immersion of the clusters in D/H gas).

How long does it take Deuterium to load into Palladium ?

Wang, Hara, and Watanabe in Materials Transactions, Vol. 48, No. 3 (2007) pp. 560 to 565 say:

"... Pure Pd, Pd-4 at%Pt and Pd-8 at%Pt ... powders smaller than 200 mesh ($<74 \mu\text{m}$) were prepared ... hydrogen absorption ...[by Pd-4 at%Pt]... was extremely fast and attained to equilibrium within tens of seconds. Hydrogen absorption by Pd and Pd-8 at%Pt was also very fast ...".

Tens of seconds is much longer than the times for TSC Fusion and for Jitterbug

so it determines the time duration of one TSC-Jitterbug Fusion Cycle

and

for the purpose of rough calculations it seems reasonable to take

36 seconds = 1/100 hour = time duration of one TSC-Jitterbug Fusion Cycle.

This time is much shorter than the usual loading time for old-type Cold Fusion experiments using Palladium rods, discs, much-larger-than 1.5 nm powder, etc because there are only 3 layers of Pd atoms in 1.5 nm 147-atom Pd clusters.

Production of Palladium Clusters

147-atom Pd clusters have diameter about 1.5 nanometers.

**1.5 nm Pd Clusters have been produced
at Sandia National Laboratories**

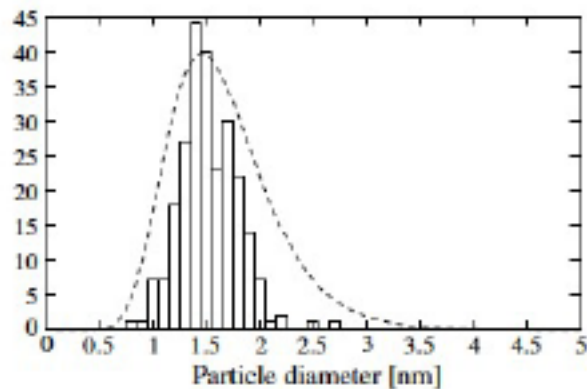
and University of New Mexico Center for Micro-Engineered Materials

according to a Journal of Catalysis article

"Facile, surfactant-free synthesis of Pd nanoparticles for heterogeneous catalysts"
at

<http://www.flintbox.com/public/filedownload/2871/2011-038%20Science%20Direct%20Article>

by Patrick D. Burton, Timothy J. Boyle, and Abhaya K. Datye showing



“ ... ”

Tim Boyle said in email October 2014:

“... We easily remade the Pd NP just need to get TEM to see what size they are.

If they come out good, we can go ahead and make some for you.

Couple of things.

This is very easy and ya'll may want to do it yourselves
(esp after the next couple of comments).

Simply dissolve Pd-acetate in MeOH and stir for 5 min,
let grow for 20 more and should have your size.

The problem is these will continue to grow and plate out onto the sides of the container,
unless you use a substrate.

Would you want these on a substrate, then that'll need to be supplied.

If we make it, we'd have to send it as a solution ...

could you handle this and could you use it?

It won't be a powder, which I think is what you want.

We can dry it down to a powder but not sure what size that will be
or how they'd cluster and how they'd redisperse or in what solvent.

we can try to deposit the materials on a number of surfaces and just let it dry.

Again, not sure how the clustering of these particles will occur.

A gram will take about 2.5 g of Pd(Oac)₂ which we have but will need replaced. ...”.

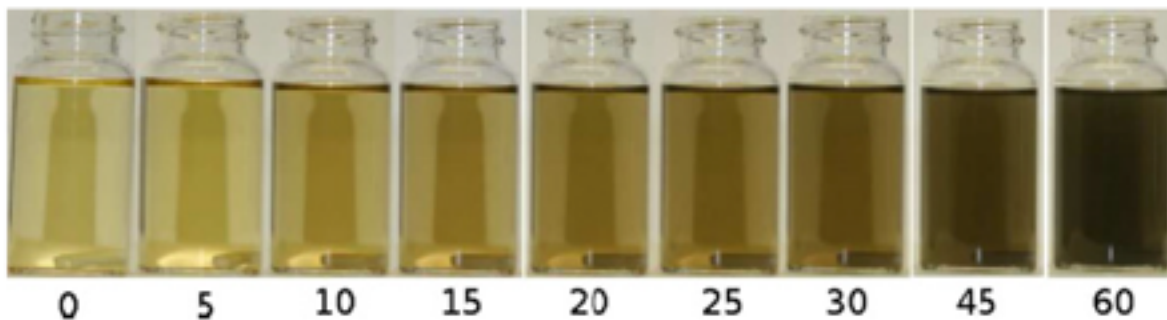
Sandia Pd Cluster Recipe

- 1 - 15 ml of methanol (MeOH) in a scintillation vial
- 2 - Add 5 mg palladium acetate (Pd(OAc)₂) whose color is red-orange
- 3 - Reduce the Pd(OAc)₂ by MeOH to Pd atoms by stirring for 5 minutes with unobstructed exposure to room lighting.
- 4 - Add 10 mg of substrate in colloidal suspension
- 5 - Place on elevated stir plate and allow to react undisturbed for 20 minutes.

During 20 minutes the Pd atoms form clusters that grow to size 1.5 nm (147 atoms)

Initially the Pd atom clusters are very small (only a few atoms) and will migrate onto the substrate and continue to grow to size 1.5 nm (147 atoms) at 20 minutes

Color of colloidal suspension changes from pale yellow to dark green over the 20 min



6 - At 20 minutes Pd-loaded substrate (and any remnant Pd still in colloidal suspension) are removed and the Pd-loaded substrate dried

7 - Pd-loaded substrate is placed in reaction chamber where it is exposed to Deuterium gas from tank and calorimeter measurements are taken to measure any heat that might be produced by TSC-Jitterbug fusion

(analogous to heat produced by Arata and Zhang (replicated by McKubre at SRI) with no external power input - only palladium powder + deuterium gas)

The substrate used initially by Sandia was SBA-15 mesoporous silica. In future experiments the substrate may be 30-40 nm Zeolite Crystals, such as Sodium Zeolite Y or ITQ-37.

At 30-40 nm size each will have about 12 to 16 large Cavities per edge About half of the Cavities will be on the Exterior Surface of the Tetrahedral Crystal where they will be easily accessible by Pd atom clusters in the colloidal suspension

In April 2015 Tim Boyle of Sandia National Lab produced Palladium nanoclusters on SBA-15 mesoporous silica substrate.

In May 2015 Mark Goorsky of UCLA did XRD (x-ray diffraction), SEM and TEM (scanning and transmission electron microscope studies of the Sandia material, saying:

“... Analysis of:

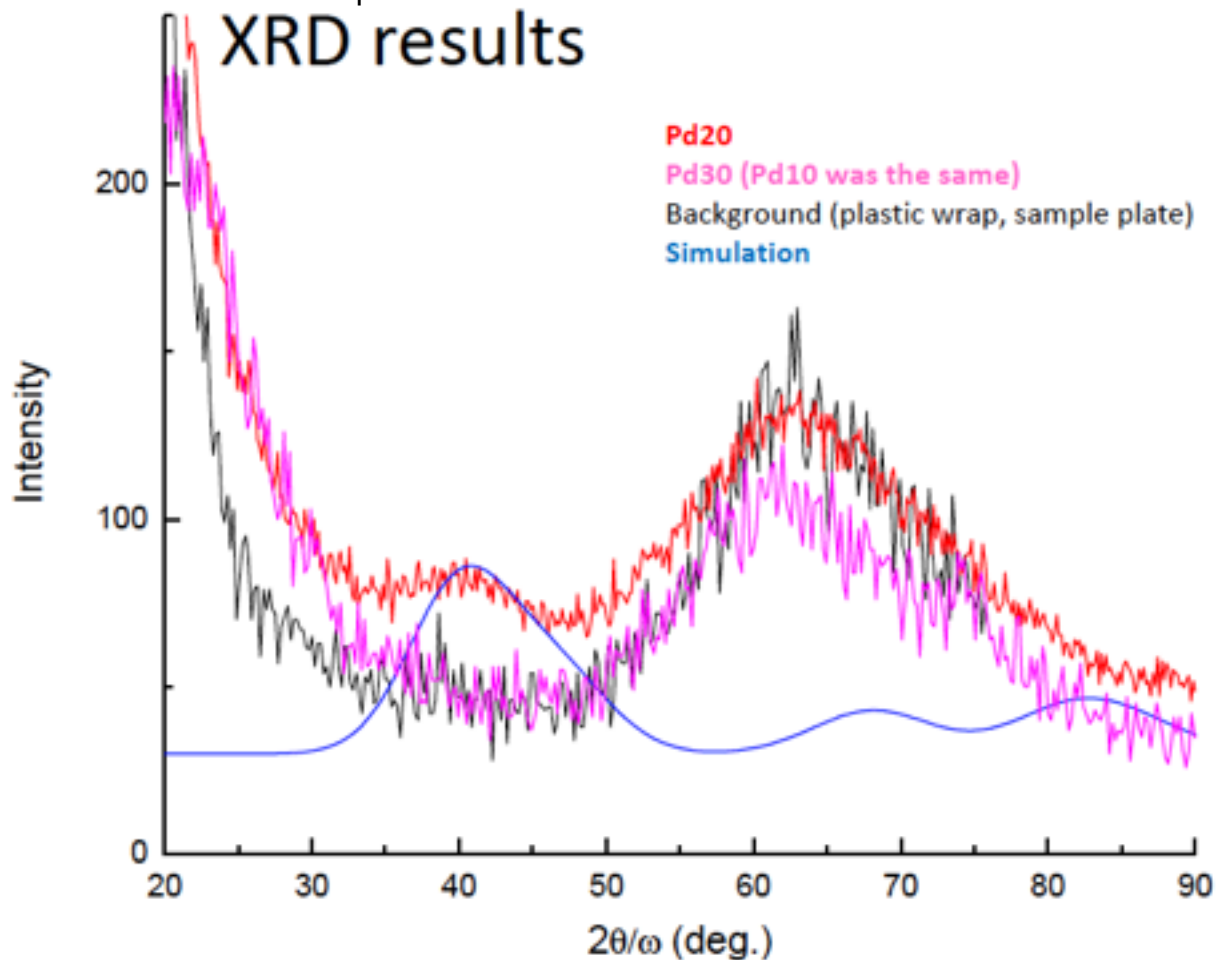
tjb.Pd/SBA.30b Pd30

tjb.Pd/SBA.20b Pd20

tjb.Pd/SBA.10b Pd10

tjb.Pd/SBA.40b: the vial for this sample (40b) was broken in transit to UCLA ...

measurements were not performed on it. ...



... All samples (Pd10, 20, and 30) showed a peak near 20° 2 theta which is typically related to amorphous SiO₂.

Pd20 exhibited scattered intensity near 40° 2 theta

Neither Pd10 nor Pd30 showed this scattered intensity ...

The simulation shows the broadening for the (111) and (200) Pd diffraction peaks

This broadening matches well with the presence of the scattered intensity in Pd20

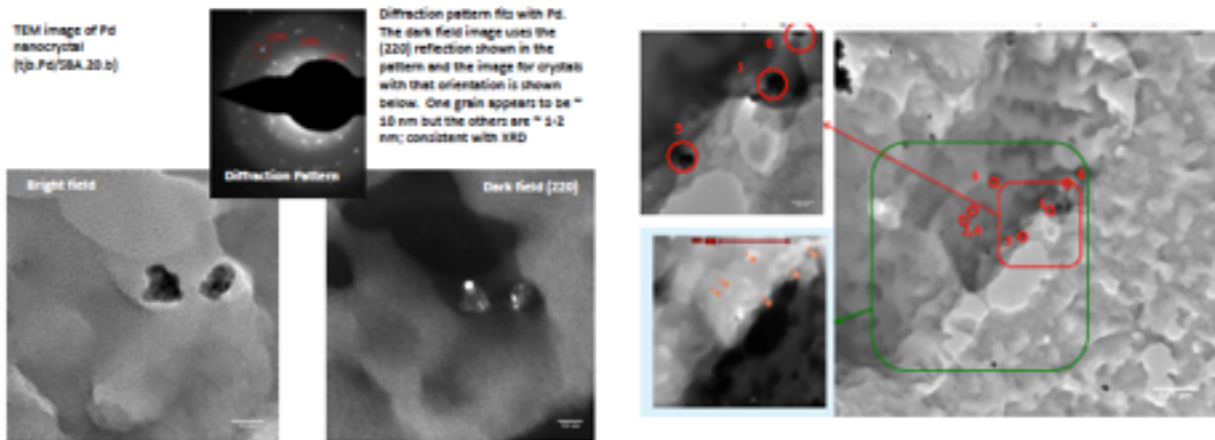
The simulated structure is based on 1.2 nm particle size

1.5 nm particle size produced a peak that was slightly sharper than shown in the figure

... the SEM does not show signs of pores ...
 but ... ~ 1 micron particle (SBA-15) are indeed observed ...
 TEM is needed to determine presence of Pd ... nanoparticles in ... pores ...
 Particles would be just below resolution of this ...[SEM]... system ...”.

The June 2015 TEM report for Pd30 shows some Pd but only in a few regions which is consistent with the XRD results in which the Pd peak was not observed.

The June 2015 TEM report for Pd20 shows Pd distributed through most of the SBA-15. The image below shows 6 sites (red circles) within a 1-micron square (green box)



4 of the red sites (1,3,5,6) were shown by EDX to be Palladium clusters.
 At least 2 other black dots in the green box look like they are likely to be Palladium clusters, so I estimate that each square micron of a layer of the material contains 5 Pd clusters.
 Since there are 1,000 microns in a millimeter,
 there should be 5×10^6 Pd clusters in a square millimeter of a layer of the material.
 If the layers are each about 1 micron thick
 then a cubic millimeter of the material should contain about 5×10^9 Pd clusters.

**Since each TSC fusion event produces 47 MeV fusion energy,
 how much fusion energy would be produced by 1 TSC fusion cycle in all of the Pd clusters ?**

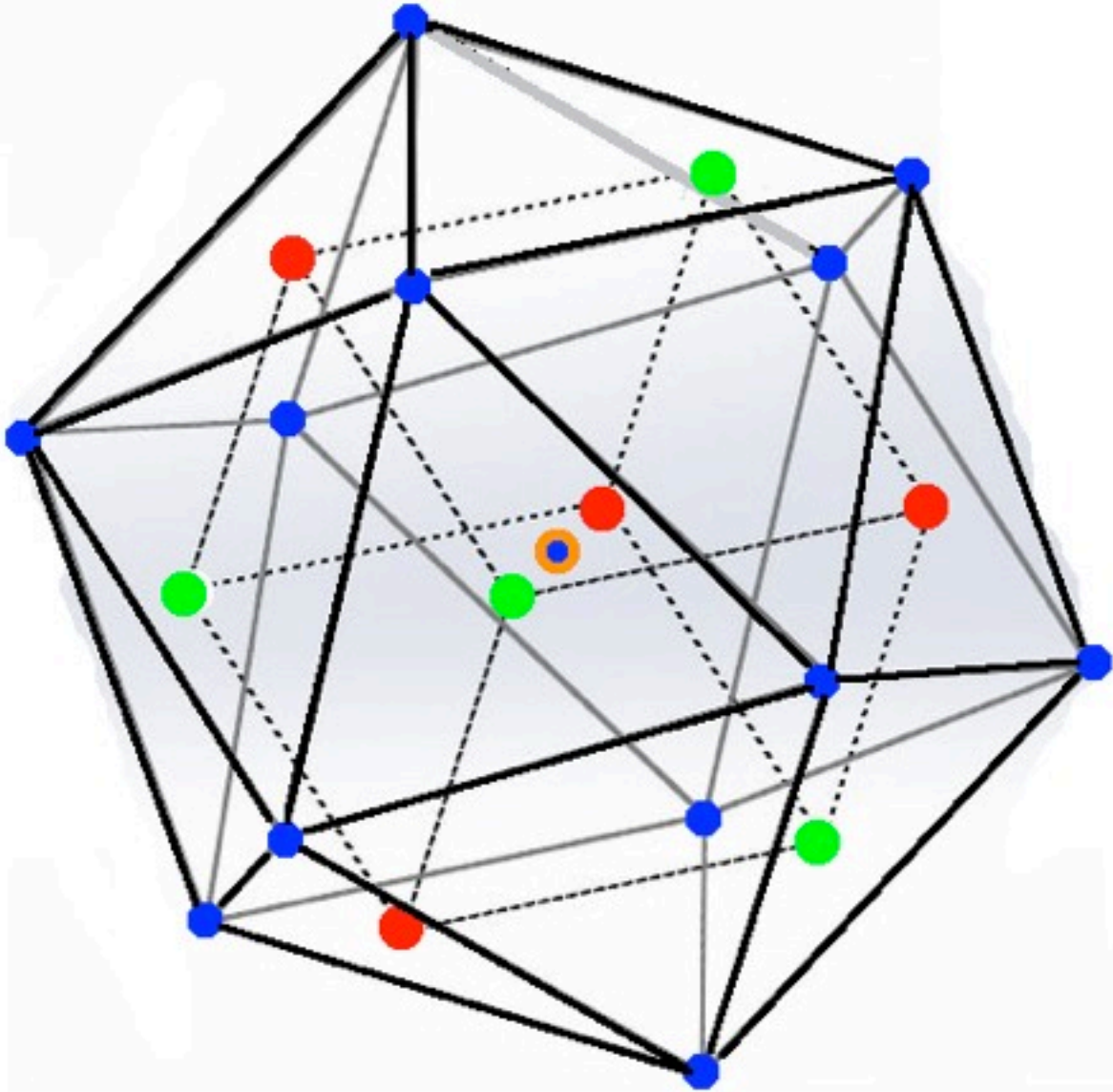
Each 147-atom Pd cluster contains 12 outer icosahedra + 1 central icosahedron.
 I estimate (guess) that all of the outer 12 icosahedra will produce a TSC fusion event in each TSC fusion cycle.
 There are about $4 \times 10^{(-17)}$ Watt-Hours per MeV, so the total energy output for 1 TSC cycle should be about
 $47 \times 4 \times 10^{(-17)} \times 12 \times 5 \times 10^9 = 11,280 \times 10^{(-8)} = 1 \times 10^{(-4)}$ Watt-Hours = 0.1 milliWatt-Hours
 For every 100 TSC fusion cycles, one cubic millimeter of the material should produce by TSC Deuterium fusion about 10 milliWatt-Hours of energy.
 I do not know the time of a TSC fusion cycle
 but if 36 seconds = 1 / 100 hour is taken as the TSC fusion cycle time
 then the power of one cubic millimeter of the material would be about 10 milliWatts.

How does TSC Condensation Fusion Work ?

Julian Schwinger in 1990 lecture at Universite de Bourgogne said:

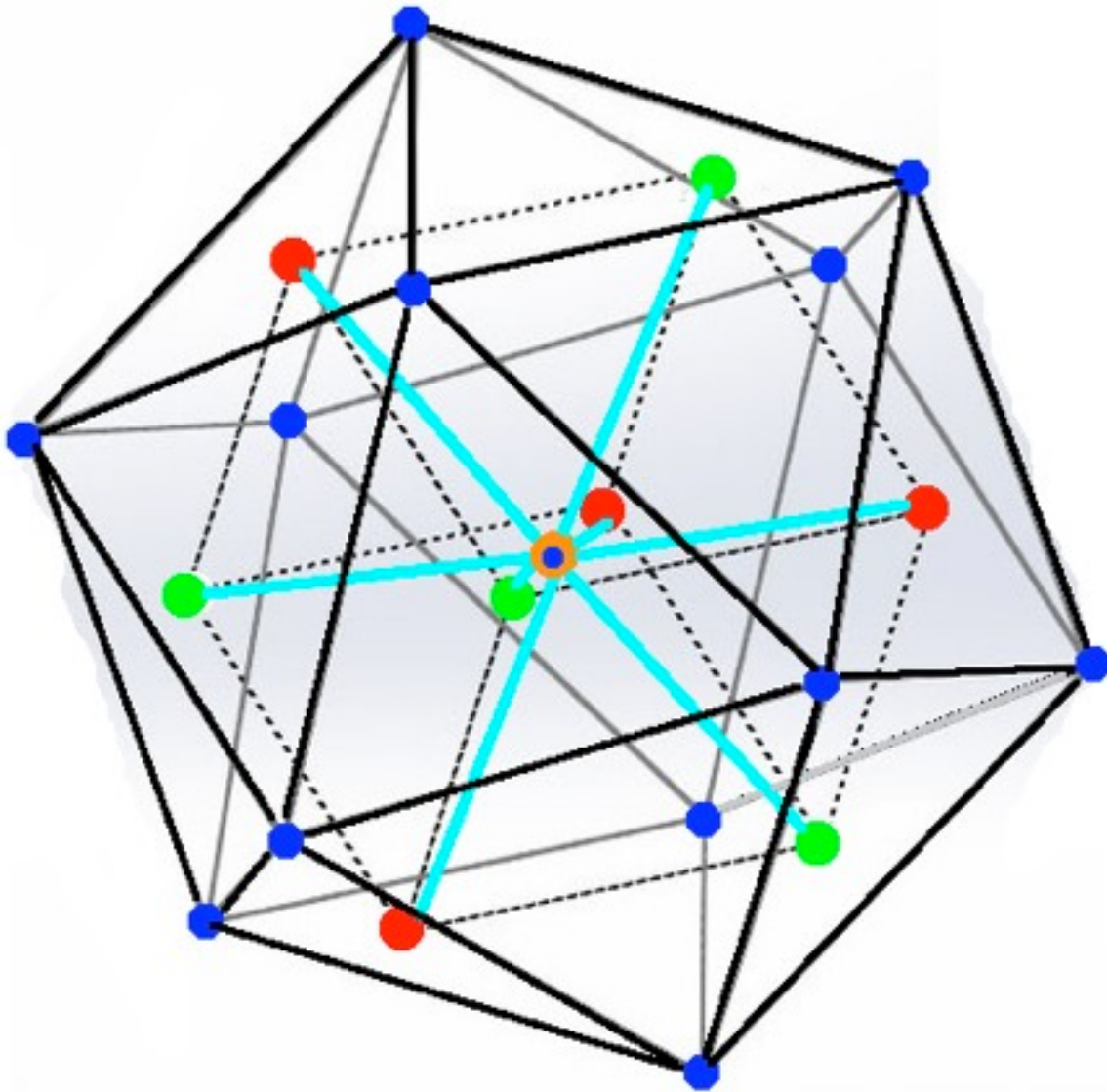
“... in the very low energy cold fusion, one deals essentially with a single state, described by a single wave function, all parts of which are coherent ...”.

This image (adapted from a Thingiverse web site image) shows



the 12 Palladium nuclei (blue dots) arranged in an icosahedral configuration plus a 13th Palladium nucleus at the center that is the TSC fusion site (orange/blue dot). The 4 Deuterium nuclei (red dots) and their 4 electrons (green dots) are at the vertices of a cube and are in a single Schwinger coherent quantum state.

That state then contracts in a symmetric way along the cyan lines going down to the center of the cube at the central Palladium nucleus (orange/blue dot) which acts as a quantum attractor for the Deuterium TSC quantum state.



The $D + D + D + D$ condenses to the orange/blue dot for TSC Fusion to form 8Be which decays to $4\text{He} + 4\text{He} + 47.6 \text{ MeV}$ energy

Takahashi said, about his TSC process:

“... Immediately at ... 8Be^* formation ... 4d-cluster shrinks to much smaller size (about 2.4 fm radius) of 8Be^* nucleus, and four electrons should go outside due to the Pauli's repulsion for fermions. Shortly in about few fs or less

(note; Lifetime of 8Be at ground state is 0.67 fs),
 8Be^* will break up into two 4He particles”
plus energy release of 47.6 MeV.

According to Hagelstein's model for fusion energy going to excited optical phonons in the Pd cluster, instead of the "... four electrons ... go[ing] outside ...", the four electrons should remain part of Schwinger's "coherent ... single state" until after fusion when the four electrons and the two 4He nuclei would produce two 4He atoms, with most of the 47.6 MeV going to excited optical phonons in the Pd cluster.

If the Pd Clusters were embedded in Zeolite Cages, heat from the Pd Cluster would be transferred to the Zeolite, from which it could be extracted by the Zeolite-Water process.

A 3-shell 147-atom icosahedral Palladium atomic nanocluster
contains 13 TSC Fusion Site Icosahedra
and each TSC Fusion event produces 47.6 MeV

$47.6 \text{ MeV} \times 13 \text{ TSC Sites} / 147\text{-atom Pd Cluster} \times 4.45 \times 10^{(-17)} \text{ Watt-Hours} / \text{MeV} =$
 $= 2.754 \times 10^{(-14)} \text{ Watt-Hours} / 147\text{-atom Pd Cluster for each Jitterbug Cycle}$

Mass of 147-atom Pd Cluster $147 \times 106 \times 1.66 \times 10^{(-21)} = 2.587 \times 10^{(-17)}$ milligrams
so **a milligram of 147-atom Pd Clusters gives about 1 KiloWatt-Hour each Cycle.**

If 36 seconds = 1/100 hour is taken as the Cycle time
then

**a TSC-Jitterbug Fusion device with 1 milligram of Palladium
in the form of 147-atom Pd clusters with full D-Loading
should produce 100 KiloWatt-Hours in an hour.**

How is TSC Fusion energy transferred to Pd Cluster Structure excited optical phonon modes ?

Hagelstein and Chaudhary in ICCF 18 (Missouri 2013) Poster:

Relativistic Coupling Between Lattice Vibrations and Nuclear Excitation say:

“... for relativistic dynamics ... the fundamental theory includes a very strong coupling between the center of mass momentum operator, and internal nuclear transitions.

This coupling is connected to changes in the internal structure of a composite when it moves (as a result of the Lorentz transform), compared to the rest frame wavefunction. Under normal conditions a generalized Foldy-Wouthuysen transformation eliminates this strong coupling, which results in a model in the rotated frame with no residual first-order interaction. As a result, one would expect generally not expect any significant coupling to survive.

The conditions under which any residual coupling would be expected are the same conditions where the generalized Foldy-Wouthuysen rotation "breaks down" ... in that it becomes very difficult to deal with the loss operator in the rotated picture.

Under conditions where the Foldy-Wouthuysen transformation "breaks down" in this sense due to the presence of a strong Brillouin-Wigner loss operator, there exists no useful general nonrelativistic limit. In this case, the strong coupling between the center of mass momentum and internal nuclear states remains, and can be used for coherent dynamical processes. ...”.

Hagelstein and Chaudhary in Current Science 108 (25 Feb 2015): Low Energy Nuclear Reactions : Phonon Models for Anomalies in Condensed Matter Nuclear Science say:

“... a... new physics model which addresses the fractionation of a large quantum; and a new fundamental Hamiltonian which describes the coupling between vibrations and internal nuclear degrees of freedom ...

the nuclear energy quantum is fractionated into much smaller quanta, which can go into vibrational modes. For this to work in the model, the vibrational modes first need to be highly excited ...

deuterons are responsible in fractionating the nuclear quanta in operation with excited optical phonon modes, and the deuterons can accomplish this cleanly.

However, THz acoustic mode excitation would also be expected to produce fractionation with participation of the host Pd nuclei, which do not fractionate cleanly (leading to disintegration of the Pd nuclei) ...

there is a strong coupling between the vibrational degree of freedom and internal nuclear degrees of freedom implicit in a relativistic model, but this coupling is normally eliminated by a generalized Foldy–Wouthuysen transformation ...

The fundamental relativistic Hamiltonian under discussion is

$$\hat{H} = \sum_j (Mc^2 + \mathbf{a} \cdot c\hat{\mathbf{P}})_j + \sum_k \frac{\hat{\mathbf{p}}_k^2}{2m} + \sum_{j < j'} \frac{Z_j Z_{j'} e^2}{4\pi\epsilon_0 |\mathbf{R}_j - \mathbf{R}_{j'}|} + \sum_{k < k'} \frac{e^2}{4\pi\epsilon_0 |r_k - r_{k'}|} - \sum_{j,k} \frac{Z_j e^2}{4\pi\epsilon_0 |\mathbf{R}_j - \mathbf{r}_k|} \quad (5)$$

If we use a Born–Oppenheimer approximation, then the lattice nuclear problem that remains is

$$\hat{H} = \sum_j (Mc^2 + \mathbf{a} \cdot c\hat{\mathbf{P}})_j + \sum_{j < k} V(\mathbf{R}_j - \mathbf{R}_k) - \frac{i\hbar \hat{\Gamma}(E)}{\hbar}, \quad (6)$$

where we have augmented the normal Born–Oppenheimer model with a loss term due to coupling with the electrons.

... we have in this a starting place to analyse coherent energy exchange between nuclei and vibrations under conditions of fractionation ... phonon - nuclear coupling matrix element... in the case of the D2 / 4He transition ... is consistent in magnitude with what is needed to account for the rate at which excess heat is observed in experiments ... Fractionation is easier when fewer oscillator quanta are involved, so we would expect the highest frequency vibrational modes to be involved (THz frequency vibrations). There is only a weak coupling between vibrations and the D2 / 4He transition ... the D2 / 4He transition occurs with a single phonon exchange with the large nuclear energy quantum transferred to other more strongly coupled transitions and subdivided (many nuclear excitations for a single D2 / 4He de-excitation), and subsequently fractionated to optical phonons ... excess heat is basically 'silent' (in that there is nothing energetic emitted in the primary reaction)

...

The rate of fractionation without subdivision then has to match the energy release rate. For example, if the system produces excess heat at the 1 W level, then there are 2.6×10^{11} reactions/sec and it must take 3.8×10^{-12} sec for each of the large 24 MeV quanta to be fractionated. If the optical phonon mode has an energy of 36 MeV, then the average time associated for the net transfer of a single phonon in connection with fractionation must be 5.7×10^{-21} sec. These numbers are consistent with the models we have studied over the years

...

If the nuclear system is treated relativistically, there is a very strong coupling present between the vibrational and internal nuclear degrees of freedom ... there exists a unitary transformation that eliminates this very strong first-order coupling. Under conditions where this unitary transformation is useful, the vibrational and nuclear degrees of freedom are nearly independent ... when the ... destructive interference ...[of]... the unitary transformation which eliminates the strong first-order coupling ... is spoiled ... there will be a[n]... enhanced rate for coherent energy exchange under conditions of fractionation ... a highly excited vibrational mode ... remove[s]... the destructive interference ...”.

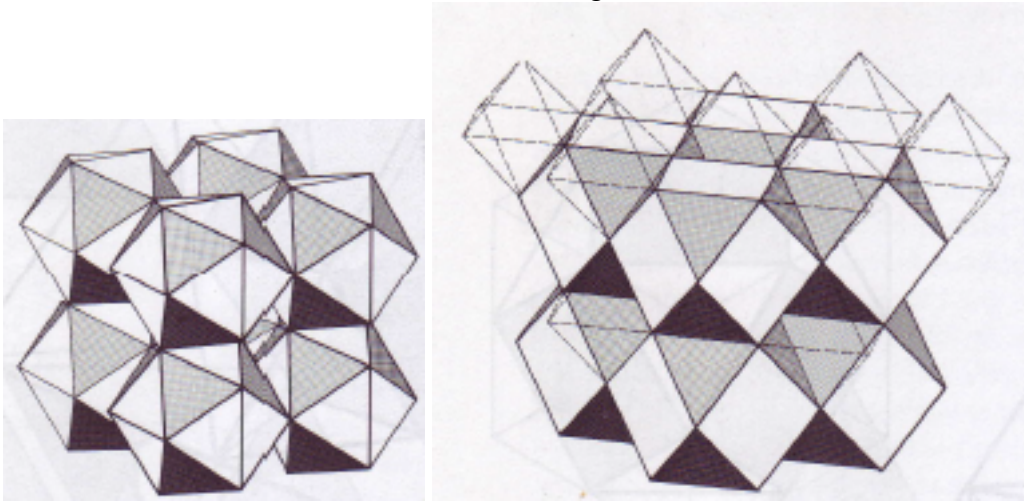
Letts in Current Science 108 (25 Feb 2015): Low Energy Nuclear Reactions : Dual Laser Stimulation says: “... PdD lattice vibrations might occur around 8 and 15 THz ...”. 8 - 15 THz Pd-D Fusion Frequency is interestingly coincident with:

Critical Temperature of BSCCO superconducting crystals
Beck - Mackey Dark Energy Josephson Junction Frequency
Energy of Neutrino Masses

How does Jitterbug Reloading Work ?

Klee Irwin's Jitterbug Transformation studies show that the stable Icosahedral phase of 147-atom Pd clusters enables TSC Pd-D Fusion which thereby expands to its metastable cuboctahedral phase, producing He Fusion Product + Energy and reloads D Fusion Fuel, and then goes back to its stable icosahedral phase for another round of TSC Fusion

Icosahedra and Cuboctahedra both have 12 vertices so that it is possible to transform them into each other. Buckminster Fuller called that transformation the Jitterbug



(images from Synergetics by Buckminster Fuller (Macmillan 1975, 1982))

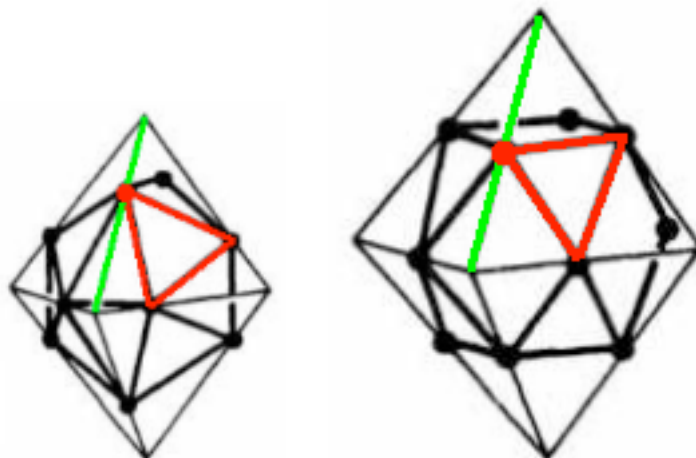
To make Cuboctahedra (unit edge length) from Icosahedra (unit edge length) choose 6 pairs of Icosahedra triangle faces (white in the above images) and lengthen the common edge of each pair by a factor of $\sqrt{2}$. That expansion flattens each of the triangle pairs to produce 6 square faces of the Cuboctahedron. The other Icosahedral $20 - 2 \times 6 = 8$ (shaded) triangle faces are rotated and become the other $14 - 6 = 8$ triangle faces of the Cuboctahedron.

,
thus increasing the number of faces from $8+6 = 14$ to $8+(6+6) = 20$ while keeping the number of vertices constant at 12.

There are two ways to choose a diagonal of an Icosahedron triangle face pair in the construction, corresponding to the two possible orientations of an Icosahedron.

Choice of diagonal for one Icosahedra triangle face pair forces (by requiring consistency) the choices for all other face pairs of all Icosahedra.

The triangle faces of the Icosahedron/Cuboctahedron are rotated by a Golden Ratio



(images adapted from Geometrical Frustration by Sadoc and Mosseri (Cambridge 2006))

angle defined by

sliding Icosahedron vertices on the edges of a circumscribing Octahedron

from points dividing edges into Golden Ratio segments

to points dividing edges into two equal segments

so that the Octahedron then circumscribes a Cuboctahedron.

If the edge lengths of the Icosahedron/Cuboctahedron are kept the same

then the Octahedron surrounding the Cuboctahedron will be an expansion of the Octahedron surrounding the Icosahedron.

Just as in the choice of a Cuboctahedron square diagonal to be compressed, there are two ways in which the edge could be divided into Golden Ratio segments, corresponding to the two possible orientations of an Icosahedron.

Choice of Golden Ratio segments for one edge forces (by requiring consistency) the choices for all other edges.

The time scale of such a Jitterbug Transformation of a Pd cluster may be on the order of a picosecond (compare Euro. Phys. J. D. 19 (2002) 333-337 by Pundt et al).

The volume expansion of the Jitterbug Transformation from Icosahedron (unit edge) to Cuboctahedron (unit edge) is:

$$\text{Icosahedron volume} = (5/12) (3 + \sqrt{5}) = 2.18169499$$

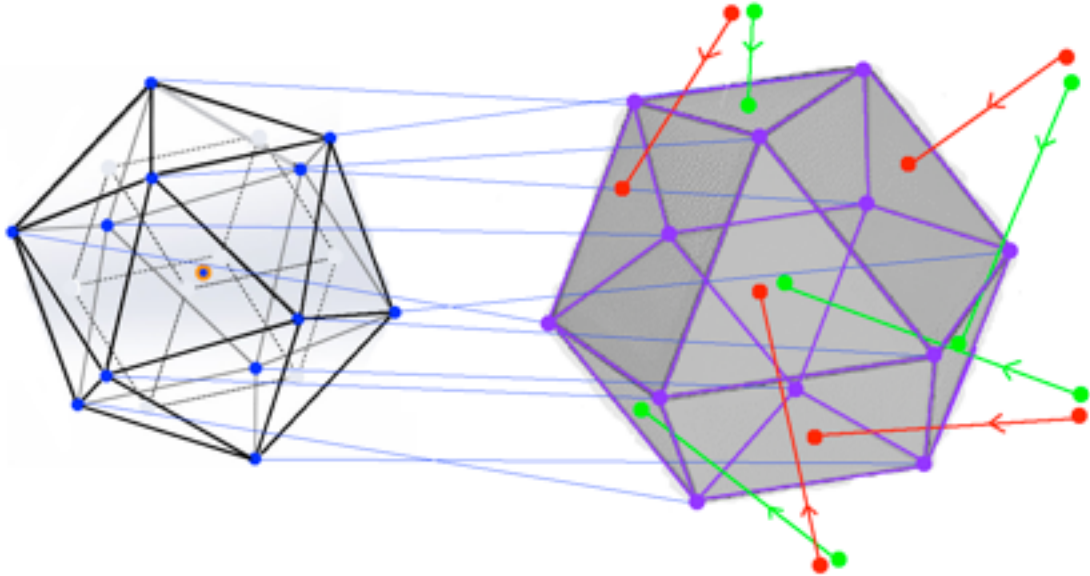
$$\text{Cuboctahedron volume} = (5/3) \sqrt{2} = 2.3570226$$

$$\text{Icosahedron/Cuboctahedron volume ratio} = 0.9256147947$$

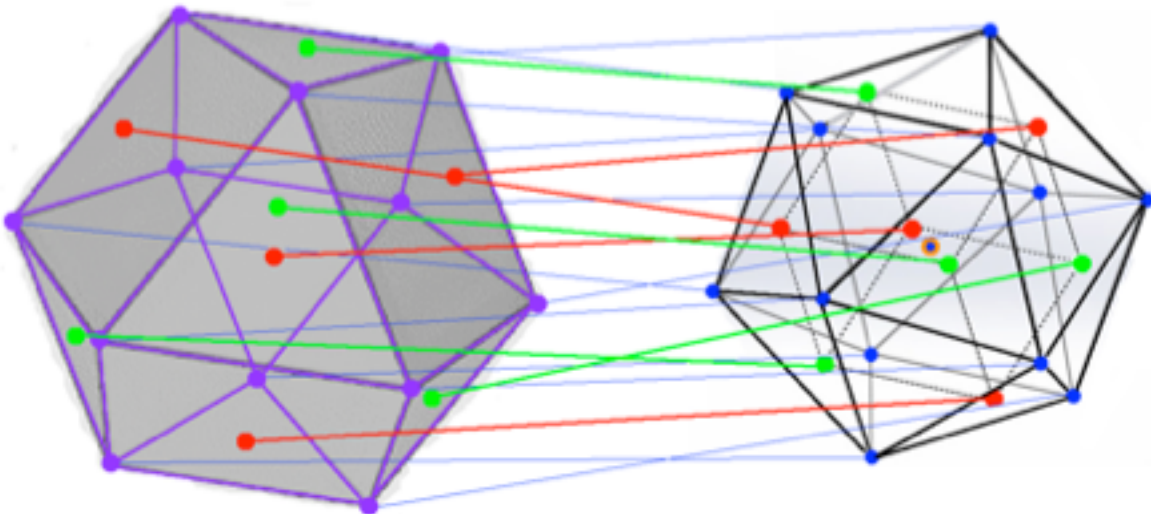
$$\text{Cuboctahedron/Icosahedron volume ratio} = 1.0803630254$$

How do Jitterbug Transformations enable D reloading ?

The cuboctahedral configuration resulting from Fusion Energy Jitterbug is not only larger than the Icosahedral configuration, it has 6 large square openings allowing easier entry into the Pd cluster of the Deuterium Nuclei (red dots) and Electrons (green dots)



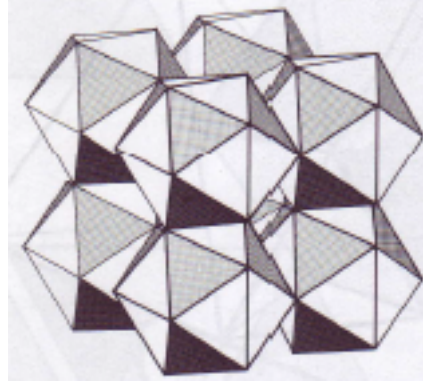
Also, the cuboctahedral configuration has 8 small triangle faces to which the 4 Nuclei and 4 Electrons of the Deuterium are attracted to form the Tetrahedral Symmetric Coherent Quantum State which is maintained after the second Jitterbug to the icosahedral ground state



thus producing a reloaded icosahedral configuration for another round of TSC fusion.

Jitterbug D-Loading analogy with Browning M1911 and Maxim Gun

(with Colt Series 80 Government 10 mm Delta Elite version of Browning's M1911 semi-auto)



"... The M1911 ... use[s] ... the short recoil ... action ... Cycle ...

1. Ready to fire position. [Slide] is locked to barrel, both are fully forward.

[Icosahedral Pd with D atoms in TSC positions]

2. Upon firing, [slide] and barrel recoil backwards a short distance while locked together. Near the end of the barrel travel, the [slide] and barrel unlock.

[Firing = D-D Fusion]

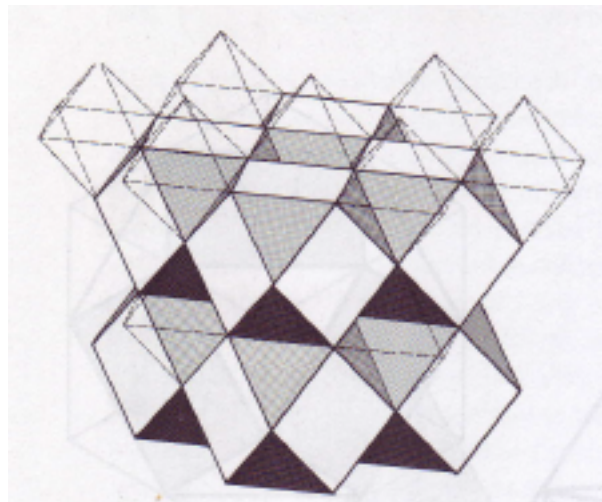
3. The barrel stops, but the unlocked [slide] continues to move to the rear, ejecting the empty shell and compressing the recoil spring.

[Recoil Spring = Icosahedral Stability Phase induces transformation of Cuboctahedra]

4. The [slide] returns forward under spring force, loading a new round into the barrel.

[Loading New Round = Cuboctahedral D atoms moved to Icosahedral TSC positions]

5. [Slide] locks into barrel, and forces barrel to return to battery.



... The very first short-recoil-operated firearm was also the first machine gun, the Maxim gun.

... Vladimirov also used the short recoil principle in the Soviet KPV-14.5 heavy machine gun. ..."

(quote from Wikipedia entries on M1911 pistol and on Recoil operation)

Experimental Results for Heat of Fusion from Pd Clusters and Deuterium gas

The only Cold Fusion experiments producing heat consistently and reproducibly are the detections of heat using Pd Clusters and Deuterium gas by Arata and Zhang (replicated by McKubre at SRI) and by Iraj Parchamazad.

Arata and Zhang (and SRI) used Palladium black with initial cluster size around 5 nm but clumping increased the cluster size to around 40 nm which Takahashi et al said, based on their similar work, made the “heat-power level drop... drastically”.

To avoid the clumping problem, Arata and Zhang worked with the initial Pd clusters dispersed in ceramics such as ZrO₂.

Iraj Parchamazad avoided the clumping problem in another way, by growing the Pd clusters within Zeolite cavities. Using Sodium Zeolite Y whose cavity size is around 1.2 nm (but capable of expansion by about a factor of 2), he produced Pd clusters of size similar to the 1.5 nm of the optimal 147-atom Pd cluster all dispersed within Zeolite cavities thus preventing clumping. Upon exposure of his Pd clusters in Zeolite to Deuterium gas, he produced heat in 10 out of 10 experiments.

Since Zeolites are far from inert passive substrate for the Pd clusters, having internal electric fields on the order of 3 Volts / nm, it is possible that the Sodium Zeolite Y played an active role in the heat production observed by Iraj Parachmazad.

To try to isolate the Pd cluster role in heat production, Iraj Parchamazad suggested putting Pd clusters on an inert substrate such as SBA-15 mesoporous silica. Pd clusters of about 1.5 nm size synthesized at Sandia by Tim Boyle were dispersed on SBA-15 mesoporous silica.

A first experimental step would be to expose Pd / SBA-15 material to Deuterium gas, so that any heat produced would most likely come from D fusion within Pd clusters and positive heat production would be supportive evidence for the TSC Fusion process initially proposed by Takahashi.

Since my primary interest is not so much conclusively validating my theoretical model, but is to use insights from my model to suggest a program of experiments that might lead to commercially useful Cold Fusion,
and

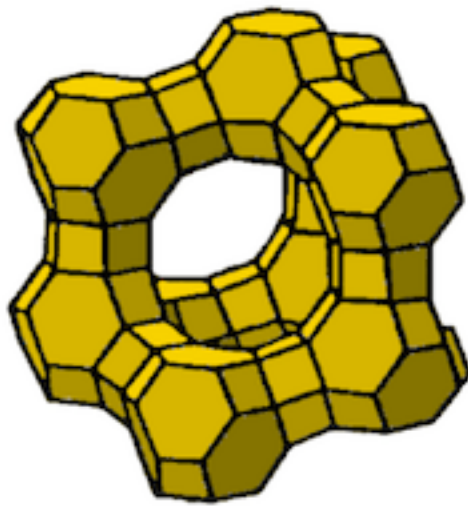
since Zeolites have useful energy storage and transfer properties,
my suggestion for the next experiment is,
after ruling out the necessity of Zeolites for making TSC Fusion work,
use Zeolite substrate to manage the heat energy of TSC Fusion,
converting it either into Steam Engine energy or directly to Electric Capacitor energy.

Transfer of TSC Fusion Energy from Pd Cluster Structure to Zeolite Structure

After TSC Fusion, by Hagelstein's process, the energy is stored in the Pd cluster as excited Optical Phonon modes.

The Pd Structure Energy of Excited Optical Phonon Modes is carried the Zeolite in which the Pd cluster is caged to be stored as Zeolite heat.

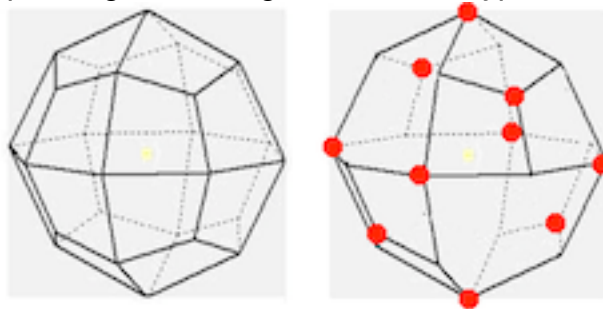
Each Zeolite Cavity is surrounded by 10 sodalite cages which are arranged in a 3-dimensional Diamond network as shown in this image



from

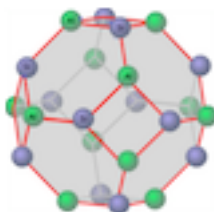
<http://www.vurup.sk/sites/vurup.sk/archivedsite/www.vurup.sk/english/products/molek/slovsit1/english.html>

The Zeolite Cavity has geometric symmetry related to an isometric trapezohedron = tetragonal trisoctahedron with the 4 holes corresponding to deleting 4 octahedral-type 3-face groups



The 10 red dots correspond to the 10 sodalite cages.

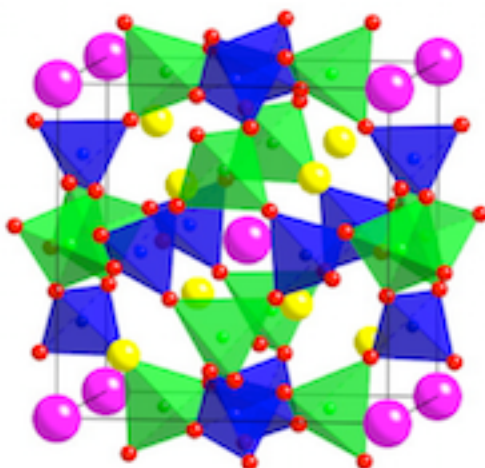
Each sodalite cage is a 24-vertex truncated octahedron as in this image from Wikipedia



A more detailed view of a sodalite cage from

<http://som.web.cmu.edu/structures/S099-sodalite.html>

has red dots for Oxygen and pink spheres for OH and yellow spheres for Sodium and blue tetrahedra for Silicon and green tetrahedra for Aluminum



It shows that of the 24 vertices of the sodalite cage, 12 are Aluminum and 12 are Silicon so each Zeolite Cavity has $10 \times 12 = 120$ Aluminum atoms.

Zeolite Cavities have Electrostatic Fields on the order of 3 V / nm .

R. A. van Santen and D. L. Vogel, in *Lattice Dynamics of Zeolites* (*Advances in Solid-State Chemistry*, Vol. 1 (1989) 151-224), said: "... The vibrational spectrum of a zeolite may be visualized as the sum of three contributions,

the first of which which is given by the zeolite framework, the network formed by SiO_4 and AlO_4 tetrahedra sharing corners.

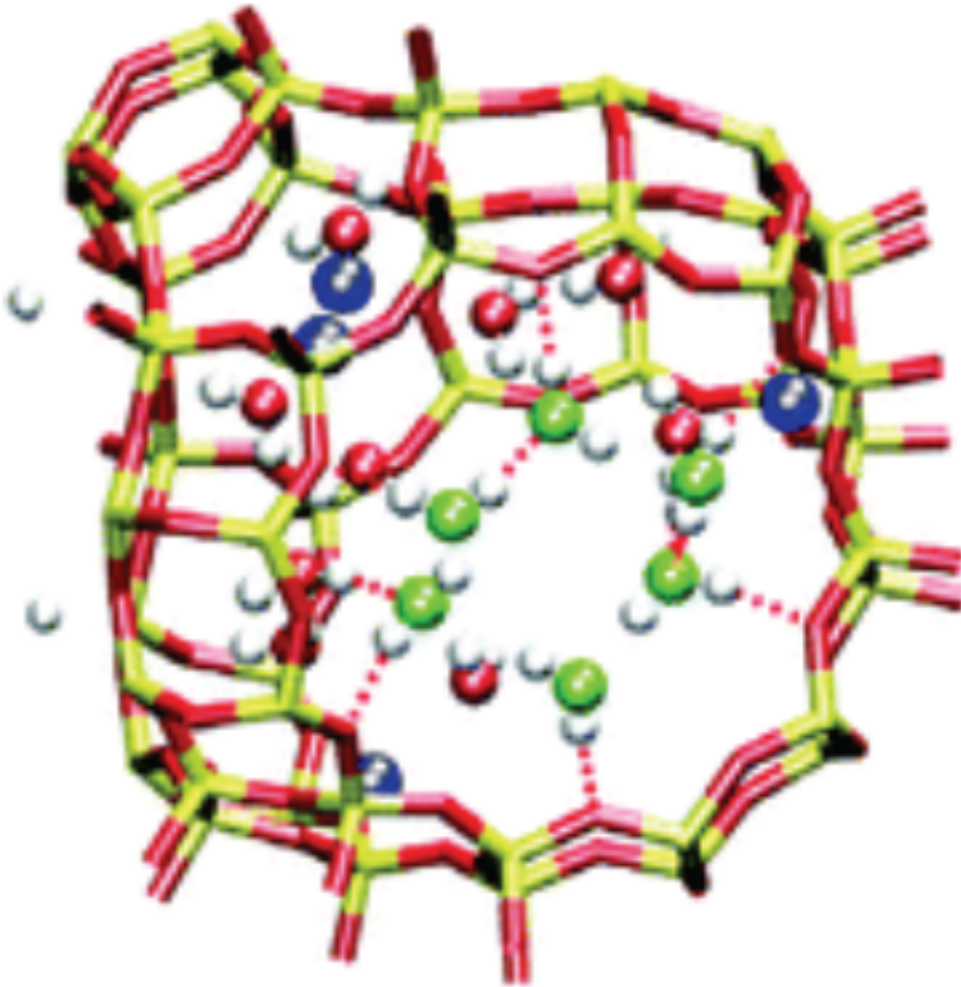
The second contribution originates from the ...[material]... located in the cages and channels formed by the framework ... The [material] vibrate[s] against the framework ...

The third contribution is given by the presence of hydroxyl groups and water molecules. Hydroxyl groups are either located in lattice vacancies, or present as isolated groups bound to the external zeolite surfaces, or internally bridging two tetrahedra. ... Due to the very high oscillator strength of the hydroxyl group, water and hydroxyl groups give rise to strong absorption bands between 3200 cm^{-1} and 3750 cm^{-1} (symmetric and antisymmetric stretching modes). ...".

Angela Di Lella, Nicolas Desbiens, Anne Boutin, Isabelle Demachy, Philippe Ungerer, Jean-Pierre Bellat, and Alain H. Fuchs, Phys. Chem. Chem. Phys. 8 (2006) 5396-5406) studied water in Zeolites, saying: "... We report ... Monte Carlo simulations of water



adsorption in [Zeolite] NaY ... faujasite ... The existence of cyclic water hexamers ... located in the 12-ring windows ... recently disclosed by neutron diffraction ...



... experiments ... were ... observed in the case of NaY ...".

Dmitry Kopelevich and Chia-Yi Chen, in Phonon interactions in zeolites mediated by anharmonicity and adsorbed molecules (Molecular Simulation 2008), said: "... thermal conductivity of nanoporous materials can be significantly affected by adsorption of guest molecules. These molecules serve as moving defects and provide additional scattering centers for heat-carrying phonons. ...

we perform molecular dynamics simulations of a model system, namely sodalite zeolite with small molecules ... encapsulated in its cages. We measure effects of sorbates ... such as correlations between different phonon modes and the phonon frequency and lifetime. ... The phonon lifetime often increases upon encapsulation of a sorbate into the zeolite which suggests that the sorbate-phonon interactions are qualitatively different from phonon scattering by point defects fixed in the lattice. ...”.

Iraj Parchamazad used Sodium Zeolite Y also known as faujasite.
The Wikipedia page for faujasite says:

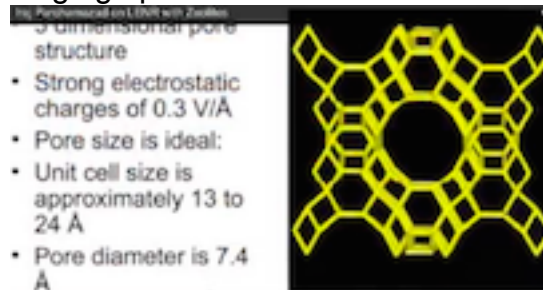
“... The faujasite framework consists of sodalite cages which are connected through hexagonal prisms.

The pores are arranged perpendicular to each other.

The pore, which is formed by a 12-membered ring, has a relatively large diameter of 7.4 Å [0.74 nm]

The inner cavity has a diameter of 12 Å [1.2 nm] and is surrounded by 10 sodalite cages. ...”.

Ruby Carat and Melvin Miles interviewed Iraj Parchamazad of University of La Verne in 2012. In that video interview Iraj Parchamazad said that the Zeolite cavity size can oscillate and vary, enlarging up to about 2.4 nm.



A corresponding enlargement of pore size is to about 1.5 nm which would permit a 3-shell 147-atom Palladium cluster to enter the Zeolite Cavity.

Iraj Parchamazad did not use Sandia’s 1.5 nm Palladium clusters in his Zeolite but

used an organometallic solution containing Palladium atoms.

After putting that into the Zeolite he heated the Zeolite

to burn off Carbon, Hydrogen, and Oxide

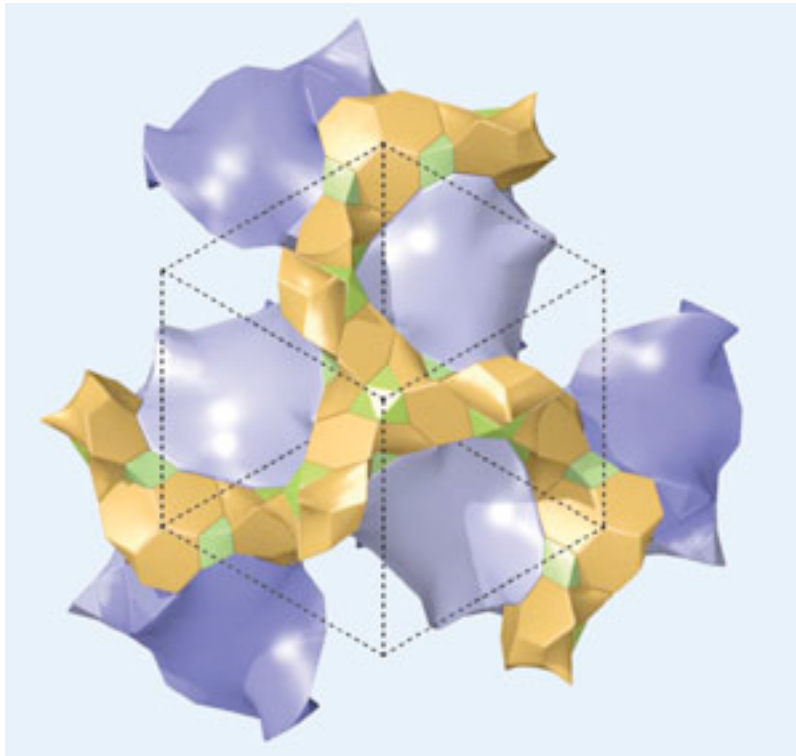
leaving a Zeolite and some Palladium.

Then he exposed the Zeolite/Palladium to Deuterium,

and got excess heat 10 out of 10 times, indicating fusion.

I would like to see experiments
with Zeolite directly using Sandia 1.5 nm Palladium NanoClusters.

If there is difficulty with getting the Sandia Clusters
to fit into the Sodium Zeolite Y
then
I would like to see experiments
with Zeolite ITQ-37



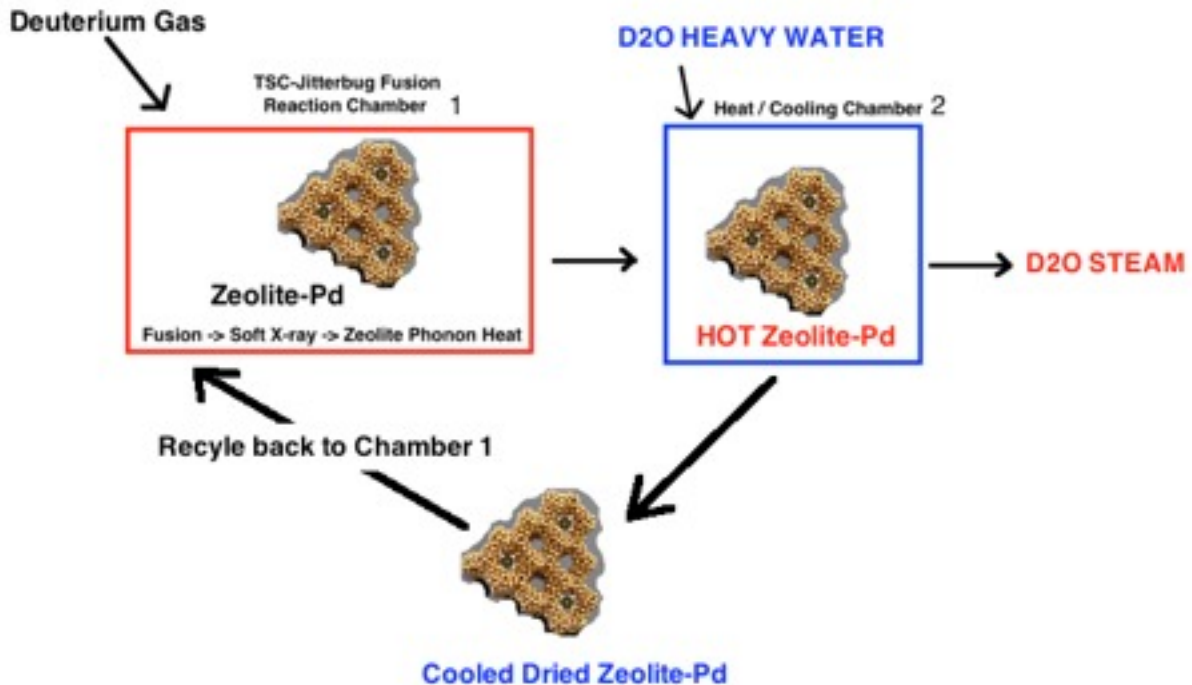
which has pore size about 2 nanometers.
(Royal Society of Chemistry, 29 April 2009 and Sun et al, Nature 2009)

Zeolite Heat and Water

After Palladium TSC - Jitterbug Zeolite fusion has been established the next step is production of useful amounts of energy

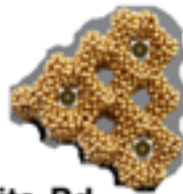
According to a 7 June 2012 techthefuture.com web article by Tessel Renzenbrink: "... Zeolite is a mineral that can store up to four times more heat than water ... zeolite retains a hundred percent of the heat for an unlimited amount of time ... When water comes into contact with zeolite it is bound to its surface by means of a chemical reaction which generates heat. Reversely, when heat is applied the water is removed from the surface, generating large amounts of steam. The transference of heat to the material does not cause its temperature to rise. Instead, the energy is stored as a potential to adsorb water. The ...[German Fraunhofer Institute]... scientists used these particular properties to turn zeolite into a thermal storage system. They created a storage device and filled it with zeolite pellets. To charge the pellets, they exposed them to heat. To retrieve the energy they simply added water. ...".

Here is my design for a TSC-Jitterbug Zeolite Pd-D fusion heat engine:



(Zeolite-Pd images adapted from Calvo and Carre in Nanotechnology 17 (2006) 1292-1299 and from <http://gwenbeads.blogspot.com/2014/04/infinite-skew-polyhedron-faujasite-4446.html>)

D2O Heavy Water is used to take heat from the Zeolite to make steam so that Hydrogen from H2O does not poison the TSC-Jitterbug process by replacing Deuterium in the Palladium nanoclusters, a possible problem pointed out by Melvin Miles.
D2O heavy water from Fisher Scientific costs about \$1,000 per liter for 99.8 atom % D.



Preparation of Zeolite-Pd

Sodium Zeolite Y has unit cell size about 2.5 nanometers which corresponds to the edge-length per cavity of its overall tetrahedral structure.

According to <http://www.google.com/patents/US20040047803>

“... Synthesis and stabilization of nanoscale zeolite particles ...
Zeolite Y is of great interest ... Zeolite crystals prepared under conventional synthesis conditions frequently have a mean particle size of between 1 and 5 μm it would ... be useful if the zeolite particles were sufficiently small to form a colloidal suspension ...
Mono- or di-saccharides can be used to keep the crystal size of faujasite (zeolite X and Y) small

... Sucrose, dextrose or other saccharides are added to a conventional aluminium silicate reaction mixture obtained by mixing aqueous alkali metal silicate and alkali metal aluminate solutions at low temperatures, followed by ageing and hydrothermal synthesis. Crystal sizes of between about 30 and 40 nm are claimed ...”.

According to a Journal of Catalysis article by Patrick D. Burton, Timothy J. Boyle, and Abhaya K. Datye, "Facile, surfactant-free synthesis of Pd nanoparticles for heterogeneous catalysts"

“... room temperature reduction of Pd(OAc)₂ in MeOH is slow enough to produce a suspension of ... metal-phase ... Pd NPs. ...

A Pd-NP/C catalyst was prepared by mixing the carbon support into the suspension of Pd NPs and evaporating the solvent. Aggregate formation was a concern, as there were no capping agents to prevent particle growth. Therefore, the nanoparticles were collected quickly before substantial aggregation could occur. ... this technique is general and can be extended to other powder supports. ...”.

An “other powder support” that would be useful for TSC-Jitterbug fusion energy would be 30-40 nanometer Zeolite Y Crystals in colloidal suspension.

As the Pd nanoclusters “... grow for 20 ... min ...” up to size 1.56 nm for the 147 atom size that is optimal for TSC-Jitterbug fusion,
they are small enough to fit into the Exterior Cavities of the Zeolite Y Crystals

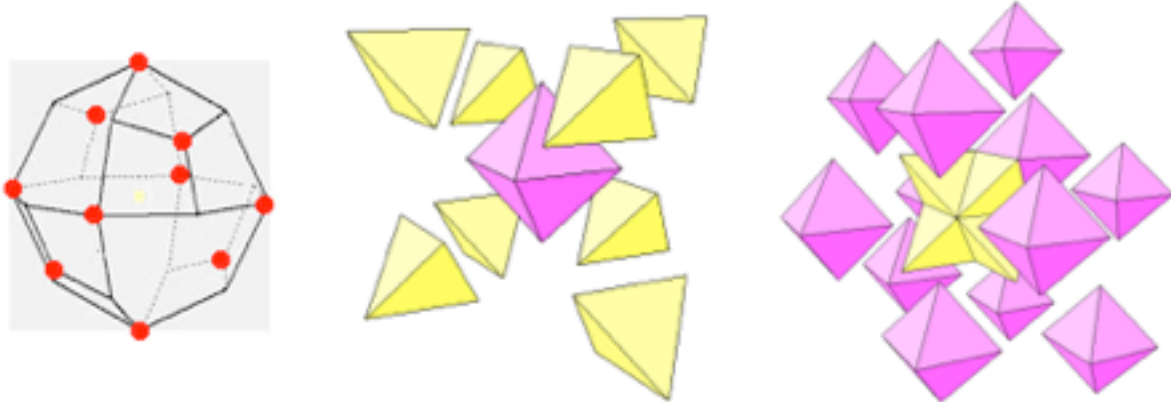
(which are have average pore opening 0.74 nm and cavity size 1.2 nm
but which sizes can oscillate to be up to about twice those sizes)

Due to the open structure of the Zeolite Y Crystals, growth up to the 147 atom size can continue inside the Exterior Cavities of the Zeolite Y Crystals.

As soon as the Pd nanoclusters have grown to the 147 atom size the solvent can be evaporated and the powder of 30-40 nm Zeolite Y Crystals loaded with Palladium can be collected and placed in the TSC-Jitterbug Fusion Reaction Chamber for exposure to Deuterium gas and heating the Zeolite Y Crystals by fusion energy.

The Zeolite Y Crystal has octahedral structure

(image from <http://whistleralley.com/polyhedra/octahedron.htm>)



and each unit cell with 1 Cavity is 2.5 nanometers in diameter
 so an octahedral Zeolite Y Crystal with diameter 35 nanometers
 would have an edge length $35 / \sqrt{2} = 25 \text{ nm} = 10 \text{ cells}$
 and the octahedron would have 19 square layers:

layer 1 = 1 external + 0 internal = 1 for total of 1 of which 1 is external
 layer 2 = 4 external + 0 internal = 4 for total of 5 of which 5 are external
 layer 3 = 8 external + 1 internal = 9 for total of 14 of which 13 are external
 layer 4 = 12 external + 4 internal = 16 for total of 30 of which 25 are external
 layer 5 = 16 external + 9 internal = 25 for total of 55 of which 41 are external
 layer 6 = 20 external + 16 internal = 36 for total of 91 of which 61 are external
 layer 7 = 24 external + 25 internal = 49 for total of 140 of which 85 are external
 layer 8 = 28 external + 36 internal = 64 for total of 204 of which 113 are external
 layer 9 = 32 external + 49 internal = 81 for total of 285 of which 145 are external
 layer 10 = 36 external + 64 internal = 100

layers 11 through 19 are mirrors of 1 through 9, for a total of 285 with 145 external
 so an octahedral Zeolite Y Crystal with diameter 35 nm would have
 $285 + 100 + 285 = 670$ cavities with $145 + 64 + 145 = 354$ (52.8 %) external and
 therefore relatively easily accessible to the Pd nanoclusters in the colloidal suspension.

Zeolite Y unit cell atomic mass is (from nptel.ac.in Introduction to Catalysis Lecture 36 Zeolites)

($56 \times 23 \text{ Na} + 56 \times 59 \text{ AlO}_2 + 136 \times 60 \text{ SiO}_2 + 264 \times 18 \text{ H}_2\text{O}$) = 17,504

for actual mass = $17504 \times 1.66 \times 10^{(-21)} = 2.906 \times 10^{(-17)}$ milligrams

The atomic mass of a 147-atom Pd nanocluster is $147 \times 106 = 15,582$

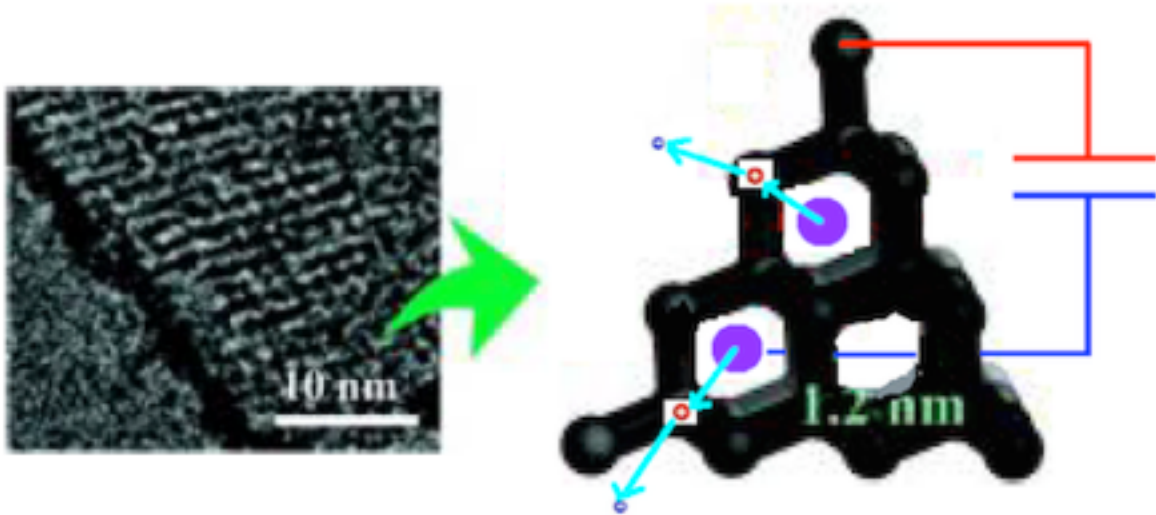
for actual mass = $15,582 \times 1.66 \times 10^{(-21)} = 2.587 \times 10^{(-17)}$ milligrams

For 35 nm Zeolite Y Crystals only about 1/2 of their Cavities are External so it may be
optimal to use Zeolite Y Crystal mass = 2 x Palladium mass in the colloid.

Zeolite Heat and Capacitor Electricity

According to a 26 January 2011 PhysOrg.com article by Lisa Zyga:

“... The unique 3D array of nanopores in zeolite-templated carbon ...



(image modified to show
 Zeolite-Templated Carbon framework as Black, Palladium NanoClusters as Purple,
 Ambient Fluid with Deuterium for TSC-Jitterbug Reloading as White,
 Excited Optical Phonons from TSC-Jitterbug Fusion as Cyan arrows
 ionize parts of the ZTC, ejecting electrons (Blue) into the Ambient Fluid
 and leaving positive ions (Red) in the Zeolite-Templated Carbon
 thus building up a Capacitance Voltage
 between the Zeolite-Templated Carbon and the Ambient Fluid)

... enables it to be used as an electrode for high-performance supercapacitors that have a high capacitance and quick charge time ... The zeolite-templated carbon consists of nanopores that are 1.2 nm in diameter ... and that have a very ordered structure ...”.

Synthesis of Zeolite-Templated Carbon

is described in the 2013 Caltech Ph.D. Thesis of Nicholas Stadie:

“... Zeolite-templated carbon (ZTC) materials were prepared ... by ... established methods ...

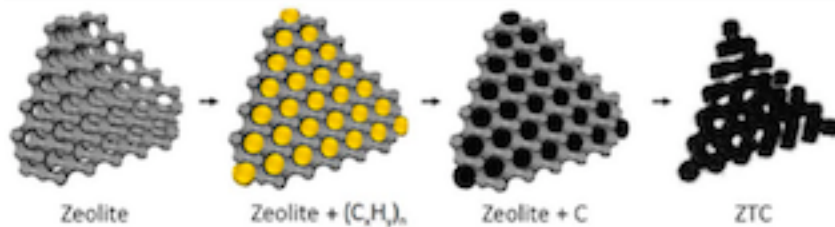


Figure 4.1. A schematic of template-carbonization in a porous zeolite framework, to produce zeolite-templated carbon (ZTC).

...”

The ZTC capacitor process converts TSC-Jitterbug fusion energy directly to electricity. Since it does not require the Zeolite-heat-water-steam chemical structure only the Zeolite Y Crystal geometric configuration is needed so all the Zeolite Y can be converted to ZTC carbon configurations attached to a single base carbon substrate that acts as a Capacitor Electrode.
(It would be difficult to use separated Zeolite Y Crystals as an electrode.)

However,
the ZTC has fewer Exterior Cavities than the colloidal free-floating Zeolite Y Crystals because
each tetrahedral structure is attached to the carbon substrate by a base face,
thus eliminating 1/4 of the Exterior Cavities so that for ZTC Capacitor fusion energy:

a 30 nm ZTC structure would have $30 / 2.5 = 12$ cavities per edge
and its tetrahedral structure would have 12 triangular layers
and a total of $1+3+6+10+15+21+28+36+45+55+66+78 = 364$ Cavities
of which $1+3+6+10+15+21+28+36+78 = 198$ would be Interior Cavities
and $364 - 198 = 166$ would be Exterior Cavities (orange dots)
so $166 / 364 = 46\%$ of the Cavities of the 30 nm ZTC structures would be Exterior
and thus relatively easily accessible to the Pd nanoclusters in the colloidal suspension.

A 40 nm ZTC structure would have $40 / 2.5 = 16$ cavities per edge
with 16 triangular layers
and $1+3+6+10+15+21+28+36+45+55+66+78+91+105+120+136 = 816$ Cavities
of which $1+3+6+10+15+21+28+36+45+55+66+78+136 = 500$ would be Interior Cavities
and $816 - 500 = 316$ would be Exterior Cavities
so $316 / 816 = 39\%$ of the Cavities of the 40 nm ZTC structures would be Exterior.

Therefore
for 30-40 nm ZTC structures only about 1/2 to 1/3 of their Cavities are External
so it may be optimal
for the number of ZTC Cavities to be 3 x the number of Pd 147-atom nanocluster

Global Energy and TSC-Jitterbug-Zeolite Fusion machines

Can TSC-Jitterbug-Zeolite Fusion produce Abundant Cheap Energy so that Expensive Competition for geologically concentrated Cheap Oil



will become unnecessary ?

Using total Earth Energy Reserves in Terawatt-years, according to M. Taube, in his book Evolution of Matter and Energy on a Cosmic and Planetary Scale (Springer-Verlag 1985), the number of years that 10^{10} people could consume energy at the present USA per capita rate, a consumption rate of about 1,000 Terawatt-years/year, is:

	Reserves (Terawatt-years)	Duration (years)
Oil	850	1
Gas	550	1
Methane	1,500	2
Coal	7,000	7
Uranium	1.9×10^9 (1/1000 of Earth supply)	2,000,000
Thorium	7.9×10^9 (1/1000 of Earth supply)	8,000,000
Deuterium	1.9×10^9 (1/1000 of ocean supply)	2,000,000
Lithium	1.9×10^9 (source of tritium)	2,000,000

As to solar energy, the total solar energy received by Earth is about 109,000 Terawatt-years/year so that 10^{10} people could consume energy at the present USA per capita rate by using about 1% (one percent) of the solar energy received by Earth. This could be done, for example, by building a lot of orbiting solar energy collection dishes and beaming the energy to Earth.

The total geothermal heat flux is about 66 Terawatt-years/year, and the total tidal energy is about 3 Terawatt-years/year, so that those sources would be inadequate to support 10^{10} people consuming energy at the present USA per capita rate.

For Everybody on Earth to be Happy, the Abundant Cheap Energy must provide a high Standard of Living (current USA standard) for a lot of people (10 billion), and:

last for a long time (more than decades) - rules out Oil, Gas, Methane, and Coal;

have no serious radioactive waste - rules out Uranium, Thorium, and Tritium (Lithium);

have realistically scalable capital cost - rules out Solar which would require Satellite collectors with area 1% of $\pi \times 6,000^2 = 1,000,000 \text{ km}^2 = (1,000 \text{ km})^2$ or cloud-free collectors on Earth surface with the same area. Less than 100% efficiency would require correspondingly larger area of collectors.

That leaves one possible source of Abundant Cheap Energy for 10 billion people:

	Reserves (Terawatt-years)	Duration years)
Deuterium	1.9 x 10⁹ (1/1000 of ocean supply)	2,000,000

Since a gram of properly structured Palladium gives TSC-Jitterbug Pd-D Cold Fusion Energy on the scale of Megawatts:

1 milligram of Palladium gives a 1 kiloWatt Machine, useful for “electric motors, tools, machines and heaters” (Wikipedia)
Such small energy machines could use the ZTC Electric Capacitor technology.

1 gram of Palladium gives a 1 MegaWatt = 1340 HorsePower Machine, useful for “large electric motors; large warships such as aircraft carriers, cruisers, and submarines; large server farms or data centers; and some scientific research equipment such as supercolliders, and the output pulses of very large lasers. A large residential or commercial building may use several megawatts in electric power and heat. ... railway... electric locomotives ... typically have a peak power output of 5 or 6 MW, although ... Eurostar ... uses more than 12 MW, while heavy diesel-electric locomotives typically produce/use 3 to 5 MW ...” (Wikipedia)
C-130 aircraft have 4 engines each with 4300 HorsePower (globalsecurity.org)
so would need a $4 \times 4300 / 1340 = 13$ grams of Pd
Such mid-sized energy machines could use, depending on portability and site requirements, either Zeolite Steam or ZTC Electric Capacitor technology.

1 kg of Palladium gives a 1 GigaWatt Machine,
useful for “large power plants ... HVDC converters have been built with power ratings up
to 2 GW” (Wikipedia)

Such machines could use either Zeolite Steam or ZTC Electric Capacitor technology,
using HVDC converters up to 2 GW to convert the ZTC Electric Capacitor DC into AC.

1,000 kg = 1 ton of Palladium gives 1 TeraWatt.

The total power used by Humans in 2006 was 16 TW.

The average lightning strike peaks at 1 TW, but lasts only 30 microseconds.

Powerful 20th century lasers produce TW, but only for nanoseconds. (Wikipedia)

1,000 tons of Palladium gives 1 PetaWatt.

The Lawrence Livermore Nova laser has power of 1.25 PW in a 5×10^{-13} sec pulse.

The total power of sunlight hitting the Earth is about 174 PW. (Wikipedia)

222 tons of Palladium were mined world-wide (based on 2006 and 2007 data, Wikipedia):

Russia produced 98 tons
South Africa produced 89 tons
Canada produced 13 tons
USA produced 11 tons
the rest of the world produced 11 tons