Transmutation Products and Excess Heat in Light Water/ H_2 LENR

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Main Focuses: Light Water LENR

- Issues
- UIUC – LW LENR
  - Transmutation –thin films
  - excess heat studies – thin films
- L W/H2 LENR Review – Other work
  - Examples of various studies carried out
- Brief review of Proposed Theories
- Conclusions

Issues

- Are proton reactions possible? (Is there more to cold fusion than D-D?)
- Significance of heavy water in light and visa versa?
- Is H loading the key parameter for reactions to occur?
- Is heat correlated to transmutations in LW LENR?
  - Do transmutation products satisfy energy balance, i.e. replacing He4 in heavy water studies?
- Reaction mechanism ??(extremely large columbic repulsion – overcome by shielding vs. neutral particle?)
- Other emissions – chg particles, radiation, …are any unique to light water reactions?
- Are there any advantages of LW vs. HW?

P-F D_20 vs. p/h_20 LENRs)

D-D Reactions

		% branching *hot fusion*	*"P-F" type*
D-D →	*T + p*	*50*	*< 0.1*
	He-3 + n	*50*	*< 10^{-6}*
	He-4 + gamma	*< 10^{-5}*	*99+*

LENRs

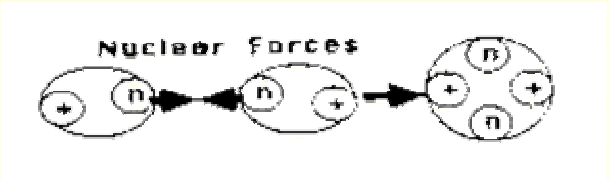
p + metal → products or "fission" product array

I -- UIUC LW Transmutation/excess ht studies

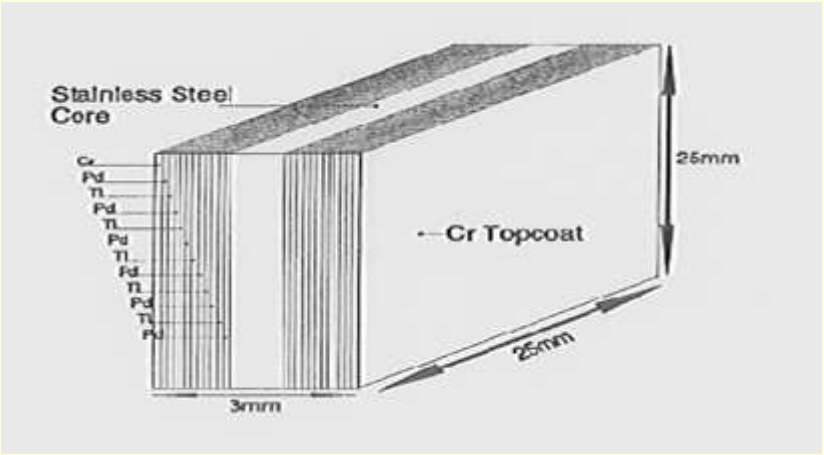
- Packed bed electrolytic unit with thin fim coated micro beads as cathode.
- Flat plate thin film electrode studies

BACKGROUND

SEL Theory and Experiments to Design Multilayer Thin-film Electrodes For LW &HW studies at UIUC.

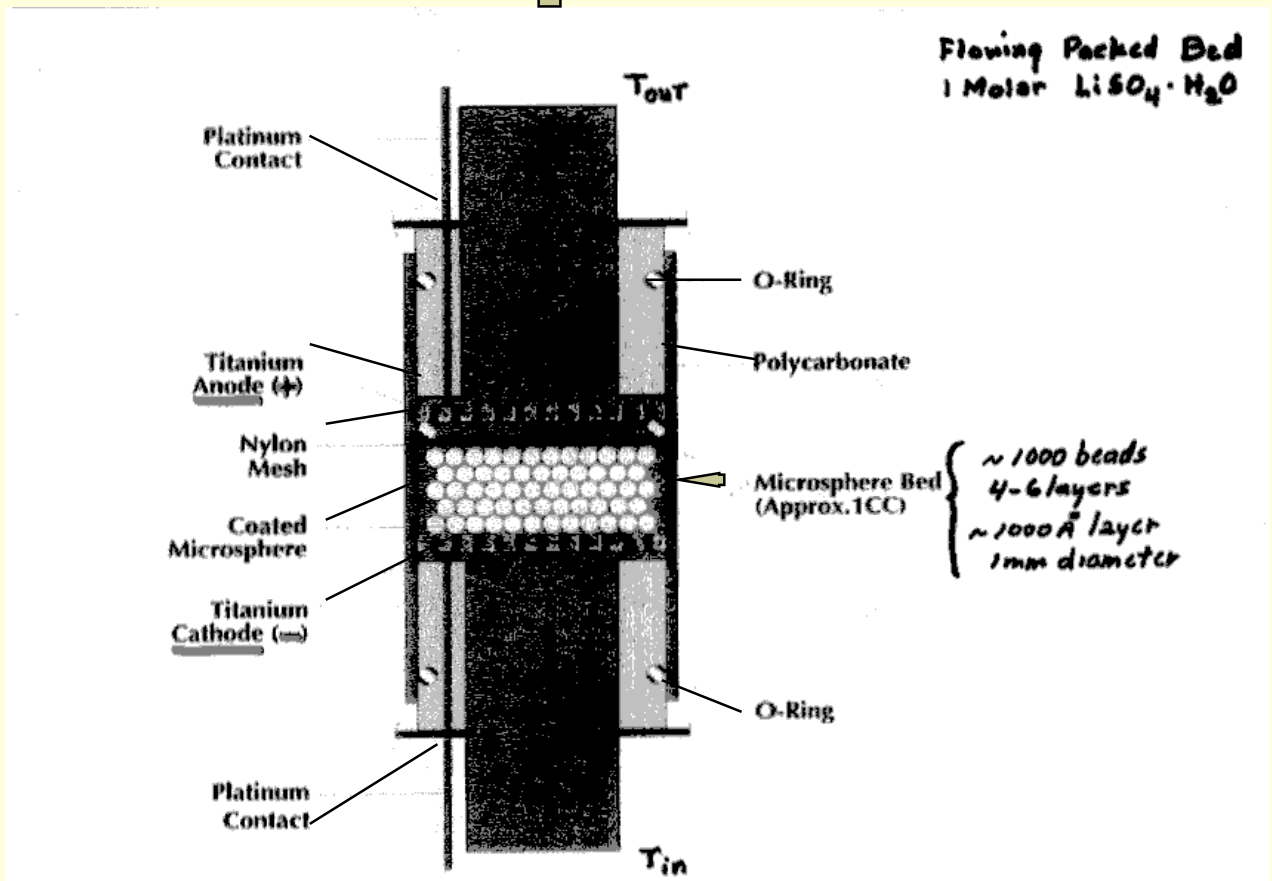


Fusion of two nuclei, shielded by the swimming electron layer



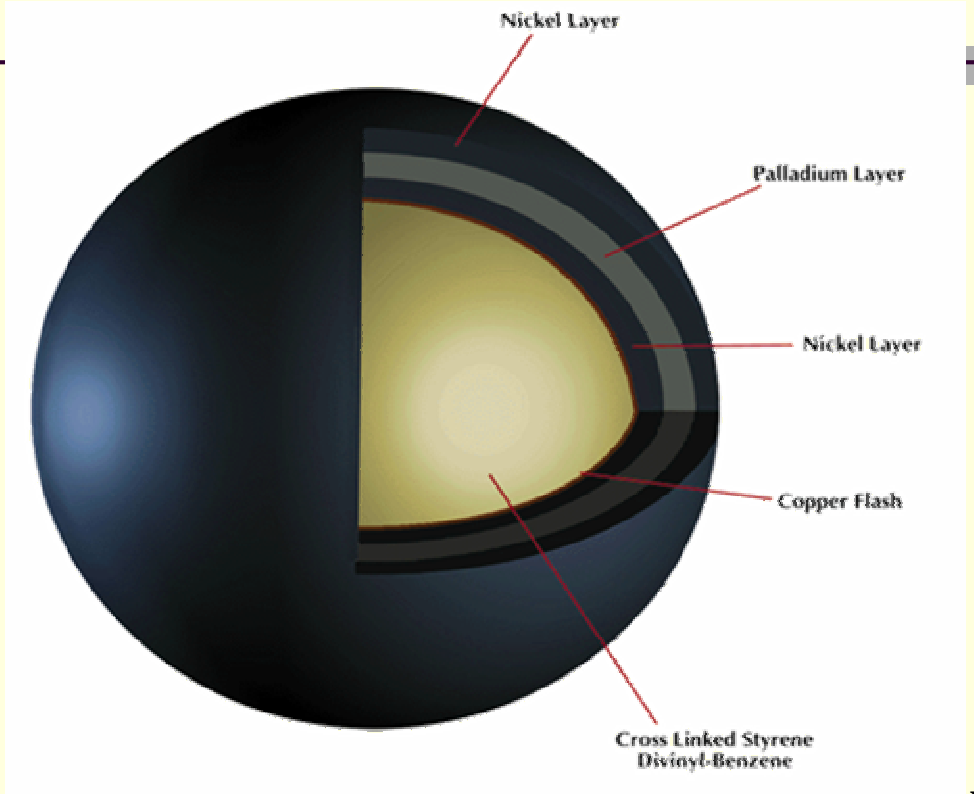
Multilayer thin-film electrode design with alternating layers of Pd & Ti with a topcoat of Cr

Example of product "array" plus heat: Miley-Patterson Transmutation Studies at UIUC used a Flowing Packed Bed Cell with LW electrolyte (see ICCF8 & *Progress in New H2 Energy*, vol 2, p 629-644, (1997)..)



BACKGROUND

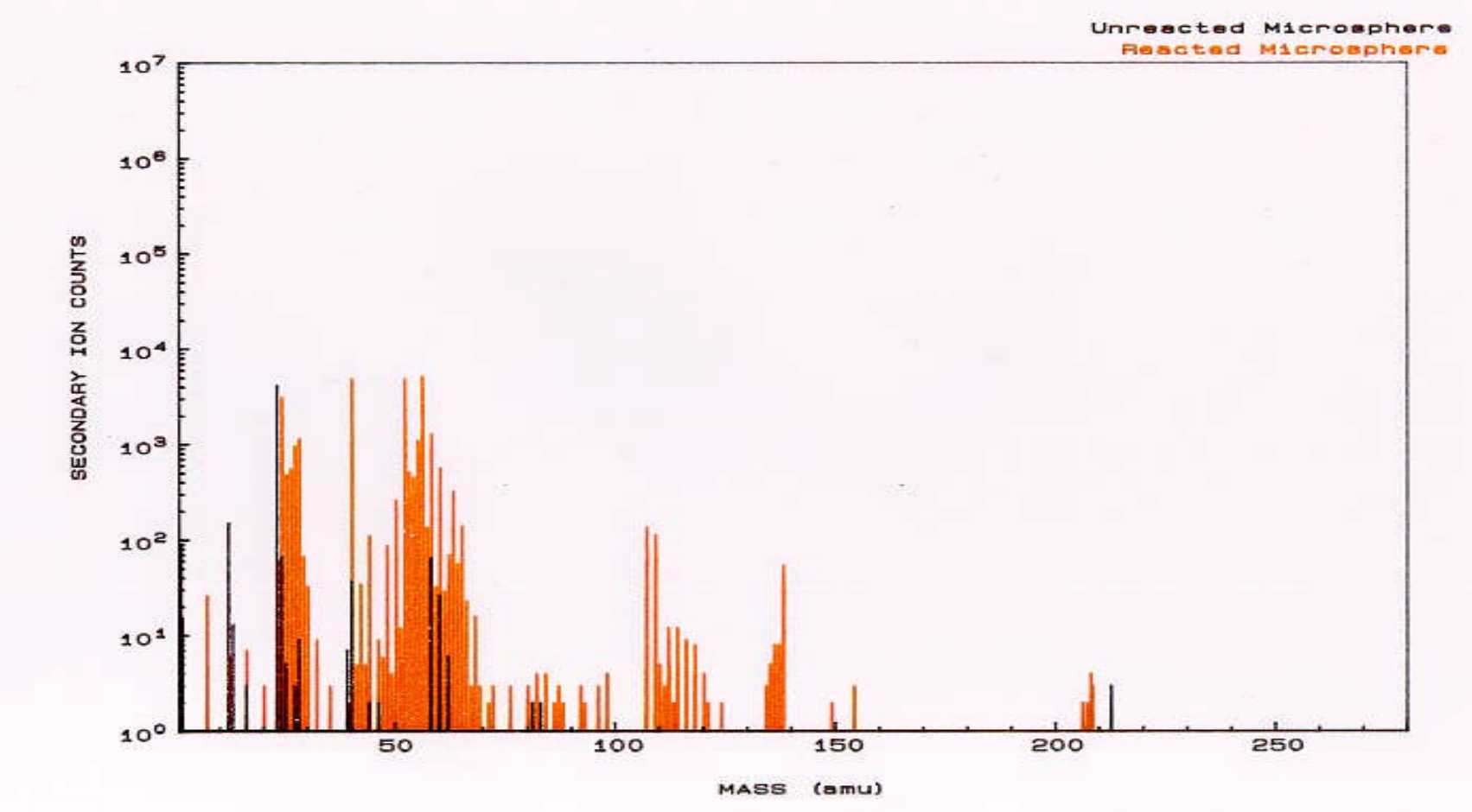
Microsphere Design



UIUC-CETI used an electrolytic coating process to coat metals on the microspheres. UIUCs sputter coating technique achieves better control of coating thickness and sharp interfaces compared to the electrolytic process. Cu flash not needed in this case. Compressibility gives robust films vs. flat plate desogns.

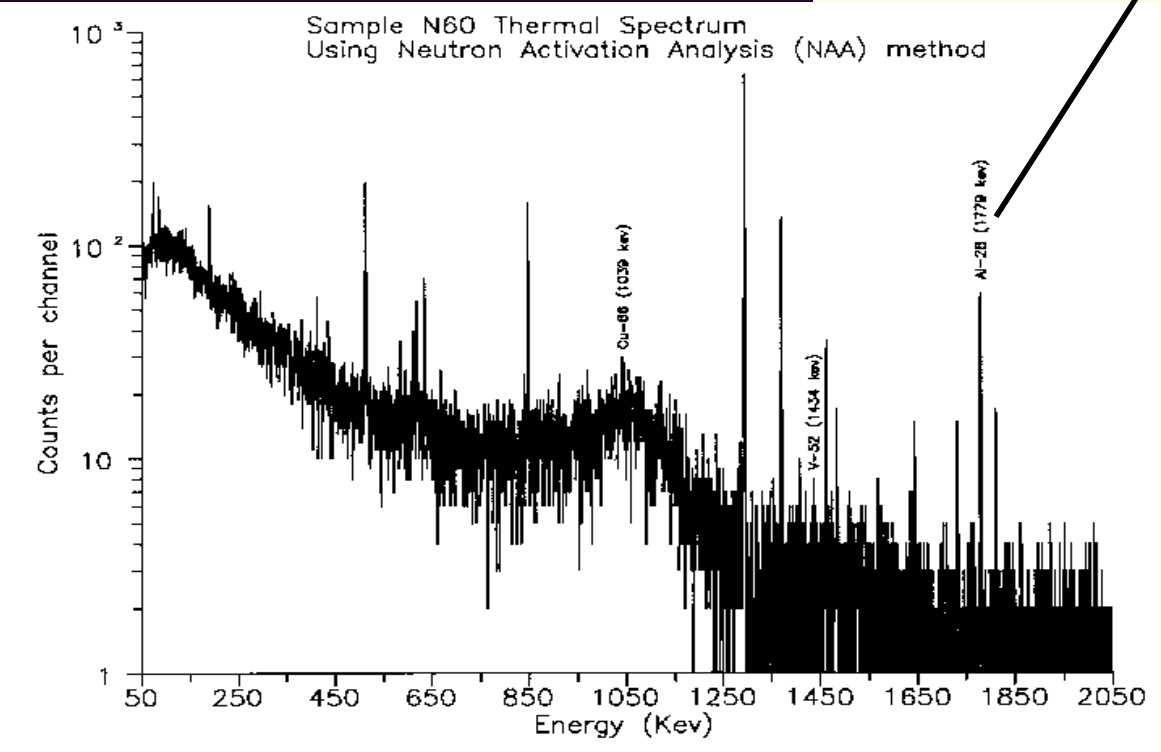
DIAGNOSTICS

Quantification of Isotopes by Combined SIMS & NAA



Mass Spectrum of a sample, indicates relative concentrations of species. Compare spectrum before and after electrolysis.

Quantification of Isotopes by Combined SIMS & NAA = essential combination NAA analyzed entire volume of beads for select isotopes.



NAA Result

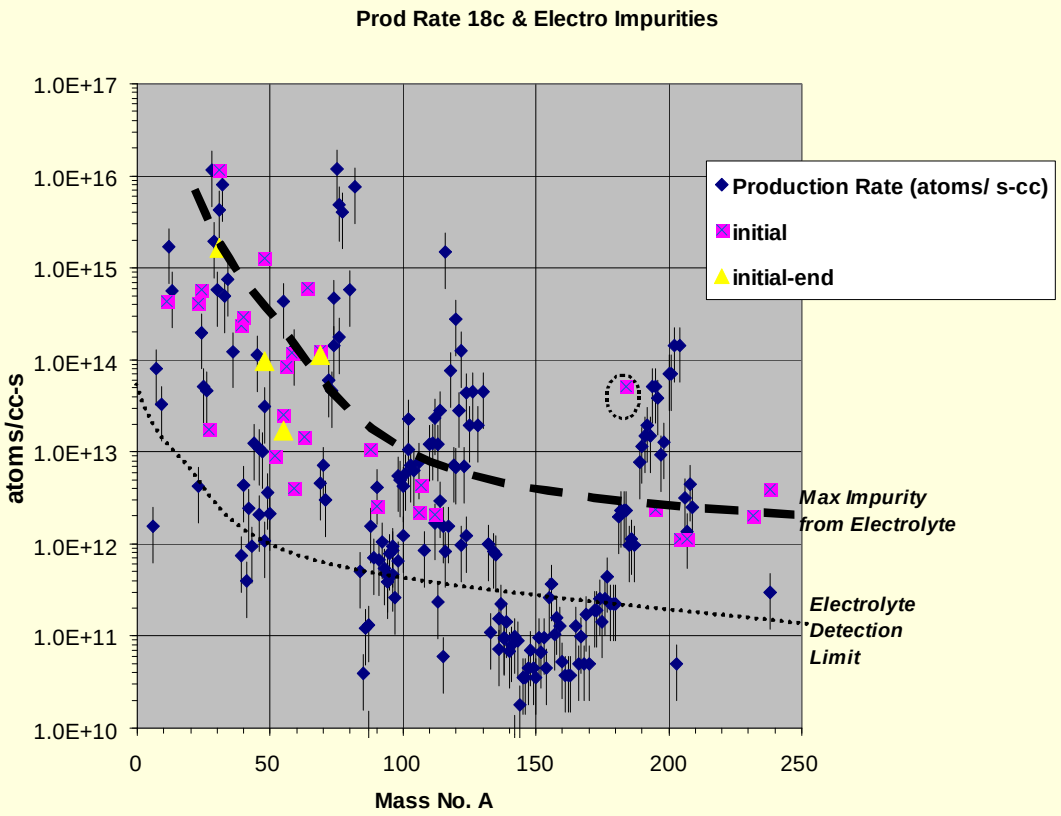
Sample ID	ppm
Ag (ppm)	125.4
Al (ppm)	11.2
Cu (ppm)	27.0
V (ppm)	0.1
Cr (ppm)	2.9
Ni (ppm)	1821.0
Fe (ppm)	217.2
Zn (ppm)	15.4
Co (ppm)	0.6

Gamma spectrum with sample chart of concentrations. The spectrum of gamma-rays is used to identify and quantify the element that emitted it. NIST standard used for calibration.

Parameters for NAA Runs – Selected to match each isotope life-time range

Method	Irradiation facility (flux, n cm^{-2} s^{-1})	Analytical Procedure		
		Irradiation time	Decay time	Counting time
Thermal short-lived	PS (3.7E+12)	10 - 300 sec.	5 - 20 min.	10 - 20 min.
Epithermal medium-lived	CLNAT (2.1E+11)	2 - 8 hrs.	2 - 5 days.	1 - 10 hrs.
Thermal long-lived	LS (3.4E+12)	2 - 6 hrs.	15 - 35 hrs.	3 - 6 hrs.

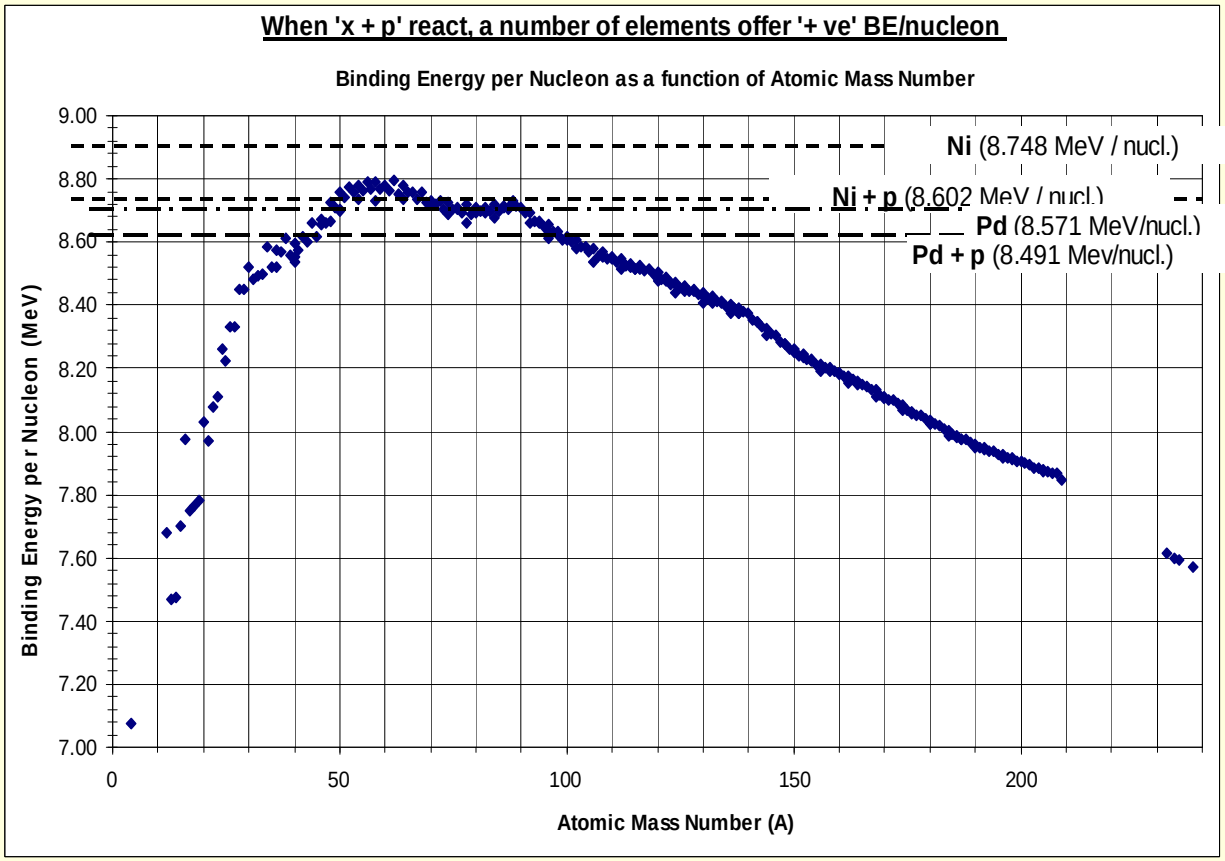
> 30 Isotopes Exceed Max Impurity Limit From Electrolyte; also many elements showed deviations from natural abundance



Summary - Key "Signatures" for LENRs
leading to product array

- Large reaction rates for key elements, e.g. Zn, Cu, Fe, Mg, and Ag.
- Peak mass zones of high yields separated by low yield "gaps."
- Non-natural isotope ratios for key products like Ag & Cu.
- Lack of energetic neutrons ,gamma radiation, during runs
  - Low-energy (~20 keV) X-ray/beta radiation (photographic film) observed post-run using long film exposure. (chg particles not studied with beads – later with plates)

BE/n FOR X+P REACTANTS Defines product pair limits.



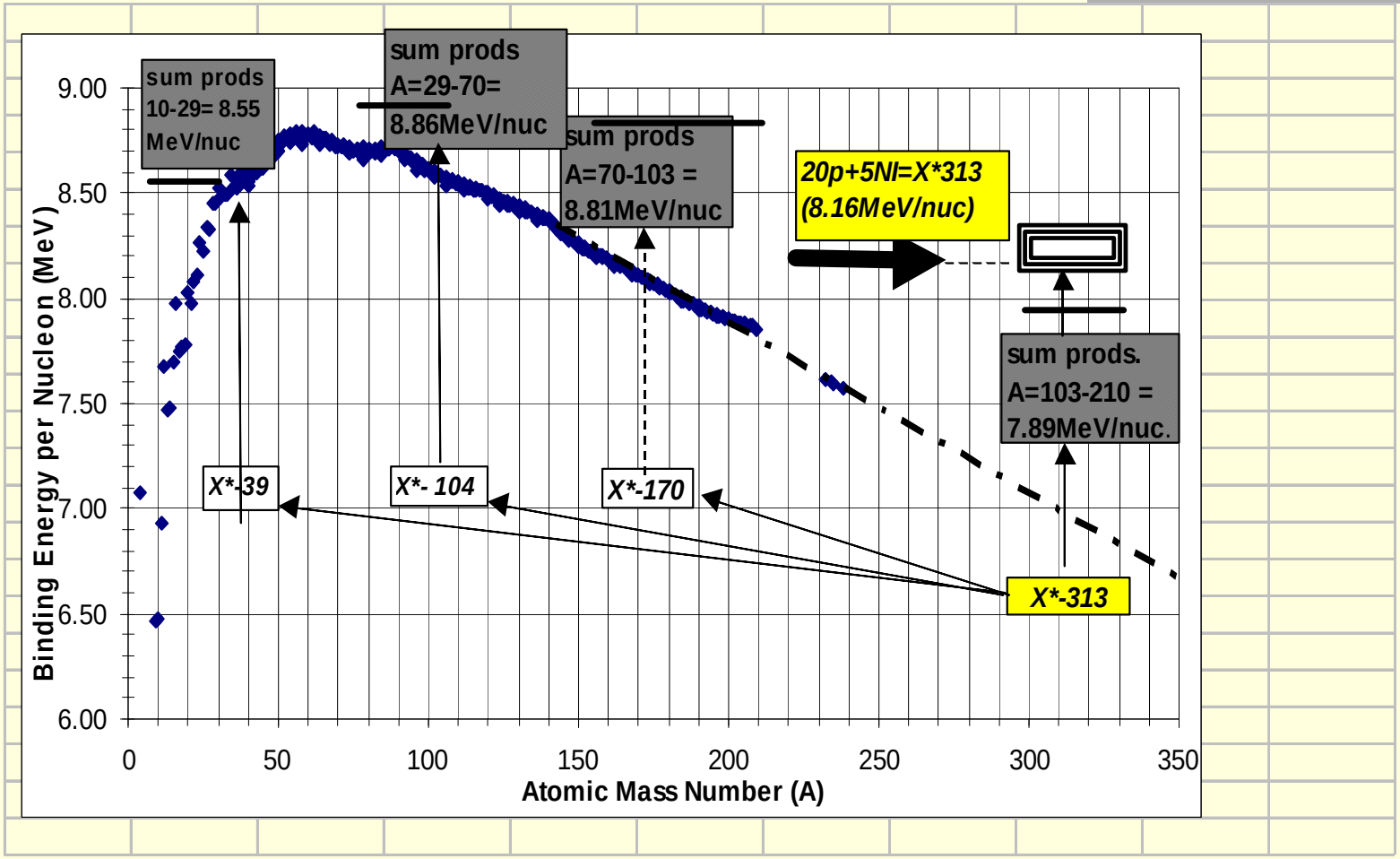
Reaction products - Basic Product Mass-Energy Balance Gives Reasonable Agreement with Experiment – Products are equivalent to He-4 from D-D (done for 3 cases). Indicate tie between excess heat and transmutations observed.

- ***RUN 8, Ni***

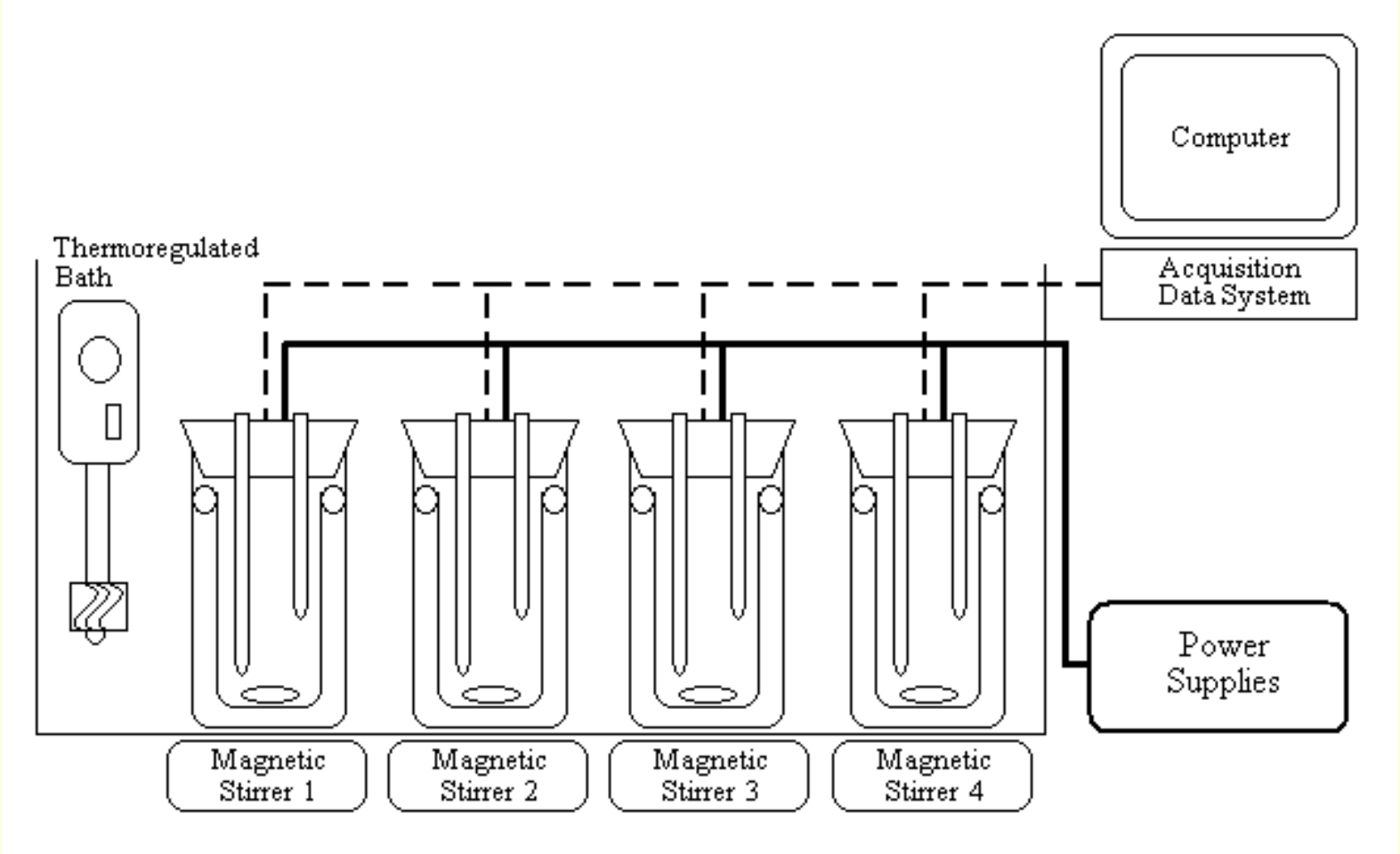
- # of nucleons of metal in cell before/after run= 6.140E+20
- BE/nucleon of {Ni+p} (MeV)= 8.602E+00
- # of nucleons reacted in run = 2.685E+20

- ***Energy produced (W) = 0.90 ±0.6***
  --- compare to --------
- ***Experiment (W) = 0.4 ±0.2***

ENERGY BALANCES FOR COMPLEX NUCLEI CLUSTERS ARE CONSISTENT WITH RESULTS



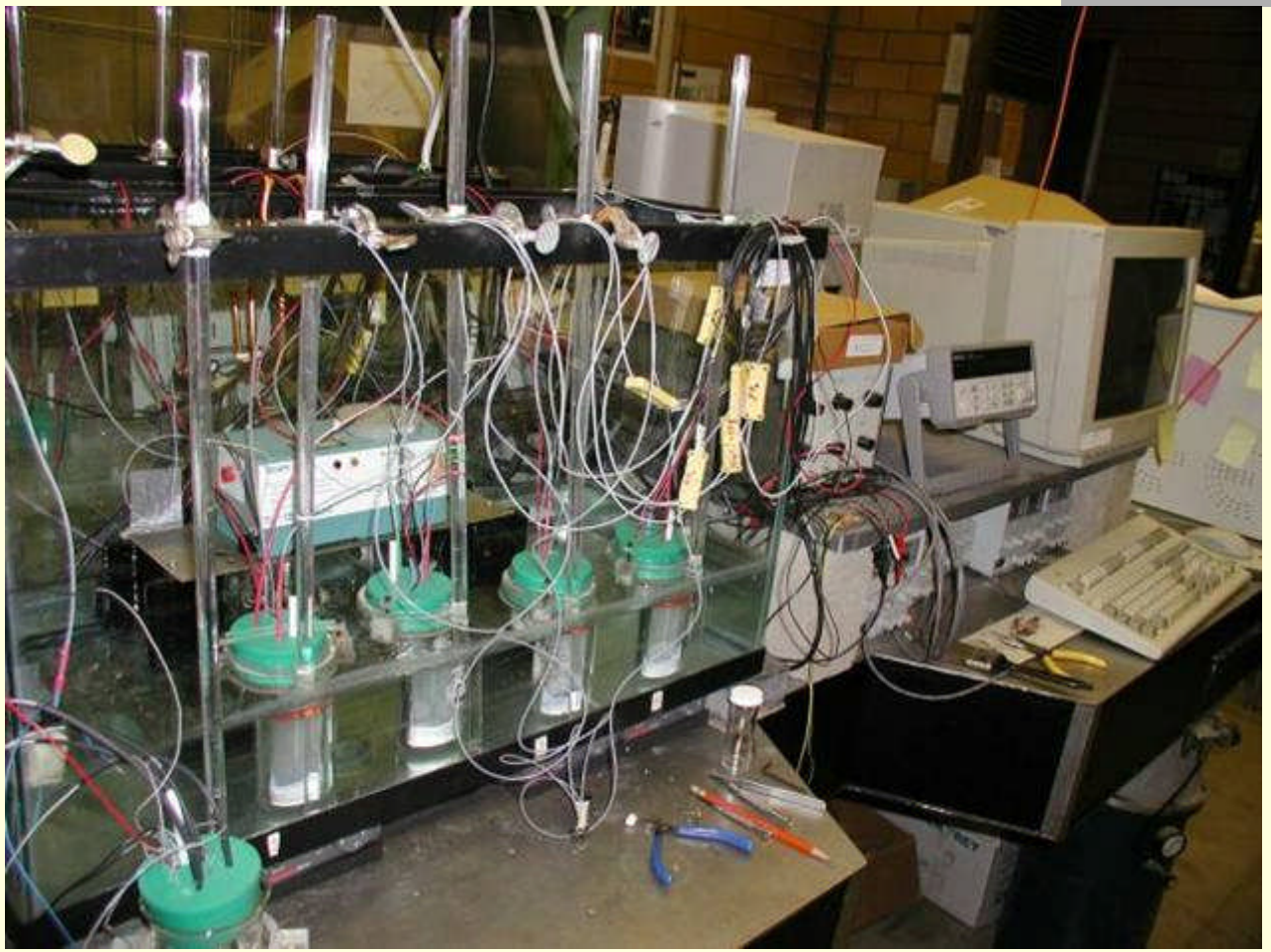
LW LENR Heat Studies with 1-M LiSO4 at UIUC - Calorimeter Set Up & Flat Plate Electrodes (see earlier ICCF mtgs)



Calorimetric System

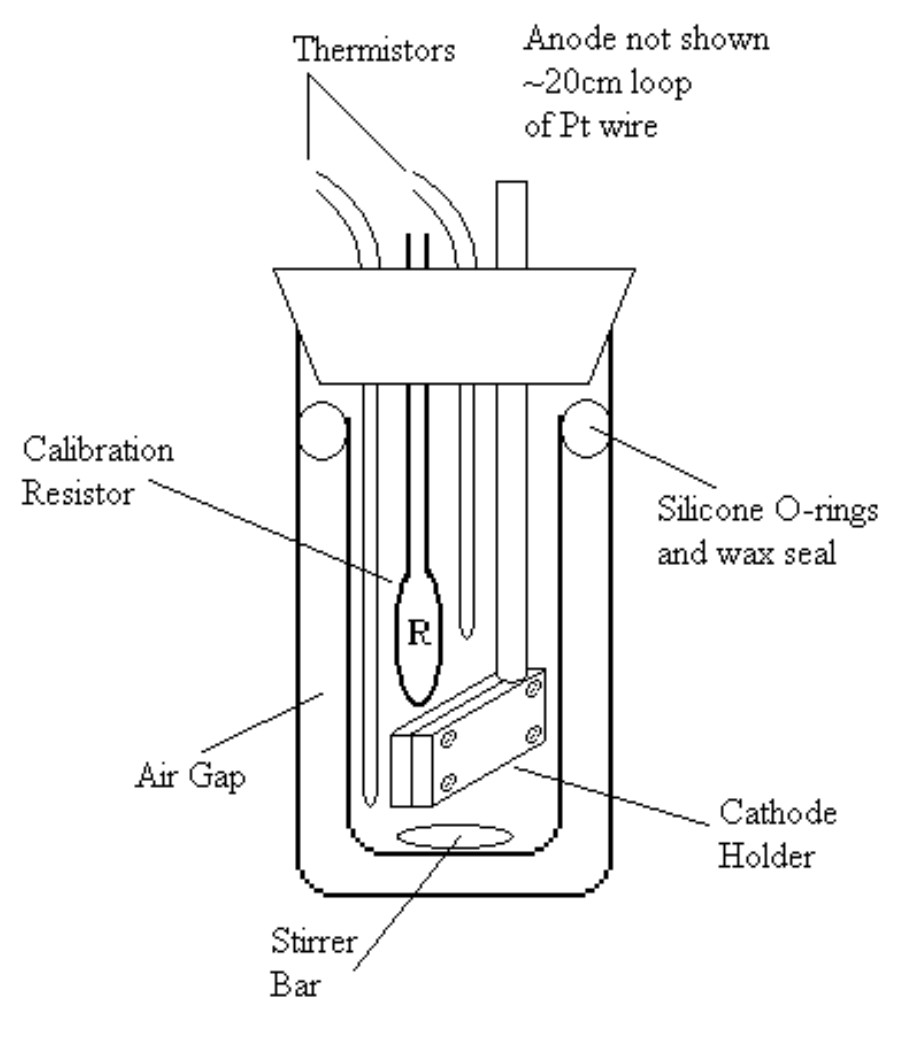
- 4 Isoperibolic calorimeters.
- Open cell electrolysis.
- Stirred magnetically.
- Two thermistors per cell (0.02°C precision).
- Accurate up to ±20mW to ±40mW.
- Dual calibration (resistor and electrolysis).
- HP34970A acquisition data system.

UIUC - LW LENR set up



Calorimeter

- τ ~ 4 hours.
- Sensitivity ~ 4°C/W
- Indicating desiccant in air gap.
- Magnetic stirring.
- Dual thermistors.
- Audible alarms for gradients in cell and in water bath.



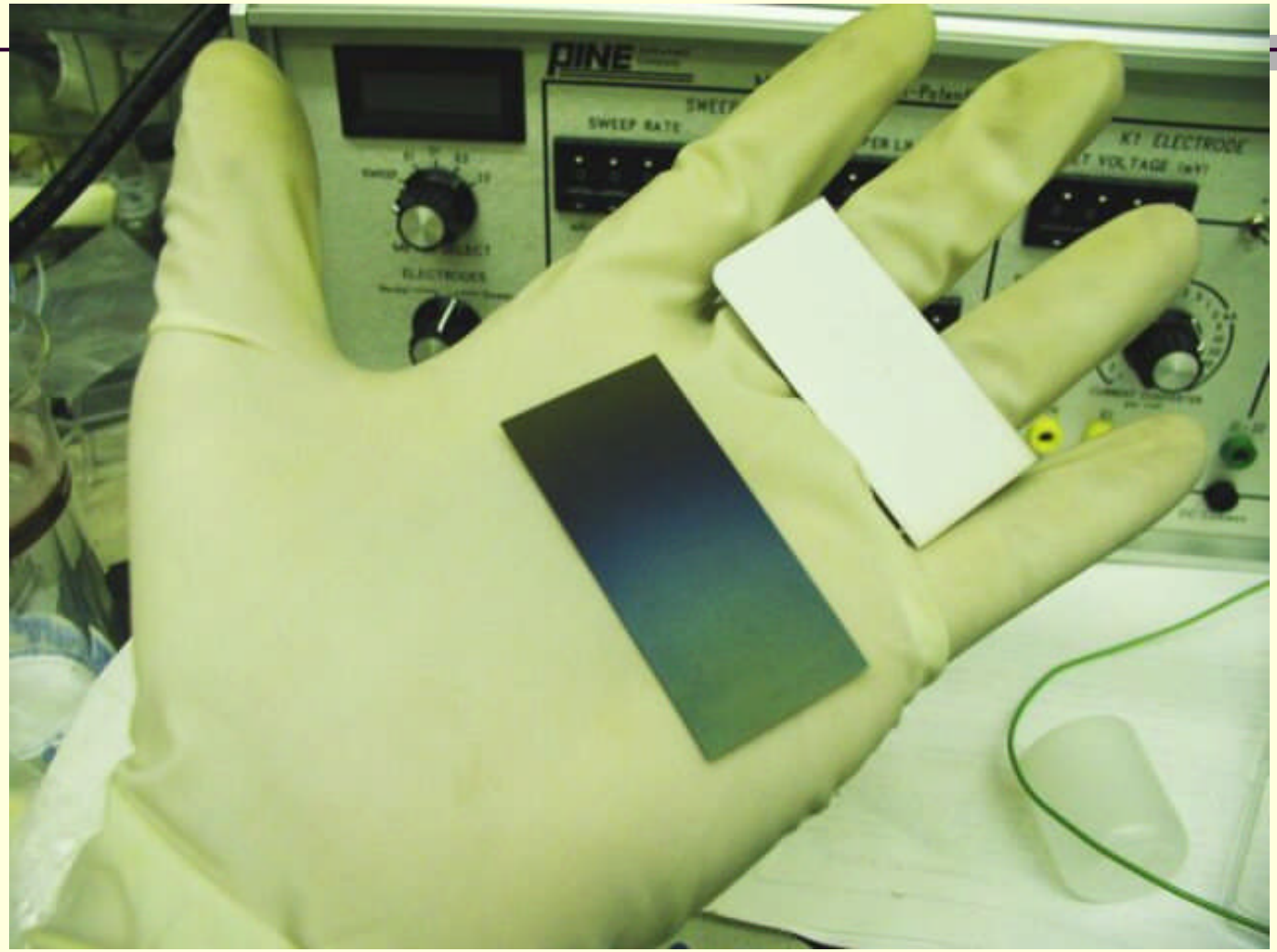
Calorimetric Accuracy

Thermistors	Accuracy - 0.1°C.
	Precision - 0.02°C (~5mW)
Bath Temp.	0.05°C (~13mW)
Gradients	Less than 0.02°C (~5mW)
T ambient	~0.02°C/°C (max. 20mW)
Recombination	<8%
Volume Cell	~3% (~5ml volume correction).
Calorimeters	Error Analysis shows ~ ±30 mW Experimentally they are ±20mW and ±40 mW high power.

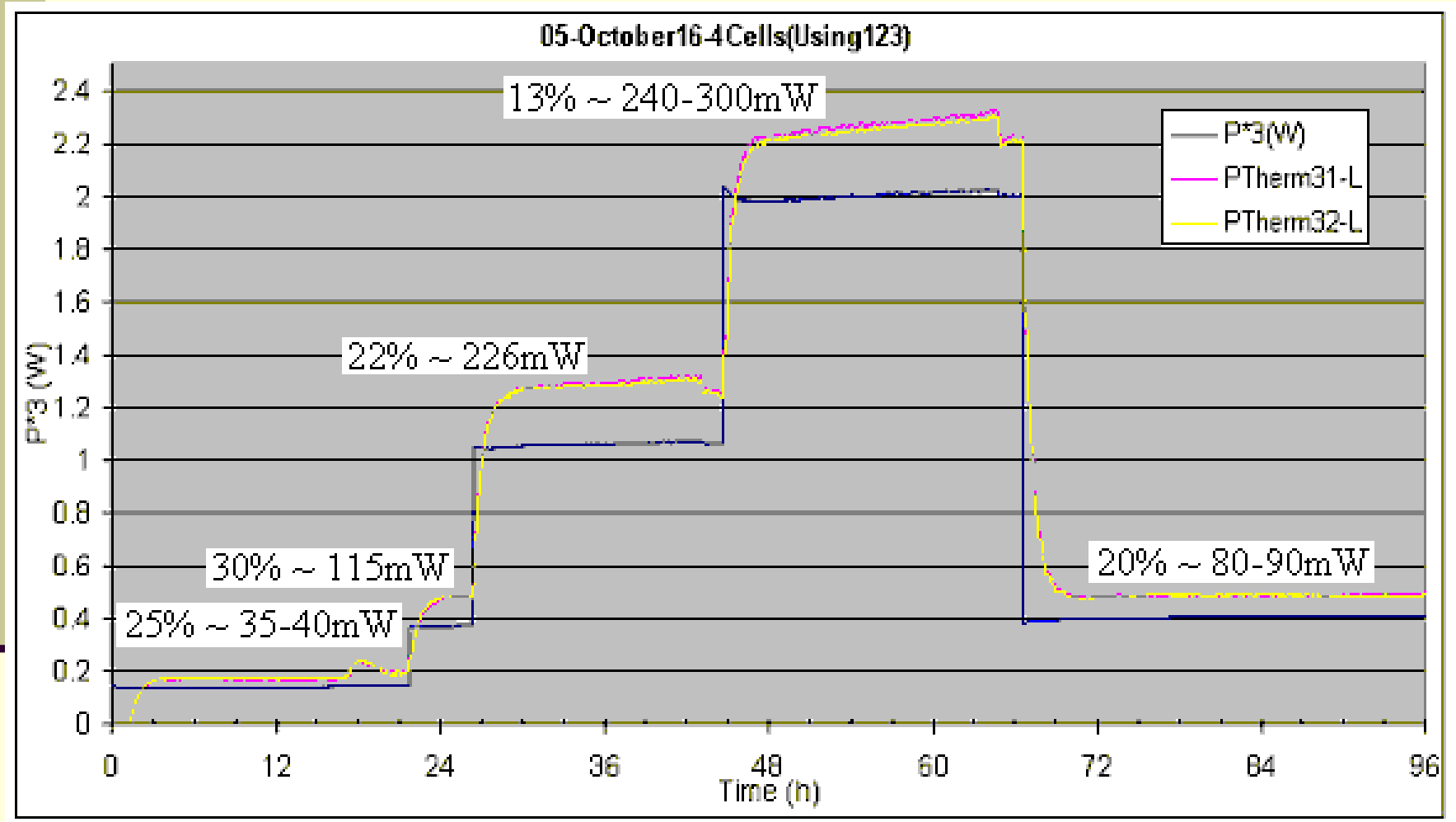
Electrodes Used

- Plate geometry. Area 13 cm^2 ±1.
- Different roughness from mirror-like to Ra ~ 3 μm.
- Several substrates, including quartz, Pt, borosilicate glass, alumina, and silicon.
- Electrodes produced by magnetron sputtering and electrodeposition.
- Details about electrode manufacture given in ICCF-9.

Alumina Electrodes



Excess Heat Event



Two layers Electrode. 8000Å Pd and 1000Å Ni on Alumina.

Events (1/2) – various Pd & Ni thin film combinations produced up to50% excess if not destroyed.

ID	Amount	Commentaries
23-011	No Excess	Sample Destroyed
23-012	No Excess	Sample Destroyed
23-013	No Excess	Al_2O_3-Pd
16-014	15%-30%	Al_2O_3-Pd-Ni
19-015	5%-40%	Pt-Pt_B-Pd_B-Pt_B-Pd_B
19-016	3%-12%	Cu-Pd
26-017	4%-15%	Pt-Pt_B-Pd_B-Pt_B-Pd_B
26-018	5%-20%	Cu-Pd

Events Continued (2/2)

ID	Amount	Commentaries
5-011	6%-21%	Macor-Pd-Ni
12-021	No Excess	Cu-Pd
12-022	Not recorded	Electrolysis of Ag (error)
12-023	5%-10%	$Pt\text{-}Pt_B\text{-}Pd_B\text{-}Pt_B\text{-}Pd_B$
20-024	18%-27%	Al_2O_3-Pd
20-025	No Excess	Sample Destroyed
20-026	No Excess	Sample Destroyed

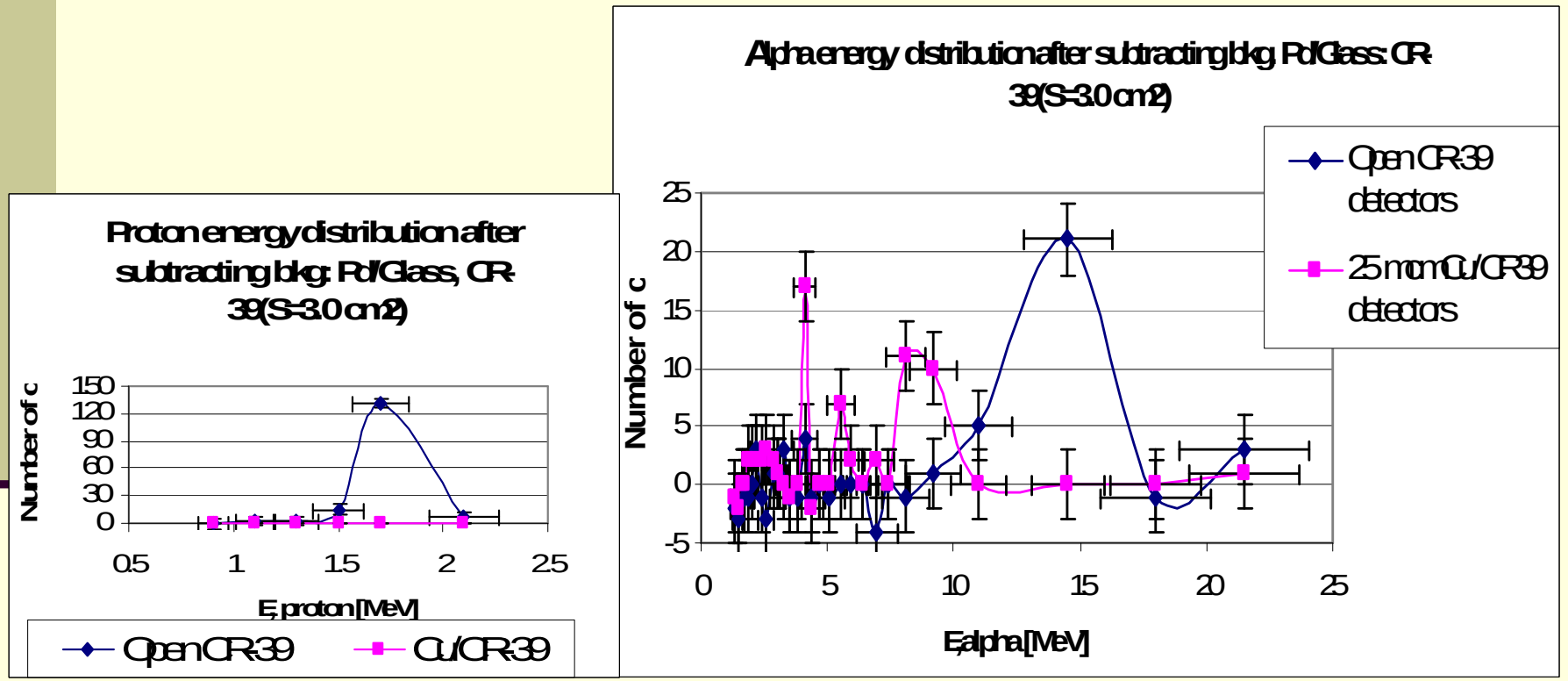
Charged-Particle and X-Ray Emission Studies with CR-39 & TLDs during flat plate LW electrolysis

- CR-39 studies at UIUC supplement earlier reaction product measurements
- Calibration: for alphas E < 8.0 MeV – alpha-sources; for E ~8.0-30.0 MeV Cyclotron of LNR, JINR, Dubna; for protons 0.75-3.0 MeV Van-DeGraaf accelerator, RINF, MSU, Moscow
- TLDs used to study low energy xrays.

- Results
  - MeV-charged particle emission observed
  - < 20 keV X-rays observed - barely above background

MeV Charged Particle Emission shows two energetic particles,

~ 1.7 MeV protons & ~15 MeV alphas
recorded in-situ with CR-39



Conclusions – UIUC LW studies to date

- Transmutation data show a rich array of products under thin-film bead operation with LW.
- Energy balance based on product array consistent with calorimetry
- Thus combined heat & transmutations are consistent concepts
- Data from LW thin-film plate electrolysis gives added support for modest excess heat.
- While excess heat is < 50%, levels are well above the uncertainty limits of the calorimetry.
- Transmutation not studied with plates so combined hypothesis relis on bead data.
- Emission of energetic MeV chg'd particles and low energy (few keV) xrays seem prevalent in these studies.
- No energetic gammas or neutrons observed.
- A future objective is to improve the performance of the electrodes using new interface concepts, investigate possible transmutations.

(Incomplete) Survey of other LW LENR studies - the year and the key signatures of these studies.

Table 1: Survey of the type of Study and Time period when it was carried out.

Type of Study	Years			Total
	1990-1994	1995-1999	2000-2005	
Excess Heat & Transmutation	4	2	6	12
Excess Heat studied & Transmutation not studied	6	1	1	8
Transmutation studied & Excess Heat not studied		3	5	8
Excess heat studied & Transmutation not found			1	1
			Total	29

- Most researchers study both the anomalous element produced and the excess heat generated – indicating that they believe both are significant phenomenon in LW LENR.
- However, some researchers are also equally interested in studying these separately.
- The table also shows that in the early 1990 and now (2000 onward) research in LW LENR is active, mid 90s seem to be quieter in comparison.

II -- Survey of LW/H2 research by others

- About 60 papers/presentations reviewed.
- Issues
  - Have LW transmutations and excess heat been widely observed?
  - Methods employed?
  - Are results/trends consistent?

Summary of Various Methods Employed for the LW LENR Studies

- Majority of researchers used Electrolysis to study LENR
  - Pd/Pt, Ni/Pt are commonly used electrodes
  - K2CO3 is a popular choice as an electrolyte, a trend perhaps started by the Mills and Kneizy's early experiments.
- Gas Loading is also frequently used
- Few also reported using a Glow Discharge (GD) plasma.

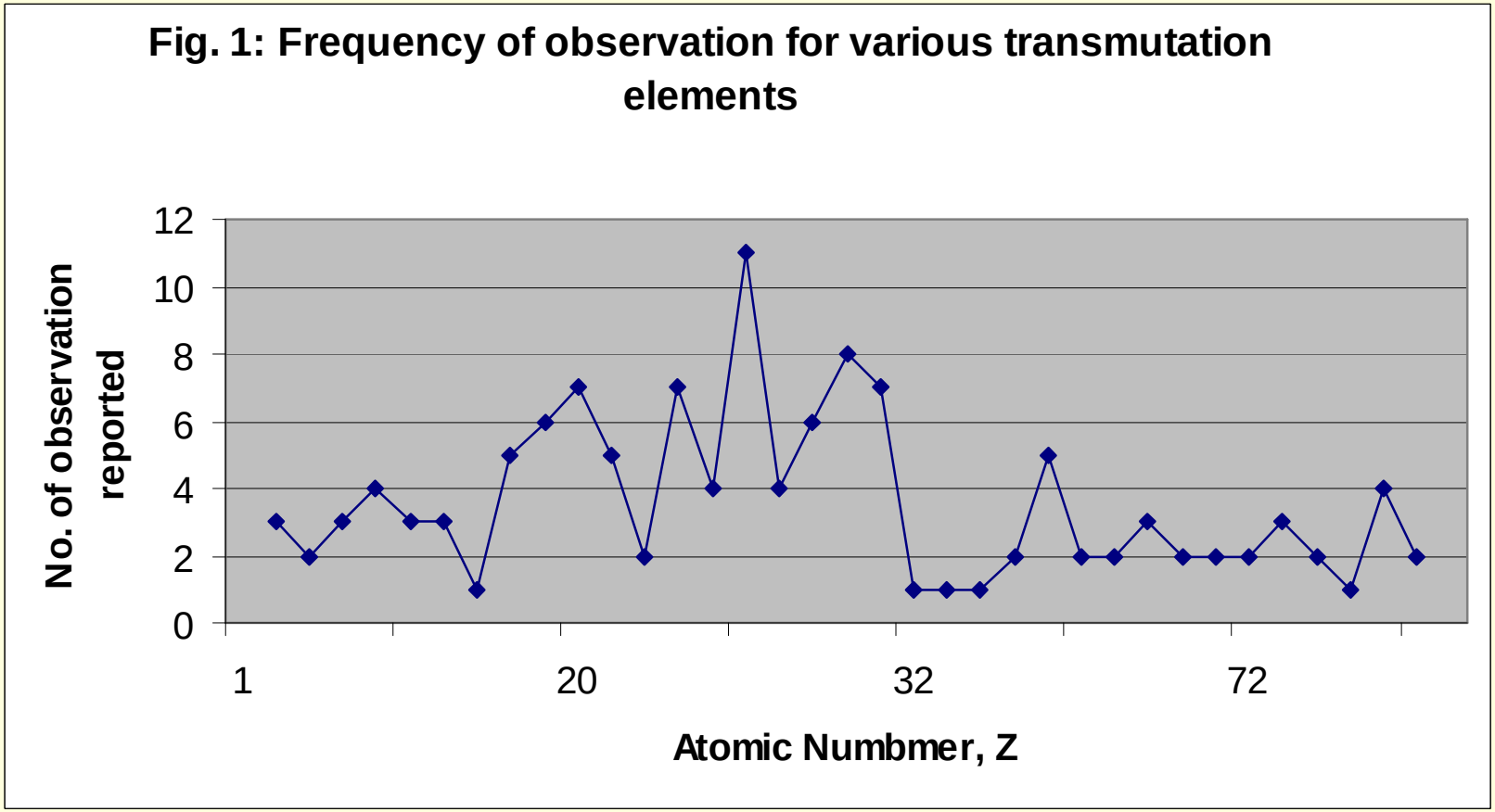
Table 2: Summary of method used for LENR study

		Total
Electrolysis	Electrode	
	Pt/Pd	14
	Pt/Ni	5
	Pt/W	3
	Pt/Au	4
	Pt/Sn	1
	Pt/Re	1
	Pt/Ti	2
	Pt/Ag	1
	Pt/Pt	2
	Electrolyte	
	K2CO3	10
	H2SO4	3
	Na2CO3	5
	Li2SO4	4
	KOH	1
	Na2SO4	5
	CS2SO4	1
	H2O	2
GD Plasma		1
Gas Loading		5

Transmutation Results – Table 3 shows the total number of reports of specific elements were produced in their experiment.

Observation Frequency	Transmutation Elements
1	As,Ge, S, Hg, Kr
2	Cd, Rr, Au, Hf, Th, Er, Yb, B, V, Cs
3	Li, Ba, Al, Os, C, Si
4	Mg, Mn, Co, Pb
5	Ag, Cl, Ti
6	Ni, K
7	Ca, Cr, Zn
8	Cu
11	Fe

Transmutation Element –The result shows that Fe and Cu were predominantly observed in these reactions. Note that the majority of times these transmutated elements have changes in isotopic composition from the natural abundance.

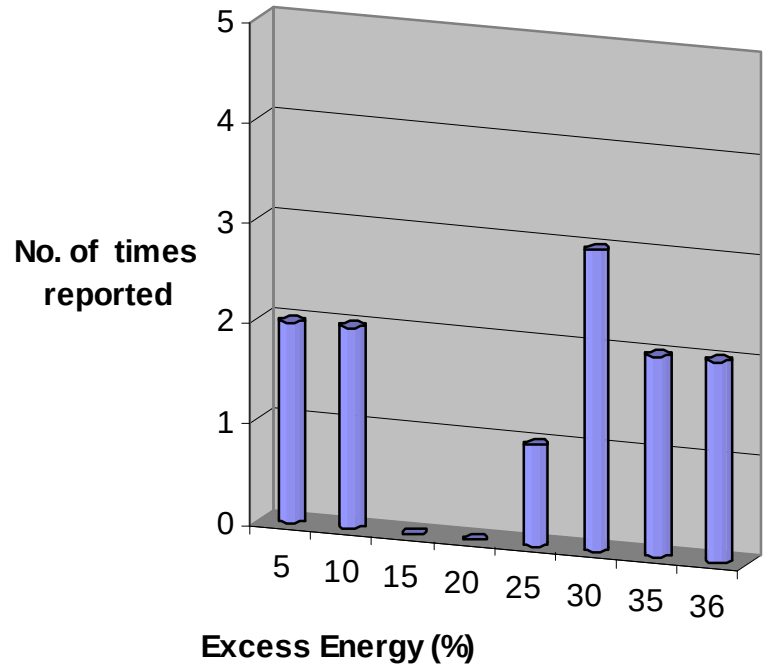


Excess Energy (%) Study – Table 4 shows the range of Excess Energy various reports have achieved in their LW experiment.

Excess Energy(%)	No. Reported
0-5	2
6-10.	2
11-15.	0
16-20	0
21-25	1
26-30	3
31-35	0
35+	2

Excess Energy Study – Fig. 2 shows the table 4 data in a graphical presentation.

Fig 2: A graph to show the range of the amount of Excess Energy (%) reported by various researcher.



Summary Table – LW LENR Studies by Others -Continues to next 9 slides.

Authors	Title	Electrodes	Electrolyte	Parameters	Analytical Tools for Products
Dash & Noble	Changes in Surface Topography and Microcomposition of Pd Cathode caused by electrolysis in acidified light water	Cathode -Pd Anode – Pt	0.06 M H2SO4 and deionized H2O	Electrolysis was carried out for 5hrs at a current density of about 0.67 A/cm2	SEM, EDS
Cano	Comparison of Heat Output and Microchemical Changes of Palladium Cathodes under Electrolysis in Acidified Light and Heavy Water	Cathode -Pd Anode - Pt	H2SO4 and deionized H2O	Electrolysis was carried out for 60 hrs. Current density at 0.75A was used.	SEM, EDS
Notoya et al	Tritium Generation and Large Excess Heat Evolution by Electrolysis in Light and Heavy Water-Potassium Carbonate Solutions with Nickel Electrodes	Cathode - Ni, Anode - Pt	0.5 mol K2CO3	Electrolysis was carried out in a dark chamber made of lead wall of 10-cm thickness which was settled in an air conditioned room at 20±1ºC.	N/A
Mills and Kneizys	Aquesous KCO2 Electrolyte	Cathode - Ni, Anode - Pt	0.57 M K2CO3/Na2 CO3 in H2O	The current voltage parameters were intermittent square wave with an offset volt of 2.2 V, peak volt of 2.75 V, peak current 175 mA and 35 % duty cycle and a frequency of ~500 Hz.	N/A

Authors	Title	Transmutation Products	Xs heat	Quantitative Results for Transmutation	Quantitative Results for Xs heat	Other results
Dash & Noble	Changes in Surface Topography and Microcomposition of Pd Cathode caused by electrolysis in acidified light water	Cl, Ag	Change in ratio of x-ray fluorescence peaks of Pd. Ratio of Pd LB1 at 2.99 KeV to Pd Lx1 at 2.84 KeV changed from 0.50 for the upper part of Pd Cathode to 0.75 for the lower edge. This contributed to Ag formation.	Yes	Yes	Altered Surface Topography
Cano	Comparison of Heat Output and Microchemical Changes of Palladium Cathodes under Electrolysis in Acidified Light and Heavy Water	Cd, Ag	Thermocouple reading was slightly higher for light water than heavy water. More Xs heat in heavy water than light water.	Yes	Yes	N/A
Notoya et al	Tritium Generation and Large Excess Heat Evolution by Electrolysis in Light and Heavy Water-Potassium Carbonate Solutions with Nickel Electrodes	N/A	Xs heat reported at 70-170% of input power	No	Yes	Tritium Production
Mills and Kneizys	Aquesous KCO2 Electrolyte	N/A	Excess heat was produced constantly.Excess power out exceeded input power by a factor of >37. 130mW of Xs heat was observed	No	Yes	N/A

Authors	Title	Electrodes	Electrolyte	Parameters	Analytical Tools for Products
Noninski	Xs Heat with Light Water Electrolysis	Cathode - Ni, Anode - Pt	0.57 M K2CO3/Na2 CO3 in H2O	Electrolysis was carried out for 14 - 16 hrs.	N/A
Cirillo and Iorio	Transmutation of metal at low energy	Cathode - W, Anode - Pt	K2CO3 in water	The solution was standardized at 20C	SEM
Tadayosi and Enyo	Excess heat evolution during electrolysis	Cathode - Ni, Au, Ag, Sn; Anode - Pt	K2CO3, Na2CO3, Li2SO4	Electrolysis was carried out at 1A current with varying input temp and potential for 20hrs.	
Dufour et al	Measurement of Xs Energy	Cathode - Pd , Anode - Pt	H2/D2	A DC current, low voltage (14 v) and 21 C internal cabin temperature was used	Mass Spec.
Arapi et al	Experimental Observation	Cathode -Pd	Glow discharge in D2 or H2 gas	Cell was operated at 2 mA, 600-800 V, 3Torr for 60 min	TOF-SIMS
Ohmori and Enyo	Iron Formation	Cathode -Pd, Au	0.5 M Na2SO4, K2CO3, KOH	Electrolysis was carried out for 7 days by a constant current of 1A.	AES, SIMS

Authors	Title	Transmutation Products	Xs heat	Quantitative Results for Transmutation	Quantitative Results for Xs heat	Other results
Noninski	Xs Heat with Light Water Electrolysis	N/A	With K2CO3 for every watt input excess heat was measured however for Na2CO3 this was not the case. The corresponding xs heat was 26 -160% of input energy.	No	Yes	N/A
Cirillo and Iorio	Transmutation of metal at low energy	Rh, Os, Au, Hf, Th, Er, Yb	Xs heat was reported	Yes	No	Shift in isotopic distribution
Tadayoshi and Enyo	Excess heat evolution during electrolysis	N/A	Largest Xs heat observed was 907mW on tin in K2SO4	No	Yes	N/A
Dufour et al	Measurement of Xs Energy	Not found	Largest xs heat observed was 5.5 W.	Yes	Yes	N/A
Arapi et al	Experimental Observation	In D2 - Be, Ni found. In H2 - Li, Ni, Baa found	N/A	Yes	No	deuteron or proton plays similar role in the reaction.
Ohmori and Enyo	Iron Formation	Fe	In Au: 9x10^18 - 1.8x10^16; In Pd: 1.2x10^15 - 4x10^16.	Yes	Yes	N/A

Authors	Title	Electrodes	Electrolyte	Parameters	Analytical Tools for Products
Dufour et al	Interaction Pd/H Isotpoe - ICCF5	Cathode -Pd, Anode - Pt	H2/D2	H2 sparked by a DC current, low voltage (14 v). The internal temperature of the cabin was 21C.	N/A
Dufour	Cold fusion by sparking H2 isotope	Cathode - Pd	H2 isotopes	H2 sparked by a DC current, low voltage (14 v). The internal temperature of the cabin was 21C.	N/A
Dash et al	Surface mrphology - ICCF4	Cathode - Pd, Anode -Pt	H2O/ H2SO4. D2O/H2SO4	electrolysed for 400hrs	SEM, EDS
Bush	A Light H2O xs heat	Cathode -Pd, Anode - Pt	0.57 M K2CO3 in H2O	The cells were studied for about 2 weeks.	N/A
Yamada et al	Production of Ba and several Anomalous Elements in Pd under light Water Electrolysis	Cathode -Pd, Anode -Pt	0.5 M Na2SO3	Electrolysis was carried out for 7-14 days at constant current of 0.5 A	TOF-SIMS
Ohmori et al.	Excess Energy and Anomalous Concentration of ^{41}K Isotopes in Potassium formed on/in a Re Electrode during the Plasma Electrolysis in K_2CO_3/H_2O and K_2CO_3/D_2O Solutions	Cathode - Re, Anode -Pt	K2CO3/H2O and K2CO3/D2O	Cell was operated at 160 V for several minutes	TOF-SIMS

Authors	Title	Transmutation Products	Xs heat	Quantitative Results for Transmutation	Quantitative Results for Xs heat	Other results
Dufour et al	Interaction Pd/H Isotope -ICCF5	N/A	Xs power of up to 7W, 25-30% input power	No	Yes	N/A
Dufour	Cold fusion by sparking H2 isotope	N/A	Xs energy generated (2 W).	No	Yes	N/A
Dash et al	Surface morphology - ICCF4	Au, Ag. More conc. of elements found in heavy water than light water	Xs energy observed. More xs heat in heavy water than light water	Yes	No	N/A
Bush	A Light H2O xs heat	N/A	Peak excess power is 4W, total excess energy is 0.3 MJ	No	Yes	N/A
Yamada et al	Production of Ba and several Anomalous Elements in Pd under light Water Electrolysis	Li, B, Mg, Al, K, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ba, Pb	Excess power of up to 9% measured.	Yes	Yes	N/A
Ohmori et al.	Excess Energy and Anomalous Concentration of ^{41}K Isotopes in Potassium formed on/in a Re Electrode during the Plasma Electrolysis in K_2CO_3/H_2O and K_2CO_3/D_2O Solutions	Large conc. of 41K was found in both cases.	Excess energy ranging from 58 - 109 W/cm2 was generated continuously. No significant difference in H2O and D2O cells.	Yes	Yes	Shift in isotopic distribution

Authors	Title	Electrodes	Electrolyte	Parameters	Analytical Tools for Products
Ohmori a& Mizuno	Strong Excess Energy Evolution, New Elements Production, and Electromagnetic Wave and/or Neutron Emission in the Light Water Electrolysis with a Tungsten Cathode	Cathode - W, Anode - Pt	0.5 M Na2SO4	Electrolysis was carried out at 20C	EDX, EPMA, SIMS
Miley	Product characteristics and energetics in Thin-Film electrolysis experiments	Cathode - Ni/Pd/Ti; Anode - Pt	1M LiSO4/H2O	Cells were operated at 2-3 V, 1-5 mA for 3-4 weeks	NAA, SIMS, ICP-MP
DiGiulo et al	Analysis of nuclear transmutation observed in D- and H- loaded Pd films	Pd films	H2 or D2 loading	Processed by excimer laser	SEM, EPMA
Mizuno et al.	Generation of Heat and Products During Plasma Electrolysis	Cathode - W, Anode - Pt	0.2 M K2CO3	Voltage: 120 V, Temperature 80C	EDX, EPMA, SIMS, AES
Fujii et al	Heat measurement during light water electrolysis using Pd/Ni rod cathodes	Cathode - Pd/Ni; Anode - Pt	1 M Li2SO4	Cell was operated at 1 A	N/A
Mills et al	Catalysis of atomic Hydrogen to Novel Hydrides as a New Power Source	W and Sr wire	H2 Gas Loading	Metal was vaporized by the filament heater at 300 W for Sr, 600 W for Mg, Bs, Na metal. Voltage was 55 V and cirrent 5.5A at 300 W	N/A

Authors	Title	Transmutation Products	Xs heat	Quantitative Results for Transmutation	Quantitative Results for Xs heat	Other results
Ohmori a& Mizuno	Strong Excess Energy Evolution, New Elements Production, and Electromagnetic Wave and/or Neutron Emission in the Light Water Electrolysis with a Tungsten Cathode	Pb, Fe, Ni, Cr, C.	Excess energy was 183 W which is 2.6 times the input power.	Yes	Yes	Pb isotopic distribution deviation.
Miley	Product characteristics and energetics in Thin-Film electrolysis experiments	High yield at A~22-23, 50-80, 103-120 and 200-210.	Excess power of 0.5W	Yes	Yes	Significant shift in isotopic distribution
DiGiulio et al	Analysis of nuclear transmutation observed in D- and H- loaded Pd films	Mg, Cl, Fe, Al, Ca, K	N/A	Yes	No	More transmutation products in light water than heavy water
Mizuno et al.	ICCF10	Ca, Fe, Zn	Large Heat observed was 1100 J. Sometimes excess heat was 30% of input heat.	Yes	Yes	N/A
Fujii et al	Heat measurement during light water electrolysis using Pd/Ni rod cathodes	N/A	In 6 out of 28 cases >10% heat observed, in most cases it was 5% or less. Error limit was 8-10%	No	Yes	N/A
Mills et al	Catalysis of atomic Hydrogen to Novel Hydrides as a New Power Source	N/A	N/A	No	No	Vacuum ultraviolet (VUV) observation

Authors	Title	Electrodes	Electrolyte	Parameters	Analytical Tools for Products
Miley et al	Quantitative Observation of Transmutation Products occurring in Thin-film coated microspheres during electrolysis	Cathode -Pd/ Ni, Anode - Pt	1 M Li2SO4, H2O	Voltage 2-3 V, current several mA for 2 week operation	EDX, SIMS, AES, NAA
Yamada et al.	Analysis By Time-Of-Flight Secondary Ion Mass Spectroscopy For Nuclear Products In Hydrogen Penetration Through Palladium	Pd foil	H2 Gas Loading	It was operated for 2 weeks at 400 C.	TOF-SIMS
Notoya	Nuclear Products of cold Fusion Caused by Electrolysis in Alkali Metallic Ions Solutions	Cathode -Ni; Anode - Pt	0.1 M CsSO4, K2CO3, Na2CO3	The cell was operated for 160 mins.	ICP-MS
Ohmori + Mizuno	Observation of the Product Elements of Nuclear Transmutation Reaction on/in Several Metal Electrodes by the Cathodic Electrolysis in Light Water Solutions	Cathode - Pd, Pt, Au, W; Anode - Pt	0.5 M Na2SO4, K2CO3	Current density of 0.2A/cm2 was used	EPMA
Ohmori et al.	Transmutation In a Gold-Light Water Electrolysis System	Cathode - Au, Anode - Pt	0.5 M Na2SO4, Na2CO3	Cells were operated at 1-3 A for 7-30 days	AES, EPMMA, SIMS
Li et al.	Nuclear Transmutation Detection in Pd/C Catalyst	Cathode - Pd	H2 gas loading	C catalyst was used. It was studied for 3-6 mnths	SEM, EPMA, EDX
Hanawa	Z-ray Spectrometric Analysis of Carbon Arc products in Water	C arc	H2O	Current used is 30 A, 20 V for 30 min	XRF, PIXE

Authors	Title	Transmutation Products	Xs heat	Quantitative Results for Transmutation	Quantitative Results for Xs heat	Other results
Miley et al	Quantitative Observation of Transmutation Products occurring in Thin-film coated microspheres during electrolysis	Products in four atomic number groups Z-6-18,22-35,44-54,75-85 with many with shift in isotopic distribution	excess power in the range of 0.1-4 W observed	Yes	Yes	X-ray emission observed
Yamada et al.	Analysis By Time-Of-Flight Secondary Ion Mass Spectroscopy For Nuclear Products In Hydrogen Penetration Through Palladium	Ti, Cr, Mn, Ni, Fe, Cu, Ag, V, Co were found.	N/A	Yes	No	Change in isotopic distribution for Ag, Fe, Cu,Cr.
Notoya	Nuclear Products of cold Fusion Caused by Electrolysis in Alkali Metallic Ions Solutions	Cs.	Excess Heat in Pt/Pt cell was 260%, in Ni/Pt cell not determined since the potential flucuated strongly	Yes	Yes	Tritium Produced
Ohmori + Mizuno	Observation of the Product Elements of Nuclear Transmutation Reaction on/in Several Metal Electrodes by the Cathodic Electrolysis in Light Water Solutions	Cr, Fe, C, Pb, Zn, Ca, Cu, Ti, Si, Mg, Fe.	N/A	Yes	No	Change in isotopic distribution
Ohmori et al.	Transmutation In a Gold-Light Water Electrolysis System	Hg, Kr, Ni, Fe, Os	Xs Energy measured at current of 1 A, reports not given	Yes	No	N/A
Li et al.	Nuclear Transmutation Detection in Pd/C Catalyst	Zn, Cl, Cu	N/A	Yes	No	N/A
Hanawa	Z-ray Spectrometric Analysis of Carbon Arc products in Water	Si, S, Cl, K, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn.		Yes	No	Shift in isotopic distribution

Mills, R.L., and Kneizys S.P., "Excess Heat Production by the Electrolysis of an Aqueous Potassium Carbonate Electrolyte and the Implications for Cold Fusion", *Fusion Tech*., 20, pp. 65-81, (1991).

- Electrodes
  - Cathode (Ni)
  - Anode (Pt)
- Electrolyte
  - 0.57 M Na2SO4, K2CO3
- Parameters

- Results
  - Excess Heat -
    - Produced constantly
    - Excess power exceeded input by >3700% in best run!!

Mills, R.L., and Kneizys S.P., "Excess Heat Production by the Electrolysis of an Aqueous Potassium Carbonate Electrolyte and the Implications for Cold Fusion", *Fusion Tech.*, 20, pp. 65-81, (1991). – contd.

Experiment	Excess Heat[f] (%)
K_2CO_3	
1	328
1A	1234
1AA	557
2	169
2A	544
3	156
3A	662
4	183
4A	1016
5	231
5A	634
6	215
6A	612
7	147
7A	705
8	252
8A	953
9	395
9A	3766
10	408
10A	2621
11A	838
12A	1027
13	217
13A	1094
14	243
14A	830
15	213
15A	1355
16A	
17A	
Na_2CO_3	
18	1.9
19	1.6

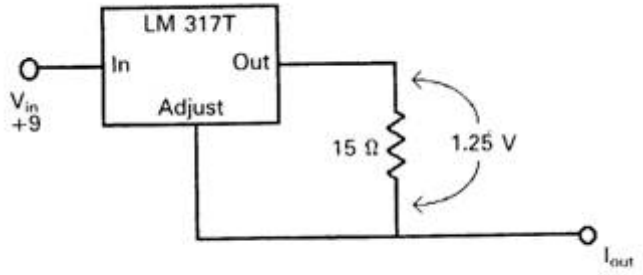


Fig. 1. Schematic of the circuit used to provide constant dc current.

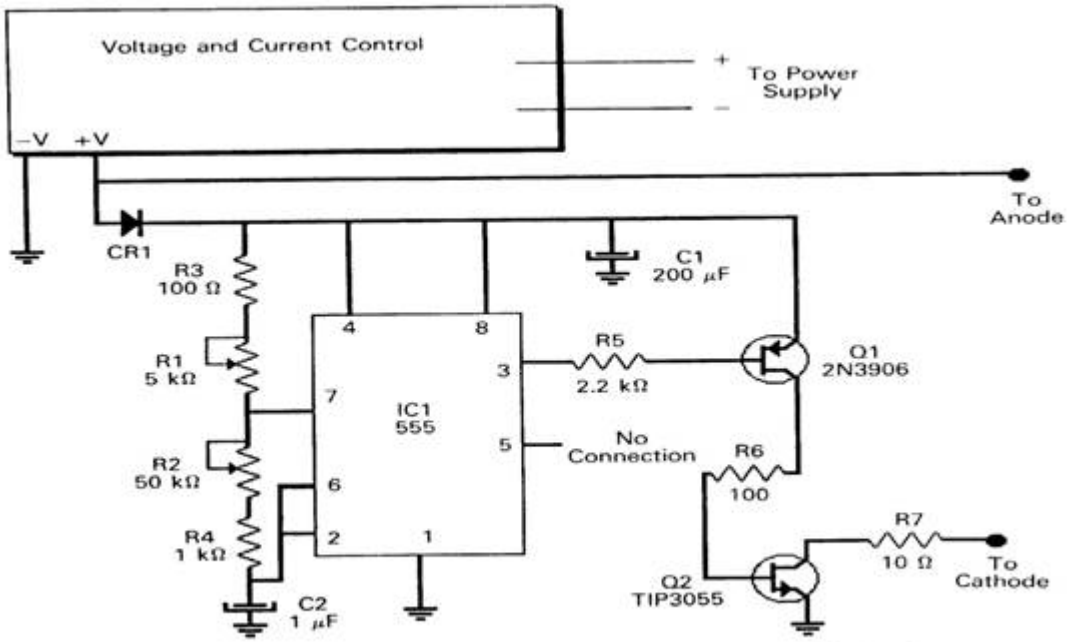


Fig. 2. Schematic of the circuit used to provide intermittent (on/off) dc voltage.

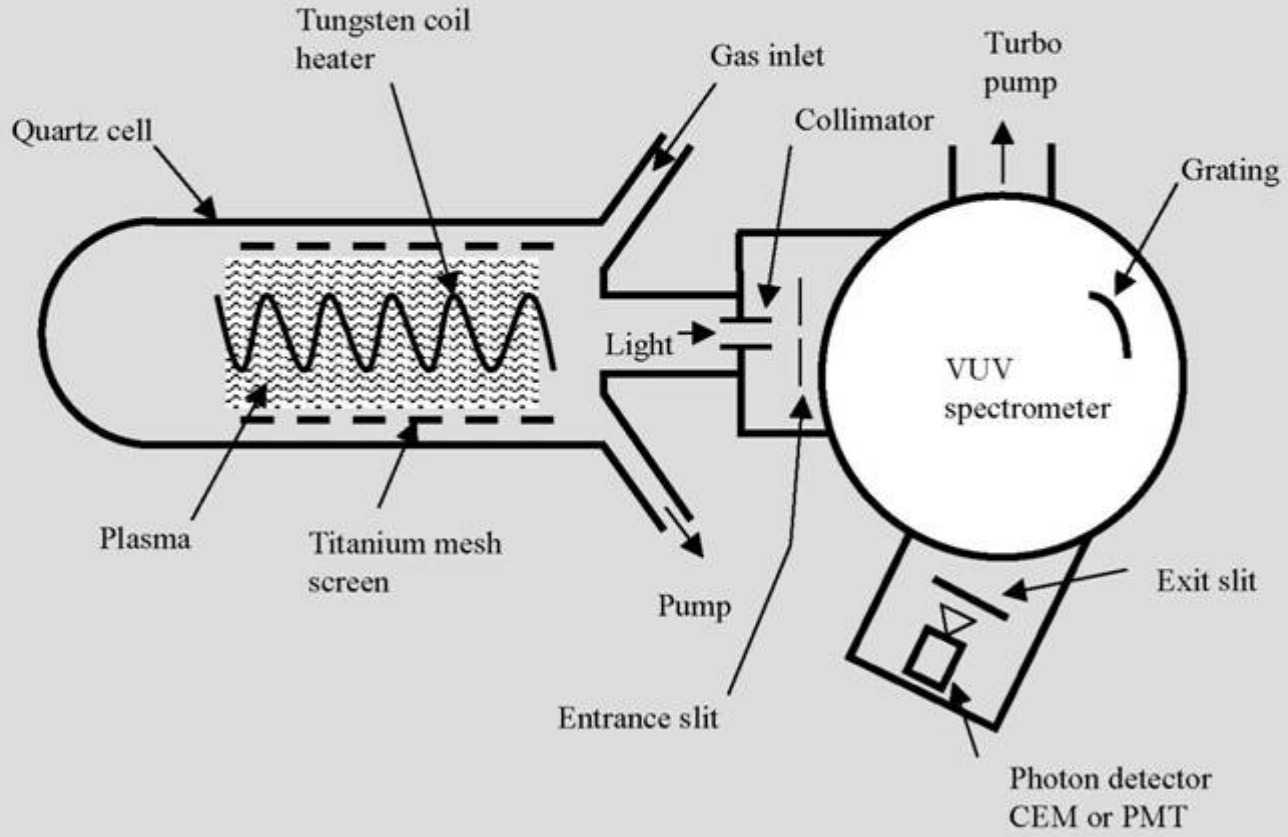
230th ACS National Meeting
August 28-September 1, 2005
Washington, DC

Catalysis of Atomic Hydrogen to Novel Hydrides as a New Power Source

Randell Mills, Jiliang He, Zhixiang Chang, Hugo Zea,
Kamran Akhtar, Ying Lu, Chunqi Jiang, Bala Dhandapani,

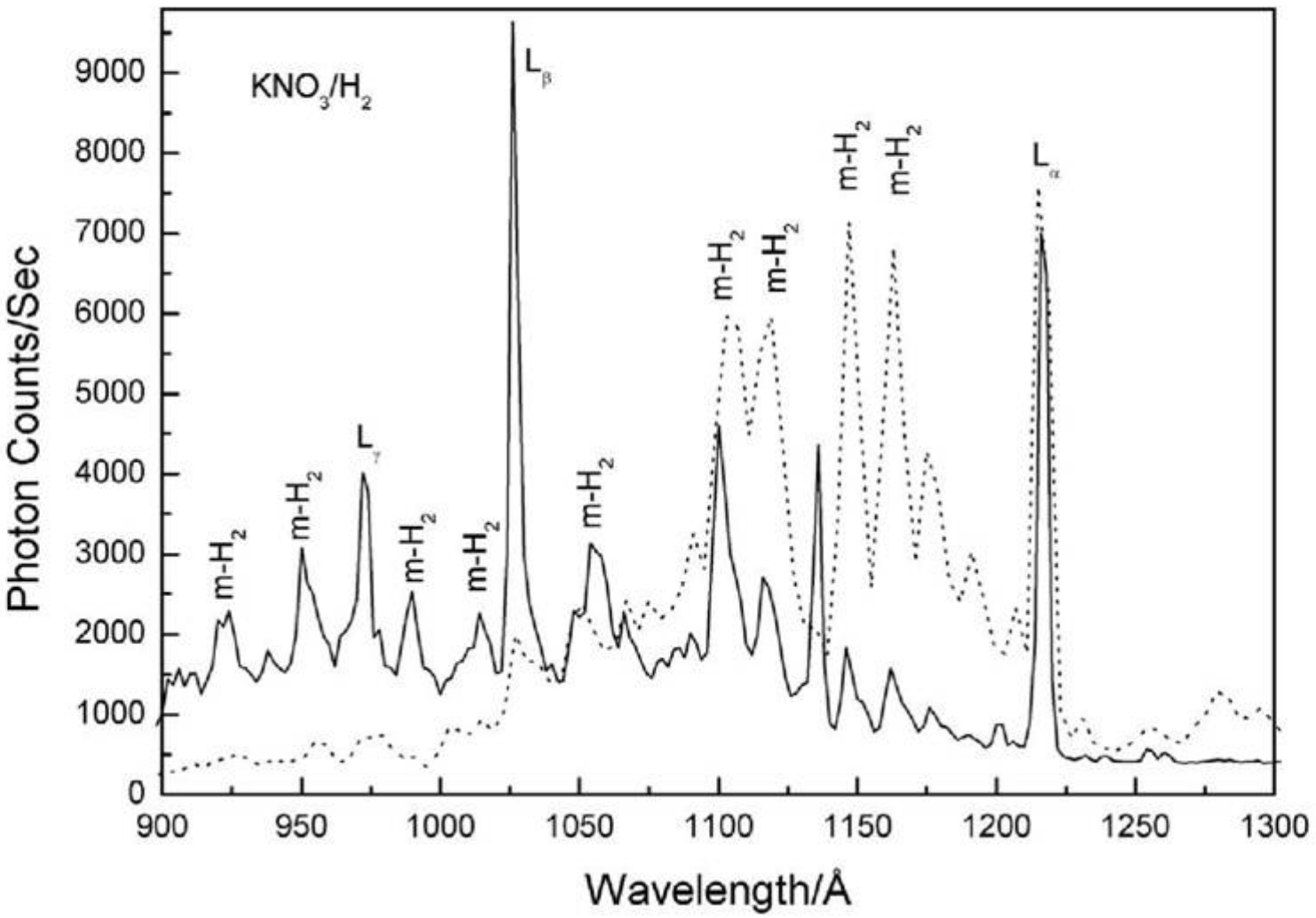
BlackLight Power, Inc.
493 Old Trenton Road, Cranbury, NJ 08512

Experimental Set-up for Chemically-Generated RT Plasma



Catalyst Resonant Energy Transfer

- $K(m) + 81.742\ eV\ (3 \times 27.2\ eV) \rightarrow K^{3+} + 3e^-$
- $K^+ + K^+ + 27.2\ eV \rightarrow K^{2+} + K$
- $Rb^+ + 27.28\ eV \rightarrow Rb^{2+} + e^-$
- $Sr^+ + 54.4\ eV\ (2 \times 27.2\ eV) \rightarrow Sr^{3+} + 2e^-$
- $He^+ + 54.4\ eV\ (2 \times 27.2\ eV) \rightarrow He^{2+} + e^-$
- $Ar^+ + 27.2\ eV \rightarrow Ar^{2+} + e^-$
- $O_2 + 54.4\ eV\ (2 \times 27.2\ eV) \rightarrow O^{2+} + O + 2e^-$



The VUV spectra (900–1300 Å) of the cell emission from hydrogen microwave plasma (dotted line) and the KNO_3–H_2 rt-plasma (solid line) with an inverted Lyman population. The increase in intensity at 1100Å compared to hydrogen emission alone was assigned to a contribution from H-(1/4).

Noninski, V., "Excess Heat during the Electrolysis of a Light Water Solution of K2CO3 with a Nickel Cathode", *Fusion Tech.*, 21, pp. 163-167, (1992).

- Electrodes
  - Cathode (Ni)
  - Anode (Pt)
- Electrolyte
  - 0.57 M K2CO3/Na2CO3 in H2O
- Results
  - Excess Heat observed was 26-160% of input energy.

Noninski, V., "Excess Heat during the Electrolysis of a Light Water Solution of K2CO3 with a Nickel Cathode", *Fusion Tech*., 21, pp. 163-167, (1992).-Contd.

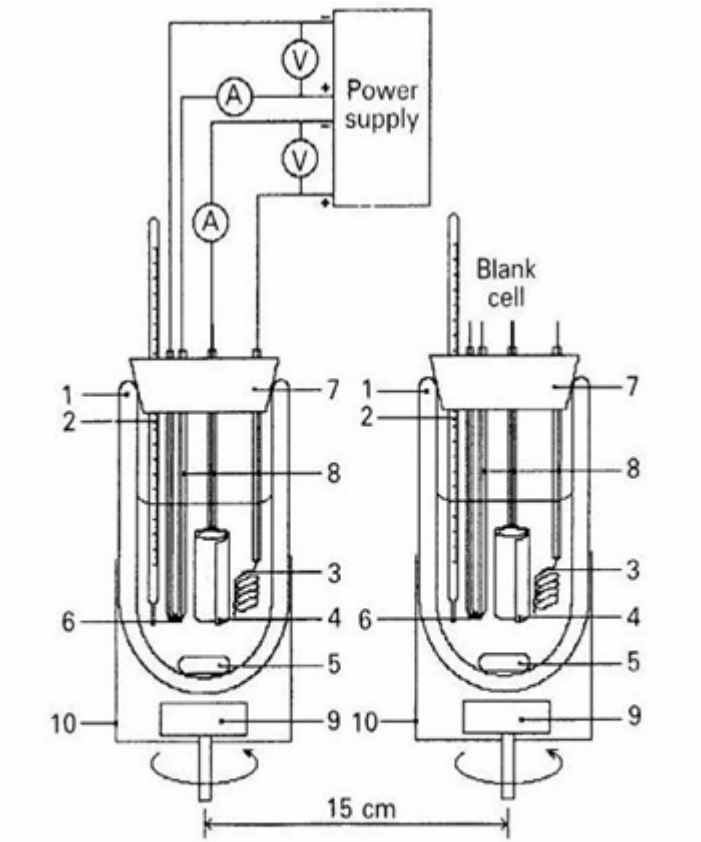


Fig. 1. Experimental setup: (1) vacuum-jacketed dewar, (2) thermometer, (3) platinum anode, (4) nickel cathode, (5) magnetic stirring bar, (6) resistor heater, (7) rubber stopper, (8) Teflon tubing, (9) magnetic stirrer, and (10) aluminum cylinder.

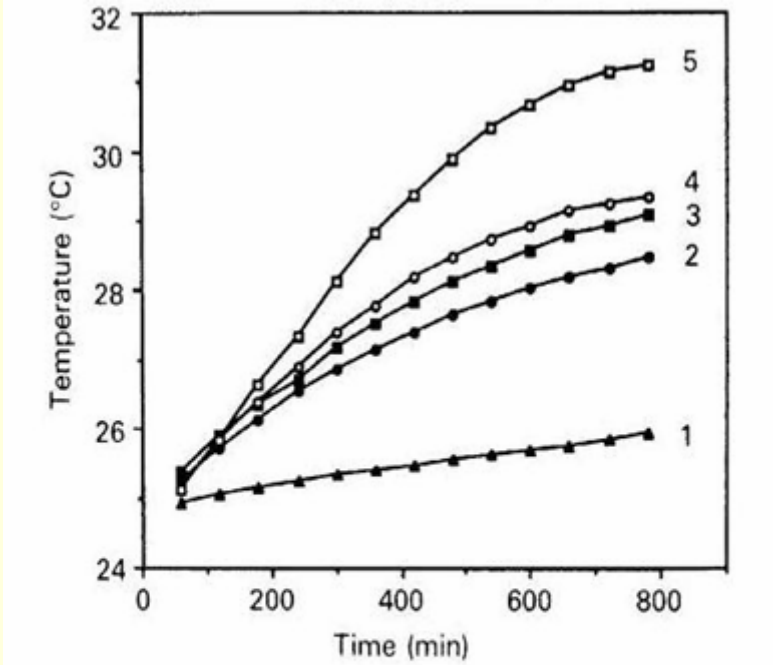


Fig. 2. Time history of temperatures: (1) blank cell (this curve is used as the blank for computing the heating coefficients of Fig. 4); (2) K_2CO_3 calibration cell (with only resistor heater working); (3) Na_2CO_3 calibration cell; (4) K_2CO_3 electrolysis cell (with only electrolysis working); and (5) Na_2CO_3 electrolysis cell.

Bush, R.T., "A Light Water Excess Heat Reaction Suggests that "Cold Fusion" May Be "Alkali-Hydrogen" Fusion", *Fusion Tech.*, 22, pp. 301-322, (1992).

- Electrodes
  - Cathode (Pd)
  - Anode (Pt)
- Electrolyte
  - 0.57M K2CO3
- Results
  - Peak excess power at 4W
  - Total excess energy is 0.3 MJ

Notoya, R., et al., "Tritium Generation and Larger Excess Heat Evolution by Electrolysis in Light and Heavy Water-Potassium Carbonate Solutions with Nickel Electrodes", *Fusion Tech.*,26, pp. 179 – 183, (1992).

- Electrodes
  - Cathode (Ni/Au)
  - Anode (Pt)
- Electrolyte
  - 0.5 M K2CO3
- Parameters
  - Temperature : 20˚C
- Results
  - Excess Heat - Largest observed was ~ 100% of input heat.
  - Tritium observed with both LW and HW (only report of tritium with light water ??)

Notoya, R., et al., "Tritium Generation and Larger Excess Heat Evolution by Electrolysis in Light and Heavy Water-Potassium Carbonate Solutions with Nickel Electrodes", *Fusion Tech.*,26, pp. 179 – 183, (1992). – contd. Table 1 =HW and LW. Table 2 = LW. Note LW performance similar to HW.

Generated Amount of Tritium and E-H During Electrolysis in 0.5 *M* K_2CO_3 Solutions of Light and Heavy Water by Use of a Worn Cathode Before This Series of the Experiments

Experiment Number	Solution	*I* (A)	*E* (V)	Duration (h)	W_{input} (W)	$T_{in\ cell}$ (°C)	E-H (%)	^3t (Bq)
Accuracy (±)		0.001	0.01	5 min	≤5%	0.15	≤5	≤5%
0	H_2O^a							0.00
0′	H_2O^b	0		22				0.31[c]
1	H_2O	0.300	−3.29	6	0.54	36.0	169	9.13[c] (36.5)[d]
2	H_2O	0.300	−3.48	6	0.60	35.2	130	8.23[c] (32.9)[d]
3	H_2O	0.300	−3.57	22	0.63	35.5	124	6.33[c] (6.91)[d]
0″	D_2O^e							32.3[c]
4	D_2O	0.300	−3.70	26	0.65	35.0	110	426[c] (393.2)[d]
5	D_2O	0.400	−4.19	26	1.06	40.1	72	54.9[c] (50.7)[d]

[a]Pure water.
[b]Electrolyte with the nonpolarized cathode.
[c]Bq denotes the amount of ^3t generated in 20 ml electrolyte.
[d]Bq[c] for 24 h.
[e]Electrolyte without any electrode.

Generated Amount of Tritium and E-H During Electrolysis in 0.5 *M* K_2CO_3 Solution of Light Water by Use of a New Cathode

Experiment Number	Solution	*I* (A)	*E* (V)	Duration (h)	W_{input} (W)	$T_{in\ cell}$ (°C)	t_{rest} (h)	E-H (%)	^3t (Bq)
Accuracy (±)		0.001	0.01	5 min	≤5%	0.15	5 min	≤5	≤5%
0	H_2O^a								0.00
0′	H_2O^b	0	0						0.00
1	H_2O	0.350	−3.76	26	0.80	36.0	20	82	1.59[c] (1.47)[d]
2	H_2O	0.400	−3.83	24	0.94	38.5	74	78	2.60[c] (2.60)[d]
3	H_2O	0.440	−3.90	21	1.07	38.7	46	108	2.88[c] (3.29)[d]
4	H_2O	0.250	−3.38	26	0.48	32.0	73	127	3.24[c] (2.99)[d]

[a]Pure water.
[b]Pure water with the nonpolarized new cathode.
[c]Bq denotes the amount of ^3t generated in 20 ml electrolyte.
[d]Bq[c] for 24 h.

Dufour et al., "Measurement of Excess Heat and Isotope Formation in Palladium-Hydrogen System", ICCF-5, Monte-Carlo, Monarco: IMRA Europe, Sophia Antipolis Cedex, France, (1995).

- Electrodes
  - Cathode (Pd)
  - Anode (Pt)
- Electrolyte
  - 0.2 M K2CO3.
- Parameters
  - F Tech 24, 205 1993
- Results
  - Excess Heat - Largest observed was 5.5 W

Dufour et al., "Measurement of Excess Heat and Isotope Formation in Palladium-Hydrogen System", ICCF-5, Monte-Carlo, Monarco: IMRA Europe, Sophia Antipolis Cedex, France, (1995). – contd

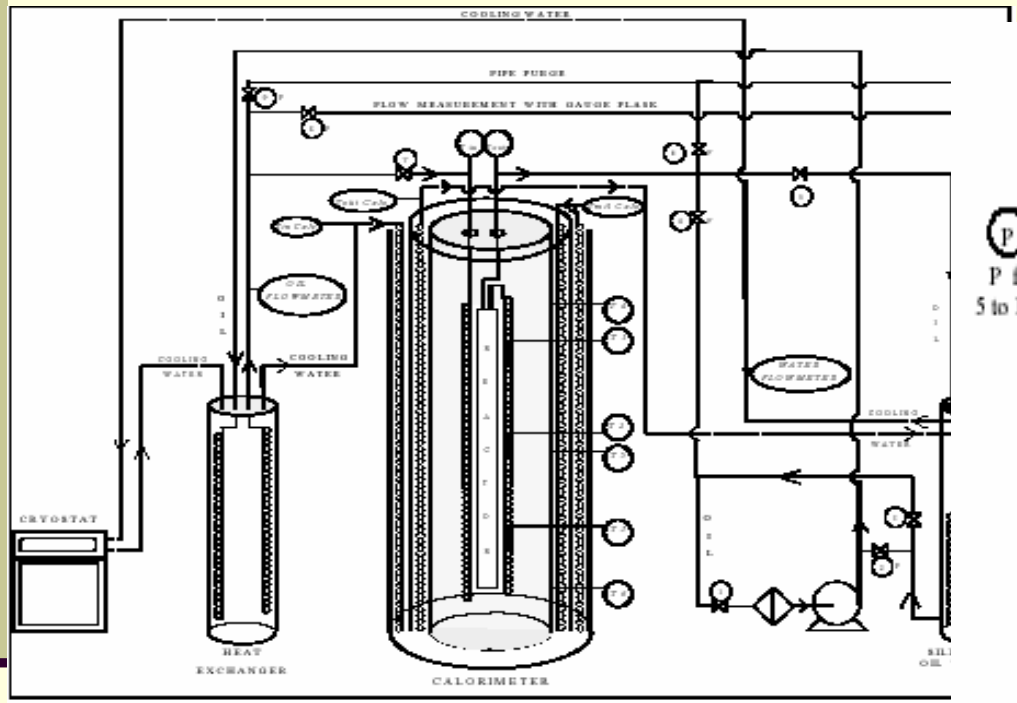


Fig. 3. OVERALL VIEW OF THE CALORIMETER SET-UP

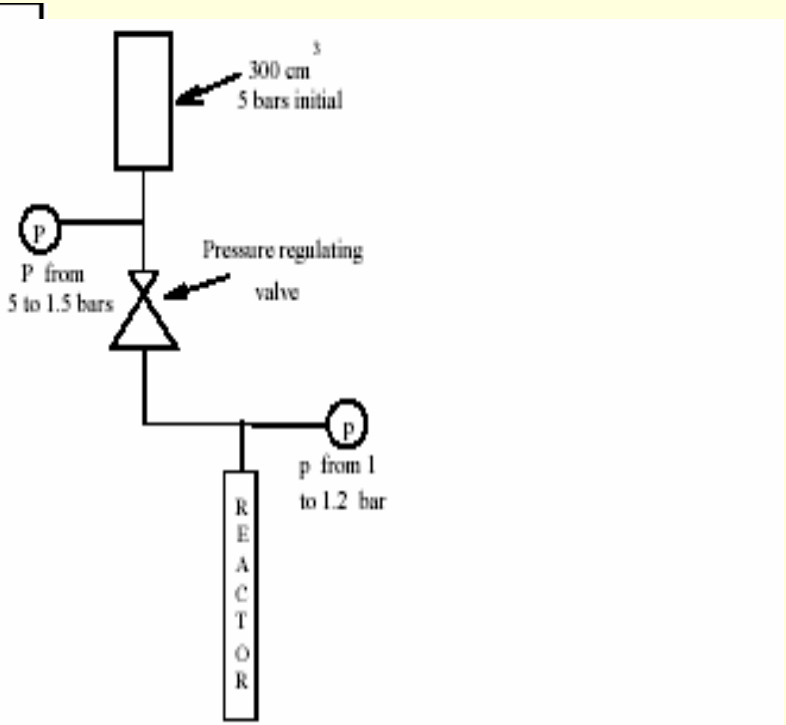
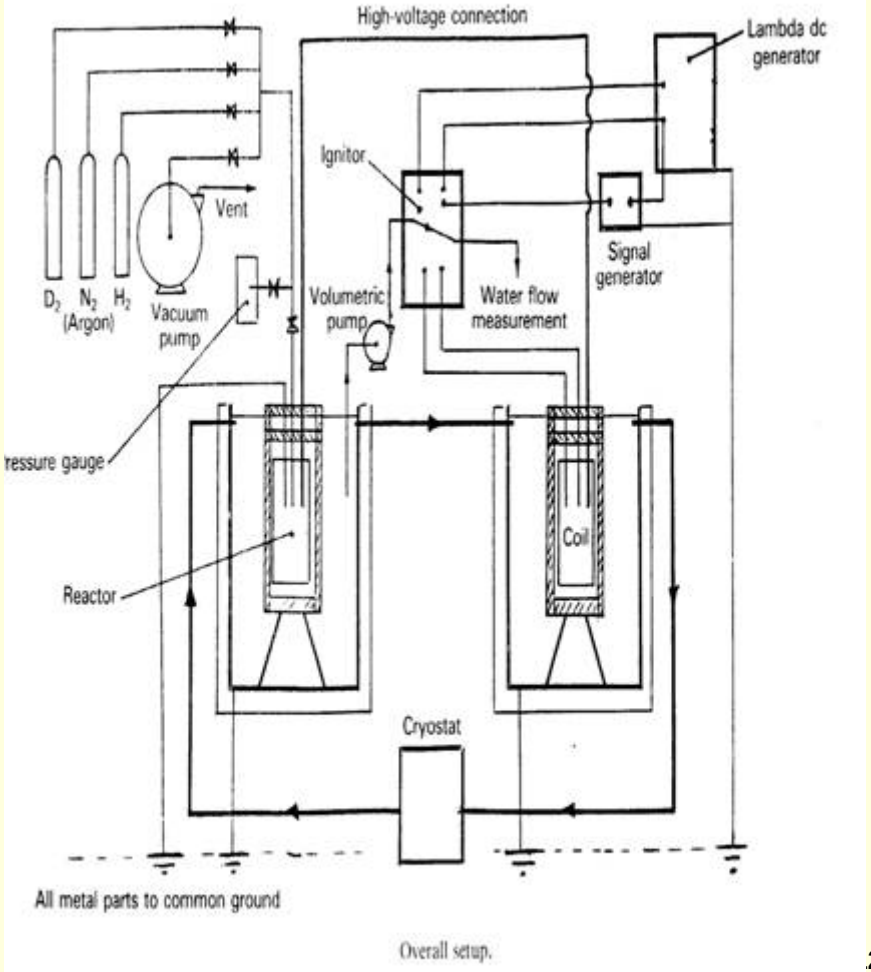


Fig. 4. HYDROGEN CONSUMPTION MEASUREMENT

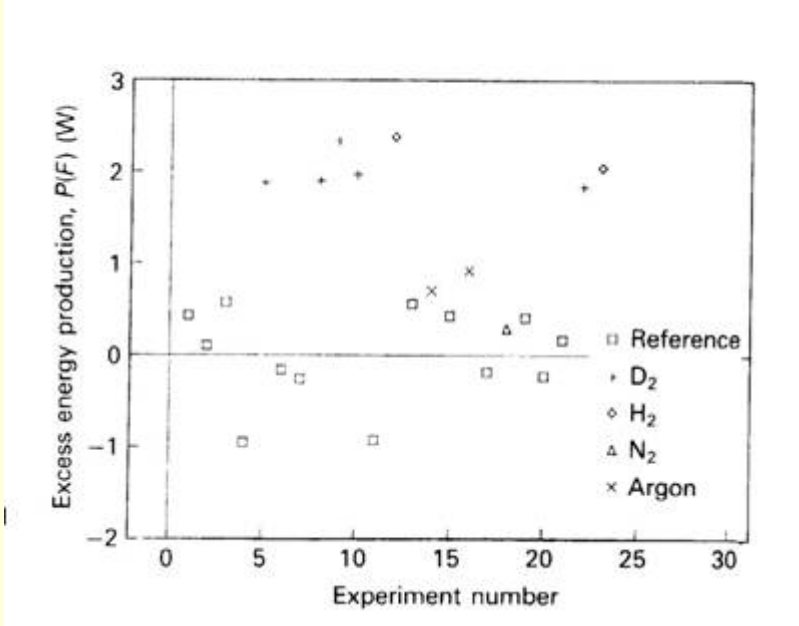
Dufour, J., "Cold fusion by Sparking in Hydrogen Isotopes", *Fusion Technology*, 24, *2*, p. 205-227,(1993).

- Electrodes
  - Cathode (Pd)
  - Anode (Pt)
- Electrolyte
  - H2 isotope
- Parameters
  - Low voltage (14 v) and DC Current Applied
- Results
  - Excess Heat
    - 2 W observed

Dufour, J., "Cold fusion by Sparking in Hydrogen Isotopes", *Fusion Technology*, 24, *2*, p. 205-227,(1993). – contd.



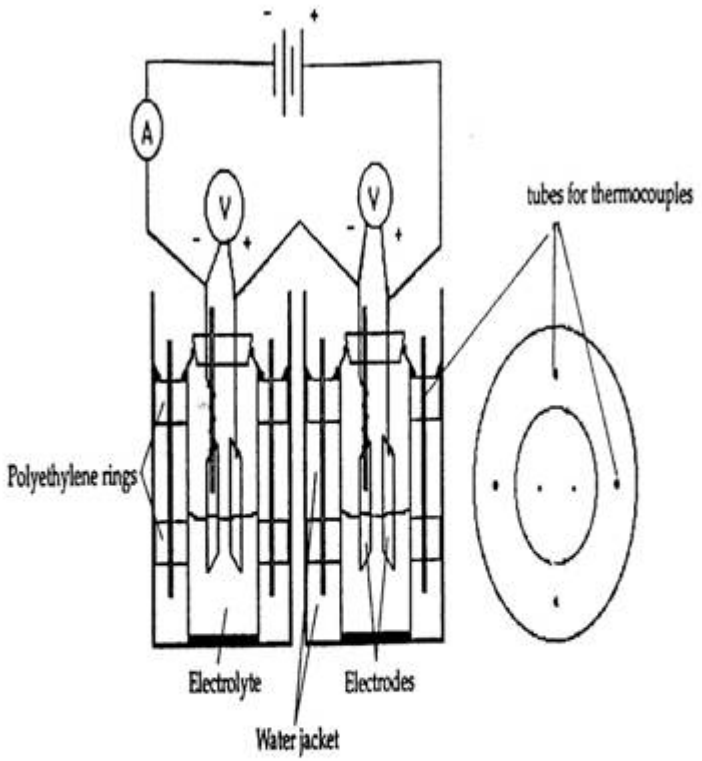
Overall setup.



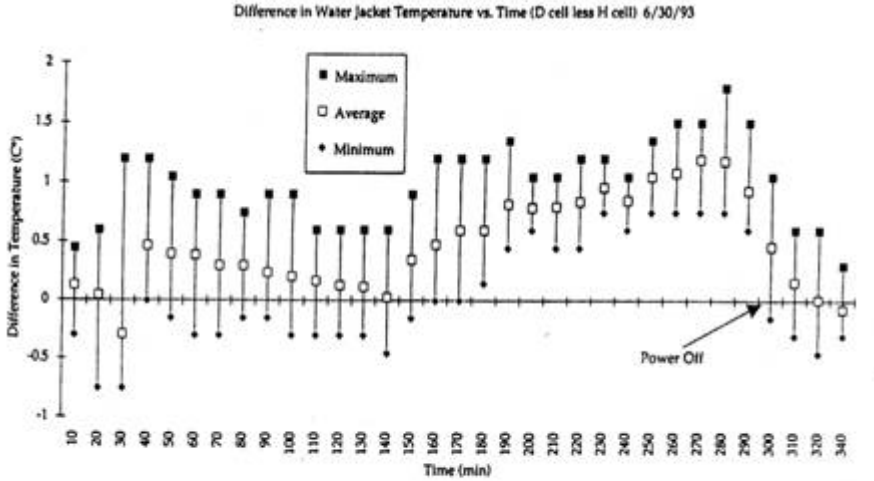
Dash, J., Noble, G., and Diman, D. "Surface Morphology and Microcomposition of Palladium Cathodes After Electrolysis in Acidified Light and Heavy Water: Correlation with Excess Heat", *Transactions of Fusion Technology*, 26, p. 299-305, December, (1994).

- Electrodes
  - Cathode (Pd)
  - Anode (Pt)
- Electrolyte
  - H2O/H2SO4 and D2O/H2SO4
- Parameters
  - Time: 400 hrs
- Results
  - Transmutation Products: Au, Ag found in both cells. Slightly higher conc. in HW
  - Excess Heat
    - Somewhat higher excess energy observed in heavy water than light water.

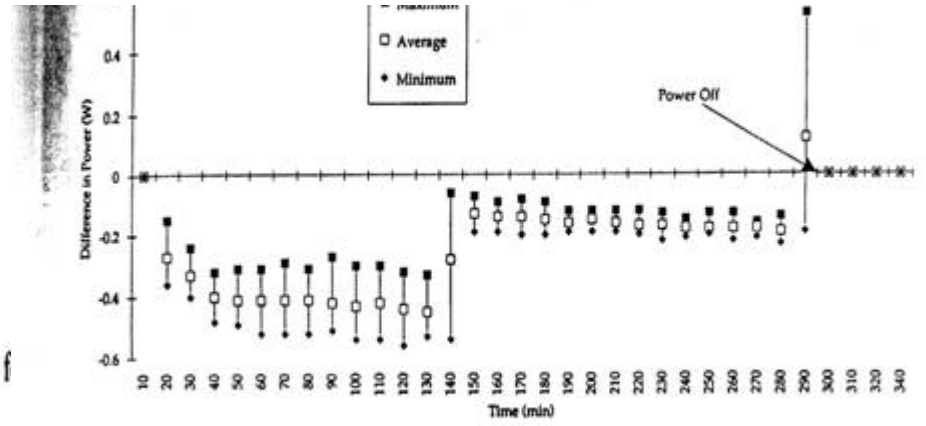
Dash, J., Noble, G., and Diman, D. "Surface Morphology and Microcomposition of Palladium Cathodes After Electrolysis in Acidified Light and Heavy Water: Correlation with Excess Heat", *Transactions of Fusion Technology*, 26, p. 299-305, December, (1994). – contd



Schematic diagram showing components of open cells and circuit used f
electrolysis of light and heavy water cells in series.



Difference in water jacket temperature of the D cell and the H cell. The positive values indicate that the D cell power output exceeded the H cell power output throughout the experiment.



Difference in power input to the heavy-water (D) cell and light-water (H) cell during electrolysis for five hours. The negative values indicate that more power was input to the H cell than the D cell throughout the experiment.

Ohmori, T. and M. Enyo, *Excess heat evolution during electrolysis of H2O with nickel, gold, silver, and tin cathodes.* Fusion Technol., 24, p. 293, (1993).

- Electrodes
  - Cathode (Ni/Au/Sn/Ag)
  - Anode (Pt)
- Electrolyte
  - Na_2SO_4, K_2CO_3, KOH
- Parameters
  - Current: 1A, Varying potential and temp., Time: 20 hrs for 7 days
- Results
  - Excess Heat
    - Largest Energy was observed with Sn electrode in K2SO4 – 907 mW

Ohmori, T. and M. Enyo, *Excess heat evolution during electrolysis of H2O with nickel, gold, silver, and tin cathodes.* Fusion Technol., 24, p. 293, (1993) - contd.

TABLE I

Results on Nickel Electrodes

Electrode	Solution	$R_{app} - IE_{th}$ (W)	ΔT (°C)	R_{ex} (mW)	$\frac{R_{ex}}{R_{app} - IE_{th}}$ (%)
Nickel	K_2CO_3	2.86	1.71	524	18
Nickel	K_2CO_3	2.40	1.26	387	16
Nickel	K_2CO_3	2.81	1.23	377	13
Nickel[a]	K_2CO_3	2.44	0.38	105	4
Nickel	Na_2CO_3	2.46	0.02	6	0.2
Nickel	Na_2CO_3	2.82	0.10	31	1
Nickel[a]	Na_2CO_3	2.46	0.05	15	0.5
Nickel[a]	Na_2SO_4	2.69	0.01	0	0
Nickel[a]	Li_2SO_4	3.02	0.01	0	0

[a]Anncaled at 600°C in helium atmosphere. In this case, an electrolytic cell with a cell constant of 3.60 was used.

TABLE II

Results on Gold Electrodes

Electrode	Solution	$R_{app} - IE_{th}$ (W)	ΔT (°C)	R_{ex} (mW)	$\frac{R_{ex}}{R_{app} - IE_{th}}$ (%)
Gold	K_2CO_3	2.86	1.71	524	18
Gold	Na_2CO_3	3.37	1.83	561	17
Gold	Li_2SO_4	3.12	1.64	503	16
Gold[a]	K_2CO_3	3.00	2.02	620	21

[a]Electrodeposited.

TABLE III

Results on Silver Electrodes

Electrode	Solution	$R_{app} - IE_{th}$ (W)	ΔT (°C)	R_{ex} (mW)	$\frac{R_{ex}}{R_{app} - IE_{th}}$ (%)
Silver	K_2CO_3	2.64	1.07	328	12
Silver	Li_2CO_4	3.62	0.31	95	3

TABLE IV

Results on Tin Electrodes

Electrode	Solution	$R_{app} - IE_{th}$ (W)	ΔT (°C)	R_{ex} (mW)	$\frac{R_{ex}}{R_{app} - IE_{th}}$ (%)
Tin	K_2CO_3	3.56	2.31	708	20
Tin[a]	K_2CO_3	3.47	2.96	907	26
Tin	Na_2CO_3	3.59	0.73	224	6

[a]Electrolyzed for 65 h.

Ohmori, T. and M. Enyo, *Iron Formation in Gold and Palladium Cathodes.* J. New Energy, 1(1), p. 15, (1996).

- Electrodes
  - Cathode (Au/Pd)
  - Anode (Pt)
- Electrolyte
  - 0.5 M Na2SO4, K2CO3, KOH
- Parameters
  - Current: 1A for 7 days
- Results
  - Transmutation Products – Fe
  - Excess Heat - The study showed that there is a correlation between Fe generated and excess heat observed (see Fig 1).

Ohmori, T. and M. Enyo, *Iron Formation in Gold and Palladium Cathodes.* J. New Energy, 1(1), p. 15, (1996). – Contd

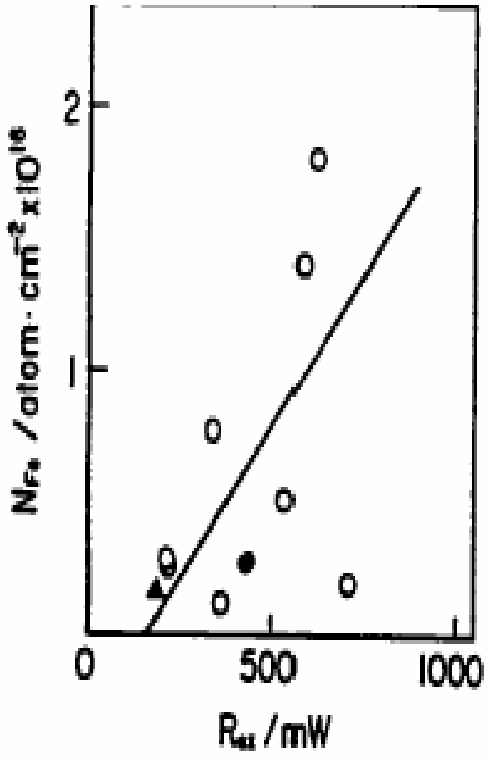


Fig. 5. Plots of the total amount of Fe atoms against the mean excess energy for Au electrode: Na_2SO_4 (O), K_2CO_3 (●), & KOH (▲).

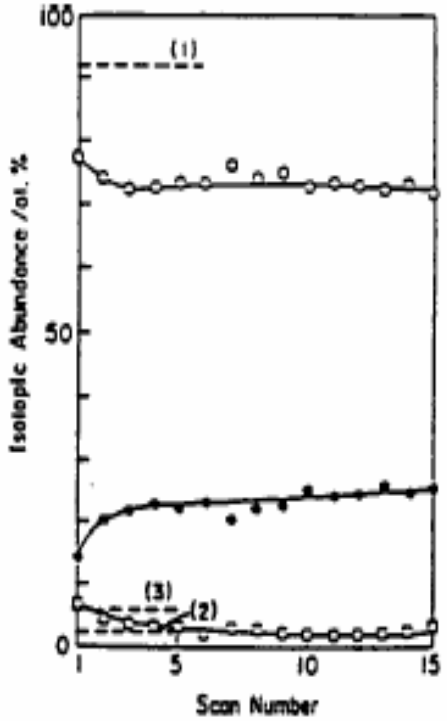


Fig. 6. Profile of the isotopic abundance of Fe atoms in the Au electrode. Solid line: the content of the particles on mass number 56 (O), 57 (●), & 54 (□). Dotted line: natural isotopic abundance levels of ^{56}Fe (1), ^{57}Fe (2), & ^{54}Fe (3).

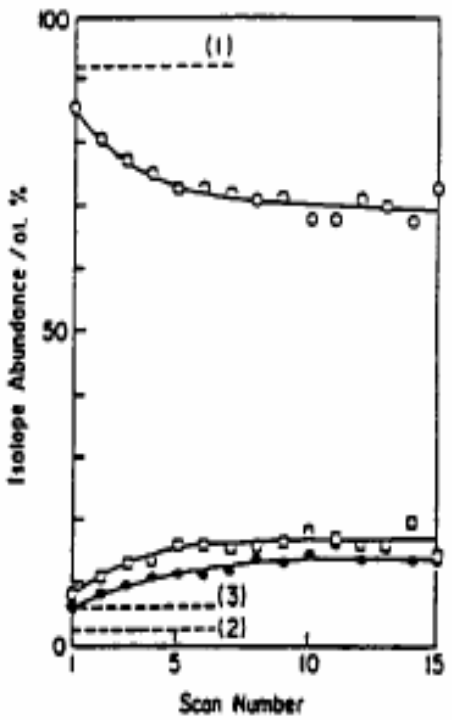


Fig. 7. Profile of the isotopic abundance of Fe atoms in the Pd electrode. Solid line: the content of the particles on mass number 56 (O), 57 (●), & 54 (□). Dotted line: natural isotopic abundance levels of ^{56}Fe (1), ^{57}Fe (2), & ^{54}Fe (3).

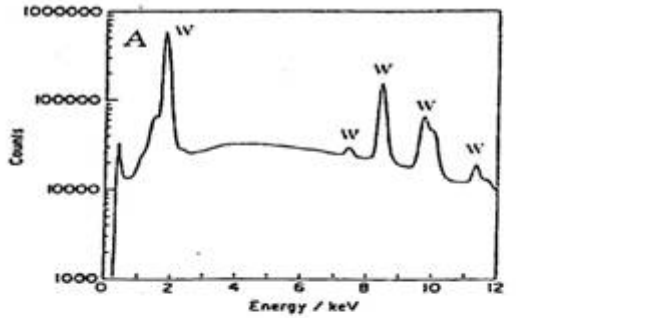
Ohmori, T. et al., "Excess Energy and Anomalous Concentration of 41K Isotopes in Potassium formed on/in a Re Electrode during the Plasma Electrolysis in K2CO3/H2O and K2CO3/D2O Solutions," *Proc. ICCf-9*, pp. 284-289, May 19-24 (2002).

- Electrodes
  - Cathode (Re)
  - Anode (Pt)
- Electrolyte
  - 0.5 M K2CO3/H2O and 0.5 M K2CO3/D2O
- Parameters
  - Current: 2A, Voltage: 160 V,
- Results
  - Transmutation Products: Large conc. Of 41K observed in both cases, with deviation from natural abundance
  - Excess Energy ranging from 58-109 W/cm2 was generated continuously.
    - No significant differences in energy produced in H2O and D2O electrolysis systems

Ohmori,T., and Mizuno, T., "Strong Excess Energy Evolution, New Elements Production, and Electromagnetic Wave and/or Neutron Emission in the Light Water Electrolysis with a Tungsten Cathode," *Proc. ICCF-7*, Vancouver, Canada, pp. 279-284, (2000a).

- Electrodes
  - Cathode (W)
  - Anode (Pt)
- Electrolyte
  - 0.5 M Na2SO4
- Parameters
  - Temperature: 20ºC
- Results
  - Transmutation Products
    - Pb, Fe, Ni, Cr, C were found
    - Pb isotopic distribution deviated from the norm.
  - Excess Heat
    - Higher amount of energy observed in heavy water than light water.

Ohmori,T., and Mizuno, T., "Strong Excess Energy Evolution, New Elements Production, and Electromagnetic Wave and/or Neutron Emission in the Light Water Electrolysis with a Tungsten Cathode," *Proc. ICCF-7*, Vancouver, Canada, pp. 279-284, (2000a). – contd. The Figures show EDX result analysis indicating Cr and Fe formation .

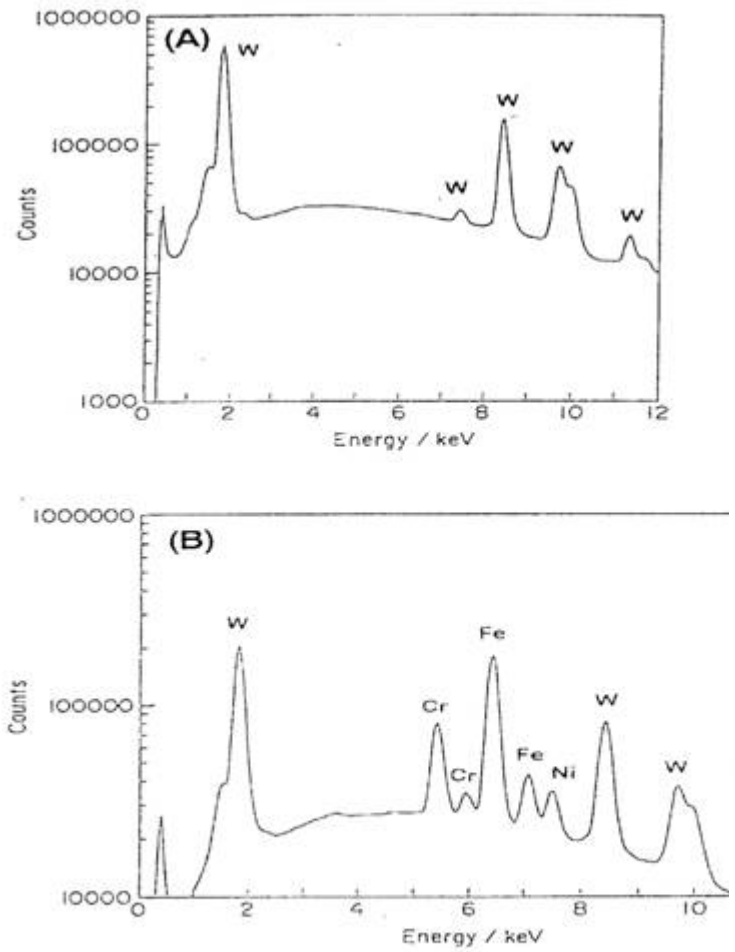


Typical EDX spectra on/in the W electrodes before and after the electrolysis: A before the electrolysis, B after the electrolysis.

Ohmori, T. and Mizuno, T., "Nuclear Transmutation Reaction Caused By The Light Water Electrolysis On Tungsten Cathode Under An Incandescent Condition," *J. New Energy*, 4, 4, pp.66-78 (2000b).

- Electrodes
  - Cathode (W)
  - Anode (Pt)
- Electrolyte
  - 0.5 M Na2SO4
- Parameters
  - Current: 1-5mA, Voltage: 2-3 V, Time: 3-4 weeks
- Results
  - Transmutation Products: Pb, Fe, Ni, Cr, C
  - Pb isotopic distribution deviation
  - Excess Power of ~ 0.5 W

Ohmori, T. and Mizuno, T., "Nuclear Transmutation Reaction Caused By The Light Water Electrolysis On Tungsten Cathode Under An Incandescent Condition," *J. New Energy*, 4, 4, pp.66-78 (2000b). – contd



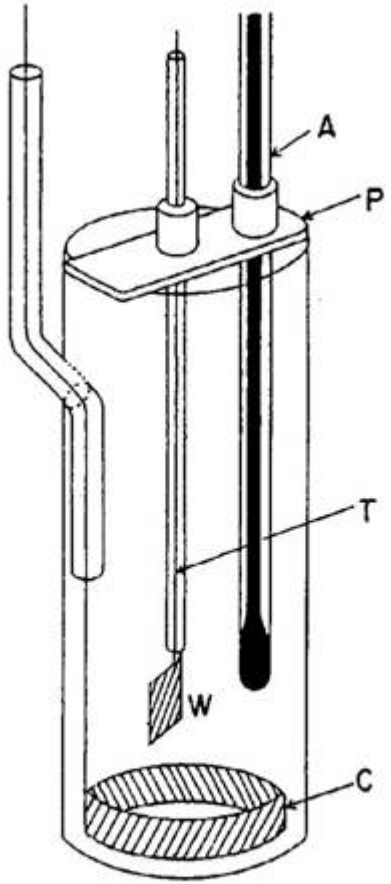
Typical EDX spectra on/in the W-type I electrodes before and after the electrolysis; (A) before the electrolysis, (B) after the electrolysis.

TABLE II

Isotopic Content of New Elements Produced on/in the Electrode and Tungsten of the Electrode Material

Element	Isotope	Isotopic content within 160 Å from the electrode surface (1st run) (at.%)	Isotopic content within 1760-2400 Å from the electrode surface (11-15th runs) (at.%)	Natural isotopic abundance (at.%)
Cr	^{50}Cr	6.1		4.31
	^{52}Cr	79.1		83.75
	^{53}Cr	12.4		9.55
Fe	^{56}Fe	91.0		91.66
	^{57}Fe	2.9		2.19
Ni	^{58}Ni	63.0		67.98
	^{60}Ni	30.8		26.23
Re	^{185}Re	48.4		37.1
	^{185}Re	51.6		62.9
Pb	^{206}Pb	38.5		25
	^{207}Pb	55.0		22
	^{208}Pb	6.5		52
W	^{182}W	25.3	26.6 $^{+0.6}_{-0.5}$	26.3
	^{183}W	14.9	14.5 $^{+0.3}_{-0.4}$	14.3
	^{184}W	30.4	30.5 $^{+0.6}_{-0.5}$	30.6
	^{186}W	29.0	28.2 $^{+0.8}_{-1.2}$	28.6

Ohmori, T. et al., "Excess Energy and Anomalous Concentration of ^{41}K Isotopes in Potassium formed on/in a Re Electrode during the Plasma Electrolysis in K2CO3/H2O and K2CO3/D2O Solutions," *Proc. ICCf-9*, pp. 284-289, May 19-24 (2002). – contd



Electrolytic cell: (A) thermometer,
C) Pt counter electrode, (P) plastic plat
T) Teflon tube, (W) Re working electrode.

Table 2

Isotopic content of ^{39}K and ^{41}K calculated from signal intensities at mass numbers, 38.9623 and 40.9607, in Table 1.

Electrodes	Isotopic Distributions* ^{39}K (%)	^{41}K
Electrode-4		
No-Sputtered	77.1	22.9
Sputtered	63.2	36.8
Electrode-8		
No-Sputtered	78.7	21.3
Sputtered	68.1	31.9

* Natural isotopic abundance of ^{39}K and ^{41}K is 93.1 and 6.9, respectively.

Table 5

Excess enegies generated during the H_2O and D_2O plasma electrolysis

Electrode	Solution	Time (min)	Current* (A)	W_{vap}	W_{sol}	W_{cell}	W_{off} (kJ)	W_{total}	W_{in}	Excess Energy (W)	Efficiency (%)
Electrode-1	K_2CO_3/H_2O	15	0.54	49.5	10	2.8	74.6	136.9	82.9	54	165
Electrode-2		17	0.51	44.5	10	2.8	79.3	136.6	83	52	165
Electrode-3		7	0.55	15.4	15.4	3.6	32.7	67.1	37	72	181
Electrode-4		9	0.52	31.6	15	3.6	41.9	92.1	45	87	205
Electrode-5		19	0.53	44.7	12.8	3.1	88.6	149.2	96.6	46	154
Electrode-6		10	0.56	24.8	14.3	3.4	46.6	89.1	53.8	60	166
Electrode-7		15	0.48	30.5	13.8	3.9	70	118.2	69.1	55	171
Electrode-8	K_2CO_3/D_2O	15	0.37	27.1	10.9	3.1	70	111.1	52.5	65	212
Electrode-9		9	0.46	20.3	10.9	3.1	42	76.3	39.7	68	192

Arapi, A.et al., "Experimental observation of the new elements production in the deuterated and/or hydride palladium electrodes, exposed to low energy DC glow discharge" ICCF 9, Beijing, China, (2002).

- Electrodes
  - Cathode (Pd)
  - Anode (Au)
- Glow Discharge
  - H2/D2 gas
- Parameters
  - Current: 2 mA, Voltage:- 600-800 volt, pressure: ~3 Torr, time: 60 min
- Results
  - H2 – Li, Ni, Ba found
  - D2 – Be, Ni found

Arapi, A.et al., "Experimental observation of the new elements production in the deuterated and/or hydride palladium electrodes, exposed to low energy DC glow discharge" ICCF 9, Beijing, China, (2002) - contd. Figures show experimental setup and table of elements for D2 and H2 cell.

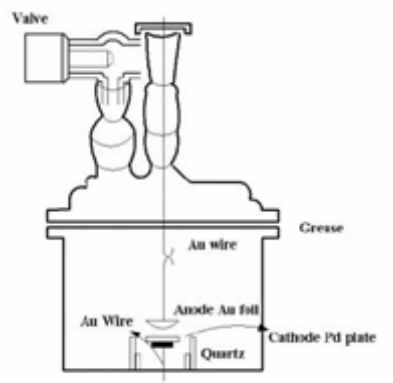


Fig.1 Pyrex glass cell

Experimental Setup

Analysis Time	Number of Areas	^{9}Be	^{56}Fe	^{58}Ni	^{63}Cu
Before Gas Loading	G01	0	1208	0	0
	G02	0	302	0	0
	G03	0	521	0	0
	G04	0	0	0	80
	G05	0	385	0	0
	G06	0	19339	0	0
	G07	0	309	0	0
After Discharge	G11	904	34713	1769	4363
	G12	445	4831	2177	0
	G13	1375	26782	5298	0
	G14	1755	46880	0	7726
	G15	4212	34550	0	6944
	G16	925	24848	771	0
	G17	308	15606	0	0
	G18	90	0	0	0
	G19	492	7772	0	0
	G20	185	7519	0	636

Counts intensity of ^{9}Be, ^{56}Fe, ^{58}Ni and ^{63}Cu for all selected areas

Data from D2 Cell

Counts of ^{7}Li, ^{58}Ni and ^{138}Ba each divided by the total counts used to normalize counts times 10000 for all selected areas

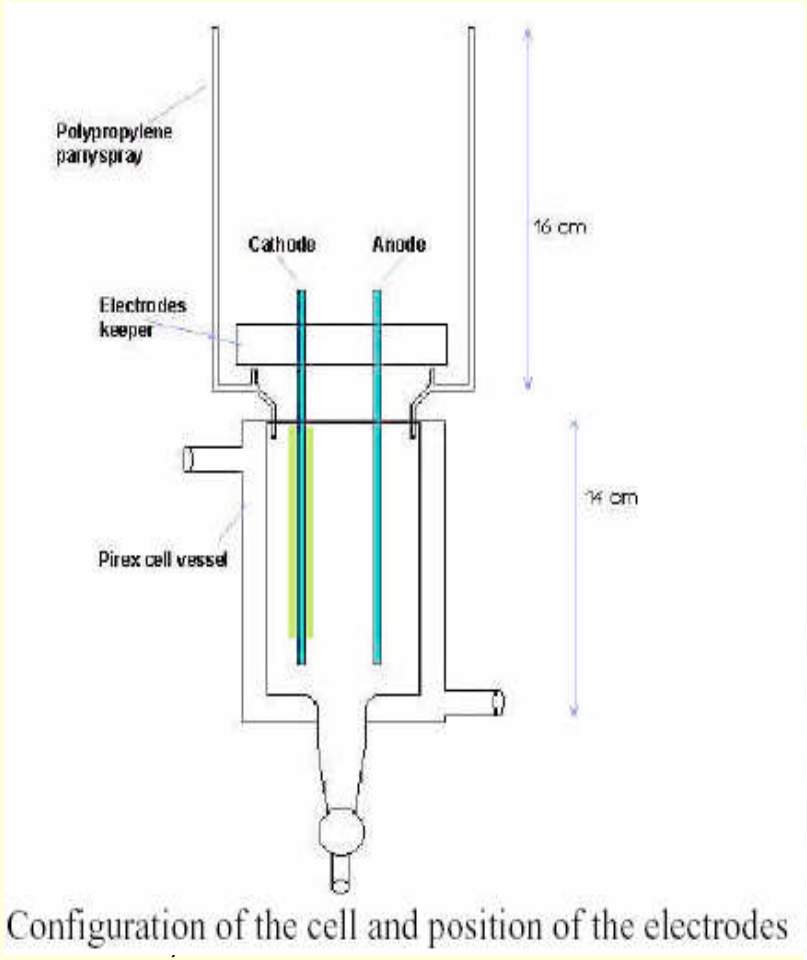
	Number of Area	Normalization Intensity ^{7}Li	Normalization Intensity ^{58}Ni	Normalization Intensity ^{138}Ba	Zone
Before Gas Loading	1	0	0	0	Uppermost
		0	0	0	Sputtering
	2	0	0	0	Uppermost
		0	0	0	Sputtering
After Discharge Experiment	3	21	49	87	Uppermost
		9	2	316	Sputtering
	4	16	24	81	Uppermost
		9	2	315	Sputtering
	5	5	35	130	Uppermost
		6	2	770	Sputtering

Data from H2 Cell

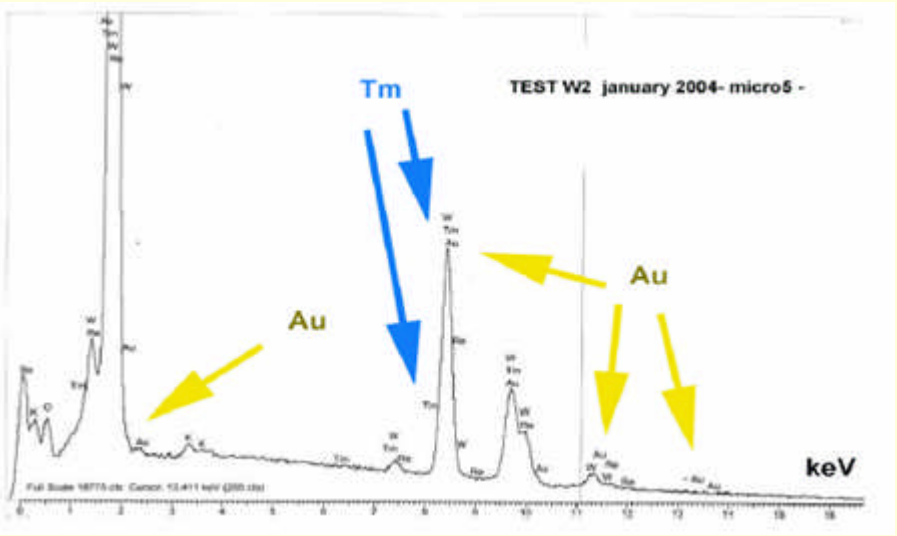
Cirillo, D and Iorio,V, "Transmutation of metal at low energy in a confined plasma in water", ICCF11 (2004).

- Electrodes
  - Cathode (W)
  - Anode (Pt)
- Electrolyte
  - 0.2 M K2CO3.
- Parameters
  - Current: 8 A, voltage: 0-340 volts and temperature: 70˚C
- Results
  - Transmutation Products – Rb, Os, Au, Hf, Th, Er, Yb
  - Excess Heat - Reported

Cirillo, D and Iorio,V, “Transmutation of metal at low energy in a confined plasma in water”, ICCF11 (2004). – Contd.



Configuration of the cell and position of the electrodes



Fujii, M et al., "Heat Measurement During Light Water Electrolysis using Pd/Ni Rod Cathodes", ICCF 9, Beijing, China, (2002).

- Electrodes
  - Cathode (Pd,Pd/Ni) rods/balls
  - Anode (Pt)
- Electrolyte
  - 1 M Li2SO4
- Parameters
  - Current: 1 A
- Results
  - Excess Heat - Significant heat observed (>10%) in 6 out of 28 cases. In most cases it < 5%. More runs required as the error limit in the system was 8-10%.

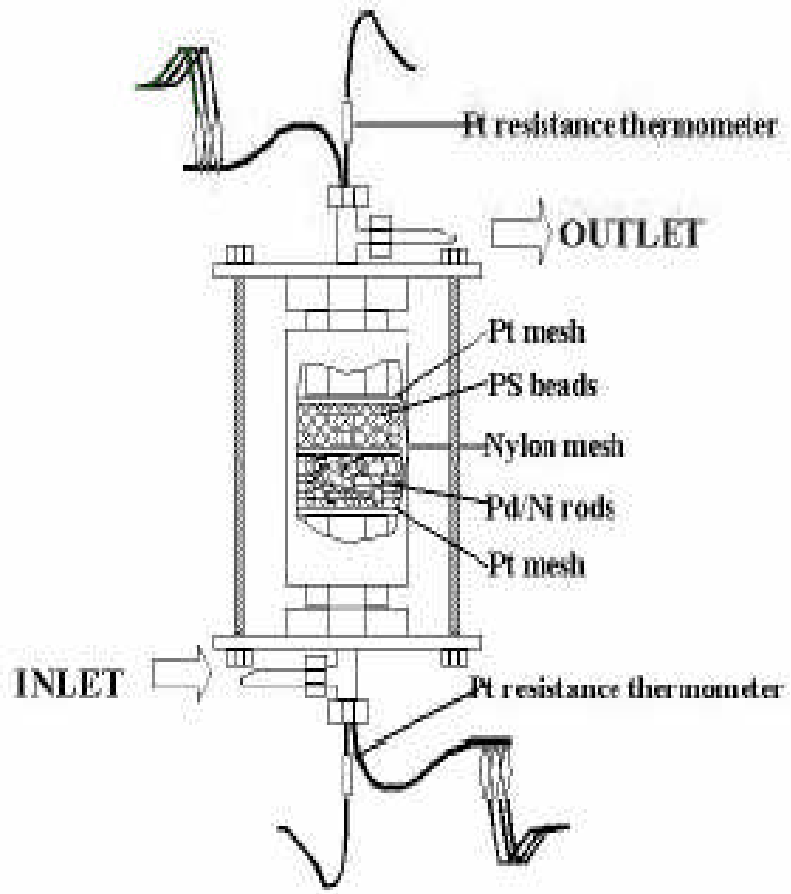


Fig. 1 Electrolysis cell.

Fujii, M et al., "Heat Measurement During Light Water Electrolysis using Pd/Ni Rod Cathodes", ICCF 9, Beijing, China, (2002). -contd.

No 1, 3,5, 7, 23 and 24 show a large excess heat (>10%).

Table 1 Heat balance of electrolysis in 1M Li_2SO_4-H_2O using Pd rods, Pd/Ni rods and Pd/Ni balls for cathode

No	Time(h)	Cathode	Cell Voltage(V)	HB_{AVE}	Corrected HB_{AVE}
1	24.25	Pd	8.8-10.7	1.30±0.07	1.45±0.08
2	75.75	Pd	13.2-15.4	0.93±0.05	1.03±0.06
3	239.9	Pd/Ni	6.3-11.3	1.33±0.08	1.52±0.09
4	30	Pd	10.5-12.2	0.93±0.03	1.06±0.04
5	72.6	Pd/Ni	6.3-11.4	1.14±0.09	1.34±0.10
6	126.9	Pd	9.8-11.8	0.91±0.03	1.05±0.04
7[a]	50	Pd/Ni	7.5-9.9	1.32±0.09	1.50±0.08
	20.05		8.3-10.9	1.11±0.09	1.41±0.10
	24.05		4.7-4.9	1.14±0.06	1.29±0.05
	29.2		5.9-6.4	1.14±0.07	1.37±0.07
8	56.75	Pd/Ni	8.1-11.8	0.85±0.05	1.02±0.06
9	25.6	Pd/Ni	10.9-12.0	0.96±0.04	1.03±0.05
10	91.5	Pd/Ni	10.0-12.3	0.88±0.04	1.03±0.06
11	20.3	Pd/Ni	12.7-16.0	0.83±0.06	0.93±0.07
12	43.35	Pd/Ni	14.9-20.5	0.96±0.05	1.04±0.06
13	76.5	Pd/Ni	9.3-12.0	0.90±0.07	1.03±0.08
14	77.2	Pd/Ni	9.4-10.9	0.88±0.06	1.03±0.06
15	74.65	Pd/Ni	9.1-10.9	0.89±0.05	1.05±0.06
16[b]	73.3	Pd/Ni	7.3-8.5	0.86±0.06	1.05±0.08
17[b]	52.2	Pd/Ni	6.4-7.1	0.84±0.05	1.06±0.06

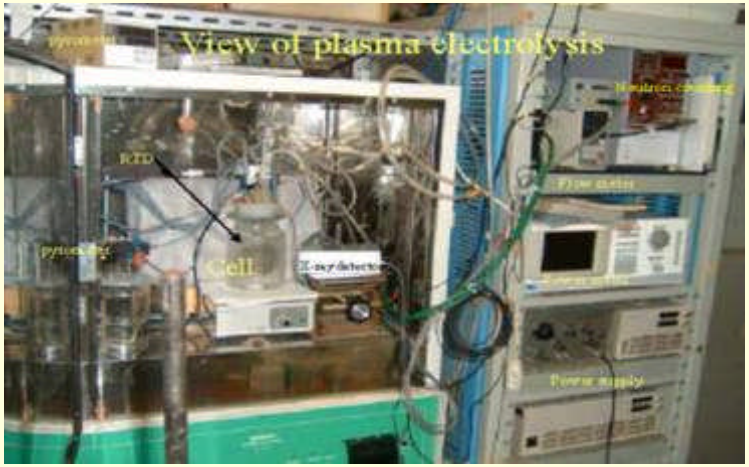
No	Time(h)	Cathode	Cell Voltage(V)	HB_{AVE}	Corrected HB_{AVE}
18[d]	54.1	Pd/Ni	7.2-8.3	0.86±0.04	1.05±0.05
19[d]	73.4	Pd/Ni	7.87-9.52	0.86±0.06	1.01±0.08
20[d]	75.7	Pd/Ni	6.68-8.05	0.76±0.07	0.96±0.08
21[d]	71.5	Pd/Ni	5.78-9.27	0.73±0.04	0.96±0.05
22[d]	49.35	Pd/Ni	5.95-8.96	0.75±0.06	0.99±0.06
23[c]	122.7	Pd/Ni	5.79-8.77	1.08±0.08	1.31±0.09
	47.1		6.56-7.15	0.90±0.06	1.10±0.08
24[e]	12	Pd/Ni	8.15-10.56	1.33±0.10	1.50±0.11
25[f]	75.7	Pd/Ni	6.9-9.1	0.76±0.07	0.96±0.08
26[f]	71.5	Pd/Ni	5.8-9.3	0.73±0.06	0.98±0.05
27[f]	49.4	Pd/Ni	6.0-9.0	0.75±0.06	0.99±0.06
28	66.1	Pd/Ni	8.9-10.4	0.87±0.05	1.02±0.04

(a) Cell current is 0.5-2.0A. In the other experiment, cell current is 1A
(b) Cell current is 0.8A.
(c) Cell current is 1-2A
(d) Cathode is Pd/Ni balls by sputtering
(e) Cathode is Pd/Ni balls by chemical plating
(f) Cathode is Pd/Ni balls by sputtering

Mizuno et al., "Generation of Heat and Products During Plasma Electrolysis", ICCF-10, Cambridge, MA, (2003).

- Electrodes
  - Cathode (W)
  - Anode (Pt)
- Electrolyte
  - 0.2 M K2CO3
- Parameters
  - Voltage: 120 V, Temperature : 80˚C
- Results
  - Transmutation Products – Ca, Fe, Zn
  - Excess Heat - Largest observed was 1100J. Some times excess heat was 30% of input heat.

Mizuno et al., "Generation of Heat and Products During Plasma Electrolysis", ICCF-10, Cambridge, MA, (2003). - Contd



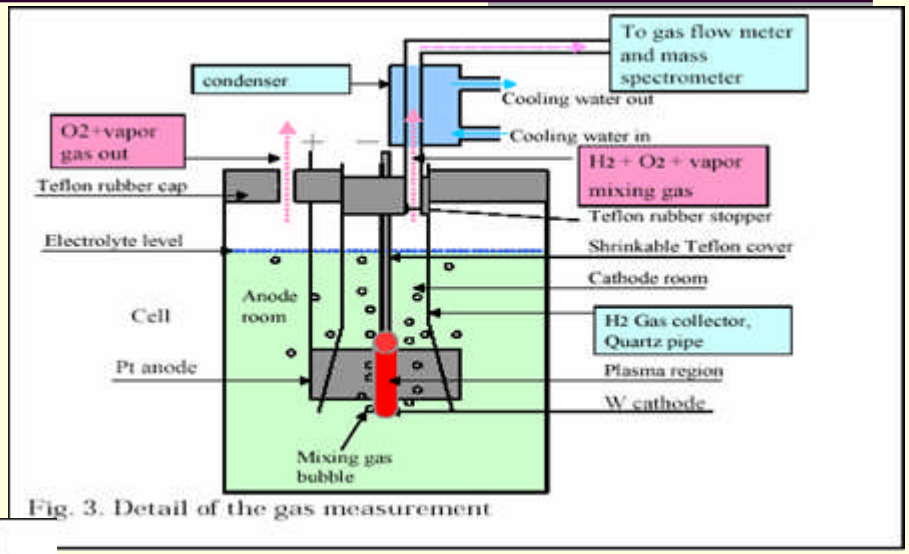


Fig. 3. Detail of the gas measurement

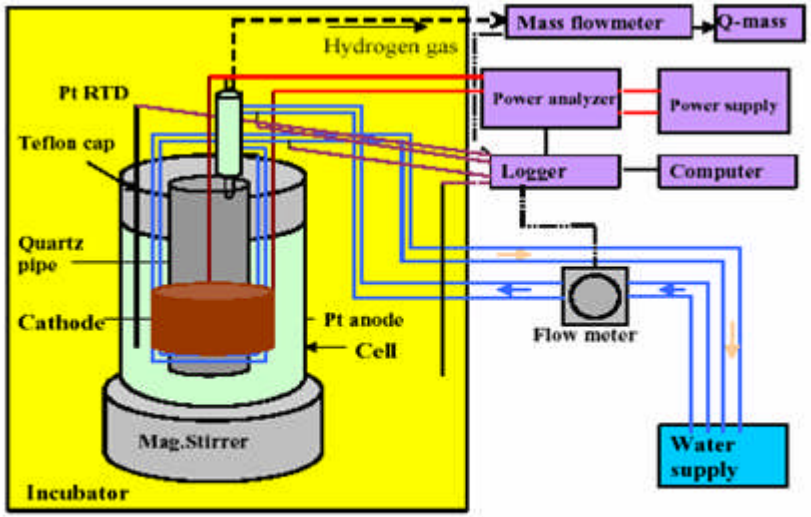


Fig. 2. Sketch of experimental set up

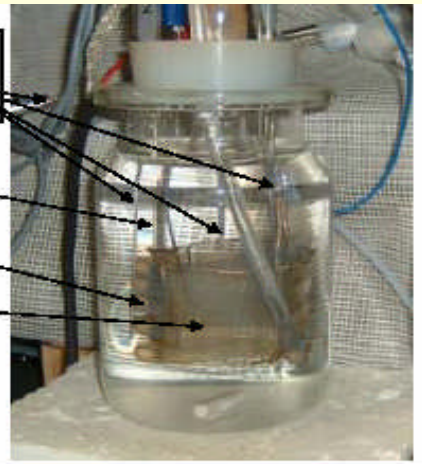
RTD: *Pt resistance thermometer, 0.001deg*

glass dome

coolant coil

Pt anode

Rectangular Pt had an integral lattice constructed using a 15cm length of 0.1cm in diameter.



The cell is 6cm in diameter and 15cm in height.

Mizuno et al., "Generation of Heat and Products During Plasma Electrolysis", ICCF-10, Cambridge, MA, (2003). – Contd.

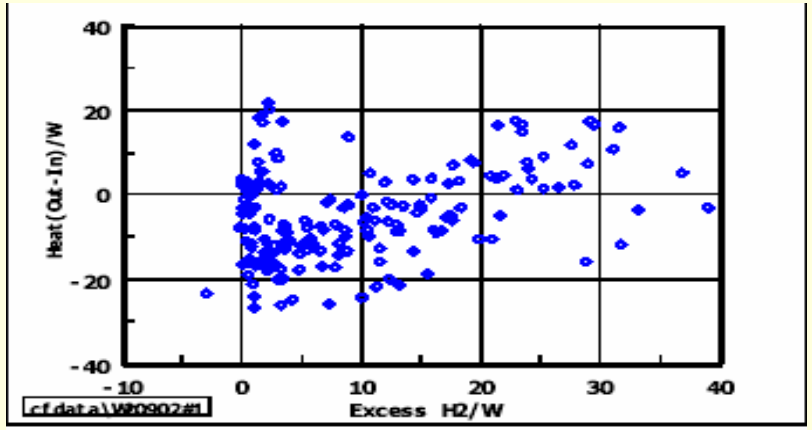


Fig. 20. Relation of heat balance and excess H2

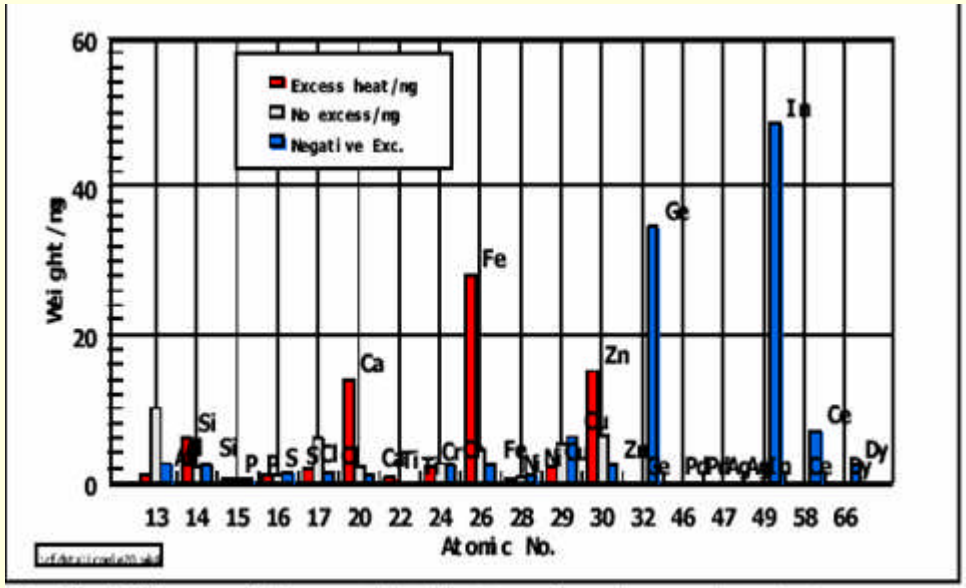
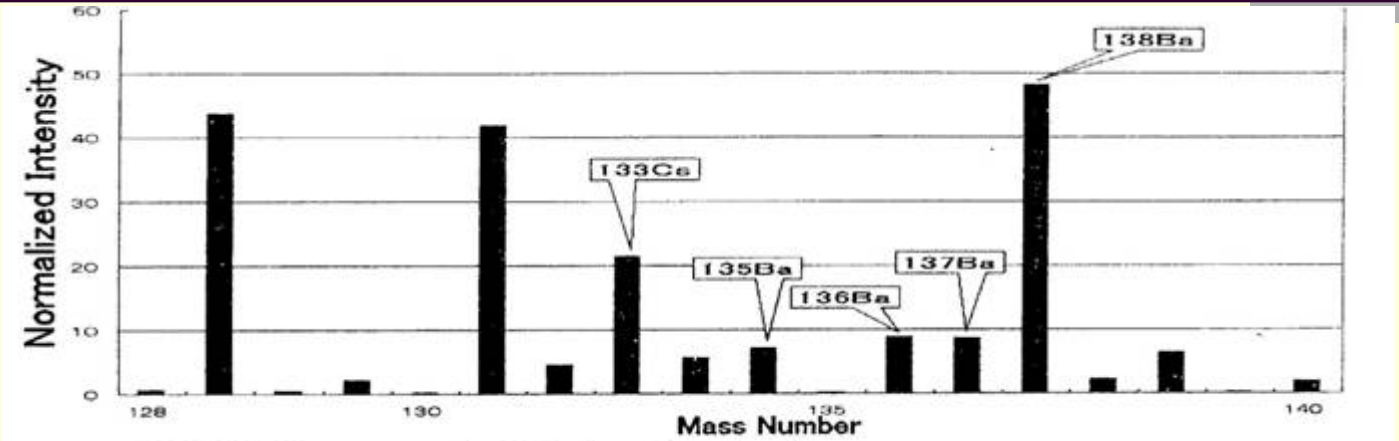


Fig. 21: Difference of element distributions after plasma electrolysis

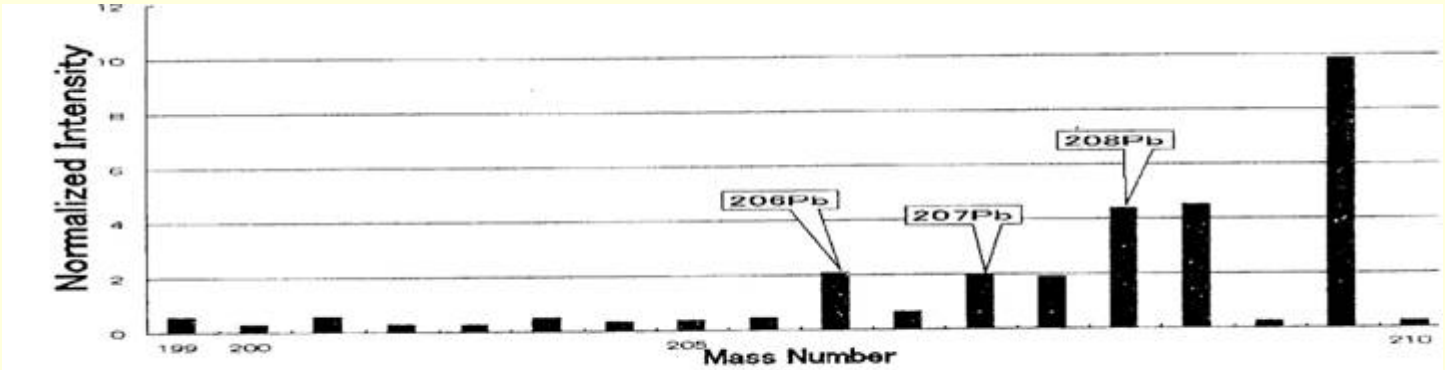
Yamada, H. et al., "Production of Ba and several Anomalous Elements in Pd under light Water Electrolysis," *ICCF-9*, Tsinghua University, Beijing, China, p. 123, May 19-24 (2002).

- Electrodes
  - Cathode (Pd)
  - Anode (Pt)
- Electrolyte
  - 0.5 M Sodium Sulfate
- Parameters
  - Current: 0.5 A, Time: 7-14 days
- Results
  - Transmutation Products: Li, B, Mg, Al, K, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ba, Pb
  - Excess power of up to 9% observed

Yamada, H. et al., "Production of Ba and several Anomalous Elements in Pd under light Water Electrolysis," *ICCF-9*, Tsinghua University, Beijing, China, p. 123, May 19-24 (2002). – contd.



TOF-SIMS spectrum for Pd after electrolysis.



TOF-SIMS spectrum for Pd after electrolysis.

Yamada et al., "Analysis By Time-Of-Flight Secondary Ion Mass Spectroscopy For Nuclear Products In Hydrogen Penetration Through Palladium", ICCF10 (2003).

- Electrodes
  - Cathode (Pd)
  - Anode (Pt)
- H2 Gas Loading
- Parameters
  - Temp: 400C, Time: 2 weeks
- Results
  - Transmutation Products: Ti, Cr, Mn, Fe, Ni, Cu, Ag, V,Co
  - Change in Isotopic Distribution – Ag, Fe, Cu, Cr

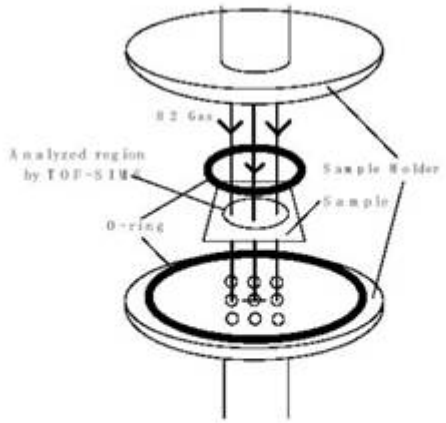
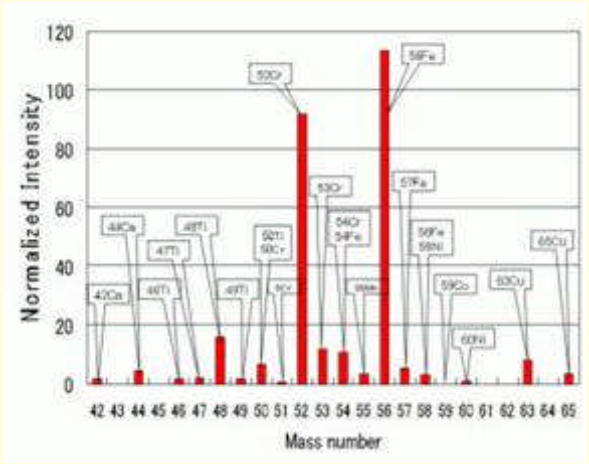
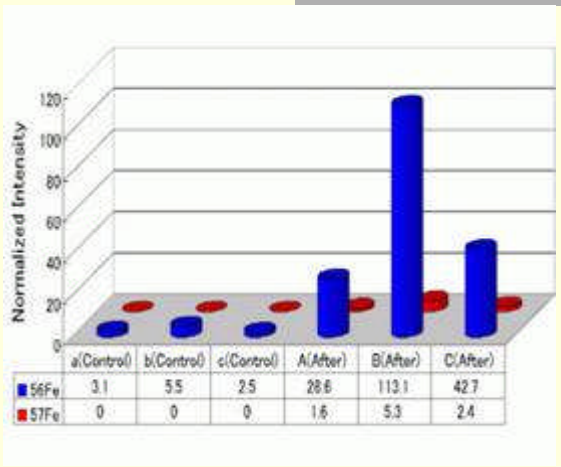
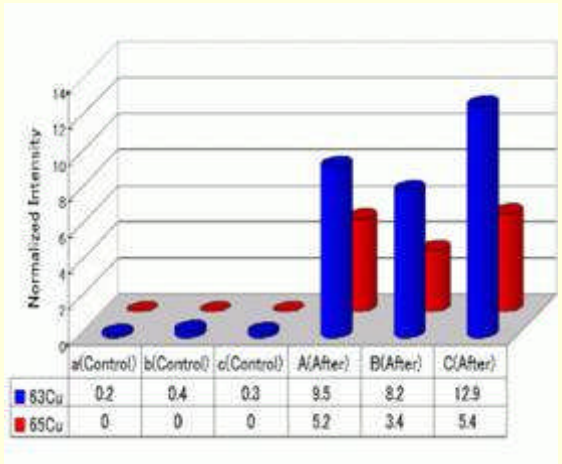


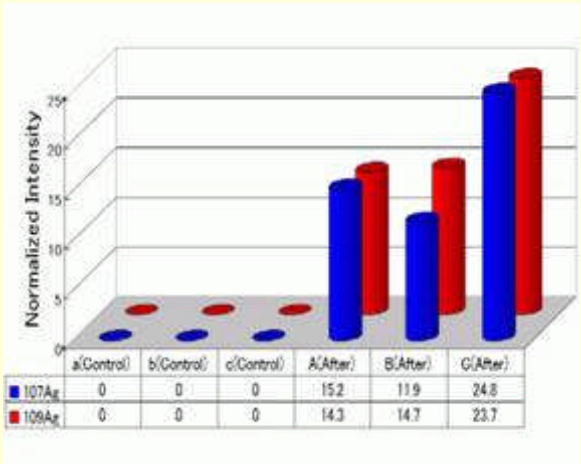
Fig. 1 Sample holder. Hydrogen flows from upper chamber to lower chamber by penetrating the Pd sample.

Yamada et al., "Analysis By Time-Of-Flight Secondary Ion Mass Spectroscopy For Nuclear Products In Hydrogen Penetration Through Palladium", ICCF10 (2003). – contd. The figures show transmutation elements and the isotopic distribution.





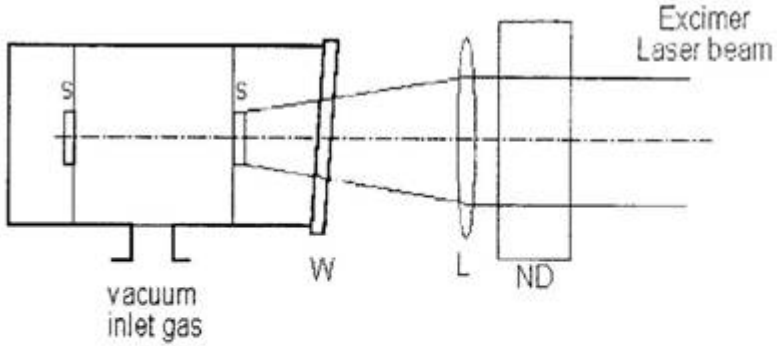




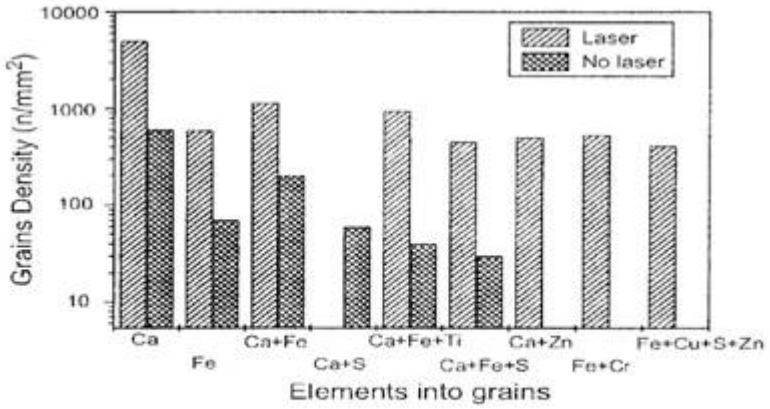
DiGiulio et al., "Analysis of nuclear transmutation observed in D- and H- loaded Pd films," *Intrn'l J. Hydrogen Energy*, 27, p.527-531 (2002).

- Electrodes
  - Cathode (Pd)
  - Anode (Pt)
- H2/D2 Gas Loading
- Processed by excimer laser
- Results
  - Transmutation Products
    - Mg, Cl, Fe, Al, Ca, K
    - More transmutation products in H2 than D2 system

DiGiulio et al., "Analysis of nuclear transmutation observed in D- and H- loaded Pd films," *Intrn'l J. Hydrogen Energy*, 27, p.527-531 (2002). - contd.



Experimental set-up for laser irradiation. ND: Neutral density filters; S: sample, W: window; and L: convergent lens.



Histogram showing the density of grains as a function of detected elements both for laser and non-laser films.

Sample characteristics, processing parameters and main morphological and analytical results

Sample characteristics, processing parameters					Morphological and analysis results										
Chamber	Sample	Silicon surface	Loading gas	Laser treatment	Island dimension (μm)	Grain density (n/mm^2)	Grain dimension (μm)	New elements found							
T	26	Rough	D_2	Yes	—	—	—								
T	27	Rough	D_2	No	—	—	—								
F	28	Rough	H_2	Yes	—	—	—								
F	22	Rough	H_2	No	—	—	—								
A	24	Smooth	D_2	Yes	10	10	1.7 ± 0.3	Ca	Fe						
A	25	Smooth	D_2	No	7	10	1.7 ± 0.3	Ca	Fe						
B	23	Smooth	H_2	Yes	15	10^4	3.6 ± 1.5	Ca	Fe	S	Zn	Ti	Cu	Cr	
B	29	smooth	H_2	No	10	10^3	1.6 ± 0.5	Ca	Fe	S	Ti				

III -- Proposed Theories, Proton Reactions – the huge reaction barrier problem

- Most of the focus of theoreticians has been on d-d reactions; however specific p-metal theories include:
  - Fisher, Neutron Cluster
  - Kozima, Free Neutron Reactions
  - Takahashi, Multi Photon and Fission
  - Chubb, R Matrix Theory
  - Mills – Shrunken Hydrogen
  - Stoppini, Electron – Proton Capture
  - Dufour, Proton/Deuteron Clusters
  - Miley, Virtual Neutron and Clusters

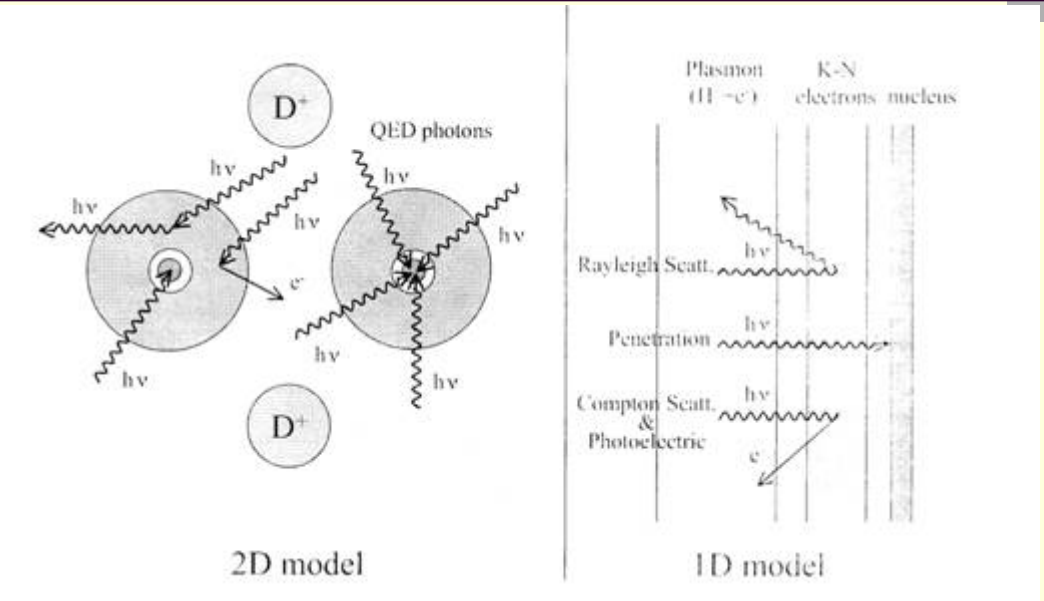
Neutron Cluster

- Neutron aggregates (size exceeding 6 neutrons) also termed polyneutrons, neutron droplets
- These complex are bound and stable
- Strong against decay
- Strong binding energy causes pairing analogous to electron pairing in superconductivity
- This theory supports their finding of shower of about 250,000 energetic charged particles in vapor of oxygen and hydrogen evolved from electrolysis (reported in ICCF 10, 2003)

Free Neutron Cluster

- It is proposed that “cf-matter” is formed when there are neutron valence bands mediated by hydrogen isotopes in transitional metal hydrides/deuterides and proton conductors where hydrogen isotopes are in state with extended wave functions
- Cold Fusion Phenomenon (CFP) seen in the LENR is a low energy version of nuclear processes occurring in stars.

Multi Photon and Fission



- Based on assumption that high flux photons (0.1-50 keV) are generated in metal-hydrides lattices
- Quantum electrodynamics (QED) photons causes Pd nucleus to achieve multiphoton-E1 absorption and leads to low energy photofissions. (See Figure above).
- However the role of PdHx(Dx), dynamics (plasmon), i.e. the coupling of QED photons and nuclear excitation, is not yet clear.

R-Matrix Theory

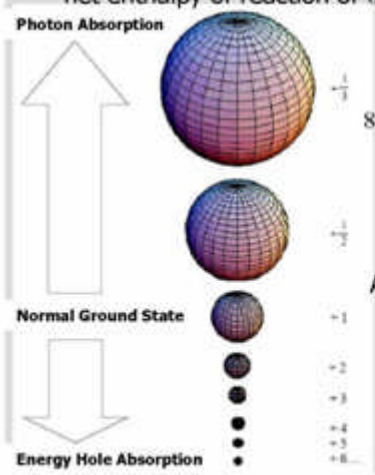
- All the reaction rate, energy transfer occur through a standard many-body physics procedure.
- A mechanism is proposed for LENRs to proceed without emission of high energy particles.
- The general model clarifies the origin of coherent processed that initiate LENR's, through the onset of ion conduction that can occur through ionic fluctutations in nanoscale crystals.

Shrunken Hydrogen

The Theory Predicts Catalysts that Allow Energy to be Extracted from a Hydrogen Atom

Hydrogen electrons are stimulated to a fractional quantum state by the presence of a catalyst with a net enthalpy of reaction of $m \cdot 27.2\ eV$.

A catalytic system is provided by the ionization of t electrons from an atom each to a continuum energy level such that the sum of the ionization energies of the t electrons is approximately $m \cdot 27.2\ eV$, where m is an integer. One such catalytic system involves potassium. The first, second, and third ionization energies of potassium are $4.34066\ eV$, $31.63\ eV$, $45.806\ eV$ respectively. The triple ionization $(t=3)$ reaction of K to K^{3+}, then, has a net enthalpy of reaction of $81.7426\ eV$, which is equivalent to $m=3$.



$$81.7426\,eV + K(m) + H\left[\frac{a_H}{p}\right] \rightarrow K^{3+} + 3e^- + H\left[\frac{a_H}{p+3}\right] + \left[(p+3)^2 - p^2\right] \times 13.6\,eV$$

$$K^{3+} + 3e^- \rightarrow K(m) + 81.7426\,eV$$

And, the overall reaction is:

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+3)}\right] + \left[(p+3)^2 - p^2\right] \times 13.6\,eV$$

Electron Capture

Based on three main points

- Possibly a high H concentration causes clusters of several H atoms to form around atoms of lattice
- Possibility that plasma oscillations entangle electrons of the plasma that will fall toward the nucleus suffering local acceleration and then nuclear capture
- The possibility that a fast rate electron capture gives rise to neutron cluster that, inside the lattice, produce anelastic nuclear reactions fusions for low (A,Z), and fissions for high (A,Z)

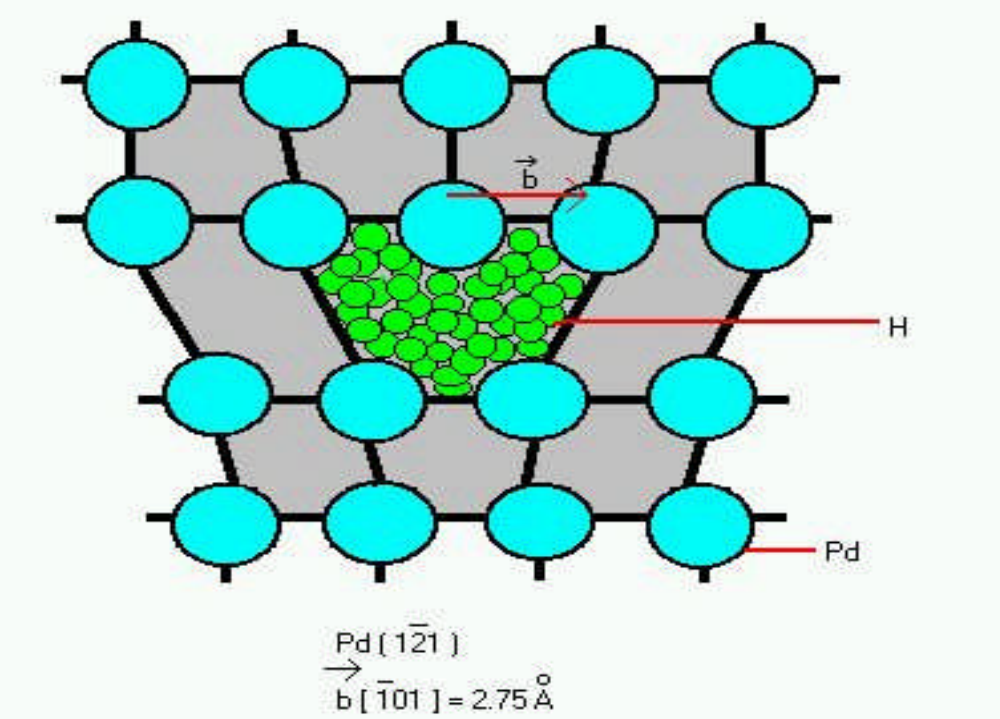
Proton/Deuteron Cluster

- “Hydrex” and “Deutex” – metastable state of hydrogen are formed when hydrogen/deuteride are contacted with metals.
- These when submitted to the action of a magnetic field transmutation and excess heat results due to “nucleon capture” by the Hydrex/Deutex.
- Hydrex are small and permanent dipole, hence can reach very close (few fm) vicinity of a “Partner Nucleus” resulting in local decrease of Coulomb barrier and overlapping of nuclear wave functions

Cluster formation via virtual neutrons

Squid measurements on Pd targets have confirmed dislocation loop loading with utra-high density of hydrogen-clusters which form a local superconducting state. [Lipson, et al., J of Physics of Condensed Matter: "Emergence of a High Temperature Superconductivity in Hydrogen Cycled Pd compounds as an Evidence of Super-dense H/D Sites"]

Schematic of edge dislocation core in Pd with Hn-condensed hydrogen phase



IV -- Conclusions

- The large data base supports the hypothesis that LW LENR exists and is quantitatively different from HW LENR – DD reactions are thought to occur while pp are very unlikely, forcing some p (or n) -metal type reaction
- Data gives a strong case of modest excess heat with properly designed LW cells.
- There is an equally strong case for transmutations in LW cells
- The correlation of the two, following nuclear reaction energy balances, seems likely, but only roughly demonstrated in a few cases
- Innovative theories exist that overcome the objections to LW reactions, but as in HW LENR, none have been clearly benchmarked against a definitive experiment.

Possible answers to original questions

- Are proton reactions possible? (Is there more to cold fusion than D-D?) – much data says “yes”.
- Is H loading the key parameter for driving reactions? – unclear = virtually no studies of this for LW. As in HW, localized loading may be more crucial??
- Significance of heavy water in light and visa versa? – does not appear to explain phenomena.
- Is heat correlated to transmutations in LW LENR?
  - Do transmutation products satisfy energy balance, i.e. replacing He4 in heavy water studies? – very limited data suggests “yes”– would seem logical. The issue is whether or not reactions other than transmutations are producing heat also.
- Reaction mechanism ??(extremely large columbic repulsion – overcome by shielding vs neutral particle?) – neutral particle (or equivalent shrunken particle) concepts dominate, but type of particle varies. Issue unresolved.
- Other emissions – chg particles, radiation, …are any unique to light water reactions? While observed, do not seem unique.
- Are there any advantages of LW vs. HW? Not clear – if reaction involved proton state, unique reactions may be possible vs. DD.

  However, both appear to produce heat and transmutations – with D the transmutation may be a “side” reaction vs. the primary with H.

What to do next in LW research??

- Need independent reproduction of one or more of the key experiments reported, esp. unique transmutation products.
- Study energy balance – correlation with products, emission of energetic charged particles and x-rays.
- Systematic study of effects (heat, transmutations, charged particle emissions, x-rays, ..) as function of % D2O in H2O, D2 in H2, including 100%.
- Localized diagnostics during and after runs – understand local site effects. Examples = IR photography, scintillation plates and film, CR-39, SEM, TLD, AFC,
- Develop methods to control local structures – e.g. defect formation, interfaces, ..
- Benchmark theory against key experimental signatures.
- Your suggestions please

Thank You

- For more information, please contact

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  email: ghmiley@uiuc.edu

Also comments and added data for the final write-up would be appreciated.