The Production Of Helium In Cold Fusion Experiments: Research at NAWCWD, China Lake, California (A New Look At The Experimental Data)

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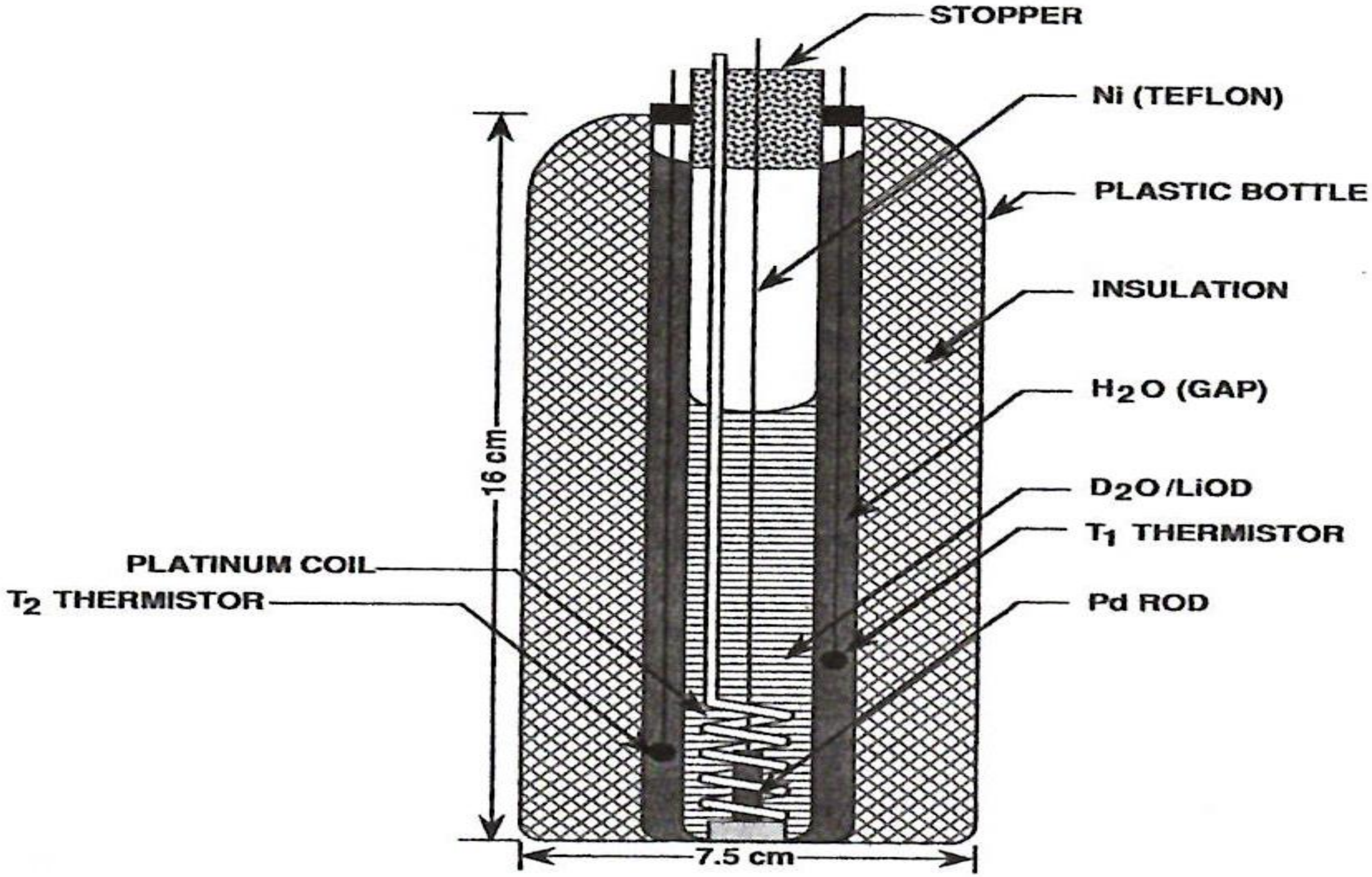
Major Goals For This Presentation

- **Derive** Relationship between Experimental Excess Power and Cell Current and Theoretical Amounts of Helium-4 in Parts-per-billion (ppb).
- **Present** Theoretical Amounts of Helium-4 Expected Based on the Experimental Excess Power and Cell Current With the Assumption of the Fusion Reaction: $D + D \rightarrow He\text{-}4 + 23.8465\ MeV$ (Lattice).
- **Prove** That Atmospheric He-4 Diffusion Into the Glass Collection Flasks Was Not a Factor in the China Lake Experiments.
- **Confirm** The Calorimetric Excess Power Results By the Helium-4 Measurements.
- **Show** That Other Possible Fusion Reactions Do Not Fit as Well With the Experimental
- Data (Predict Higher He-4 Levels).
- **Establish** That Excess Power and Helium-4 Production in Cold Fusion Experiments Are Related Based on 3 Different Sets of China Lake Experiments.

China Lake Calorimetry
(1989 - 1995)

- **Cells A, B, C, D Nearly Identical**
- **Small Glass Test Tubes / 18.0 mL Electrolyte**
- **Heat Integrator / Outer Water Jacket**
- **Insulation ($K_C \approx 0.140\ WK^{-1}$)**



Example For Calorimetric Measurements And Gas Collection Dates
(J. Electroanal. Chem., Vol. 346, 1993, p. 104)

- Calorimetric Cells A and B
- X = Power Out / Electrolysis Power = k ΔT / (E – E_H) I
- (Two Thermistors Used in each Cell)

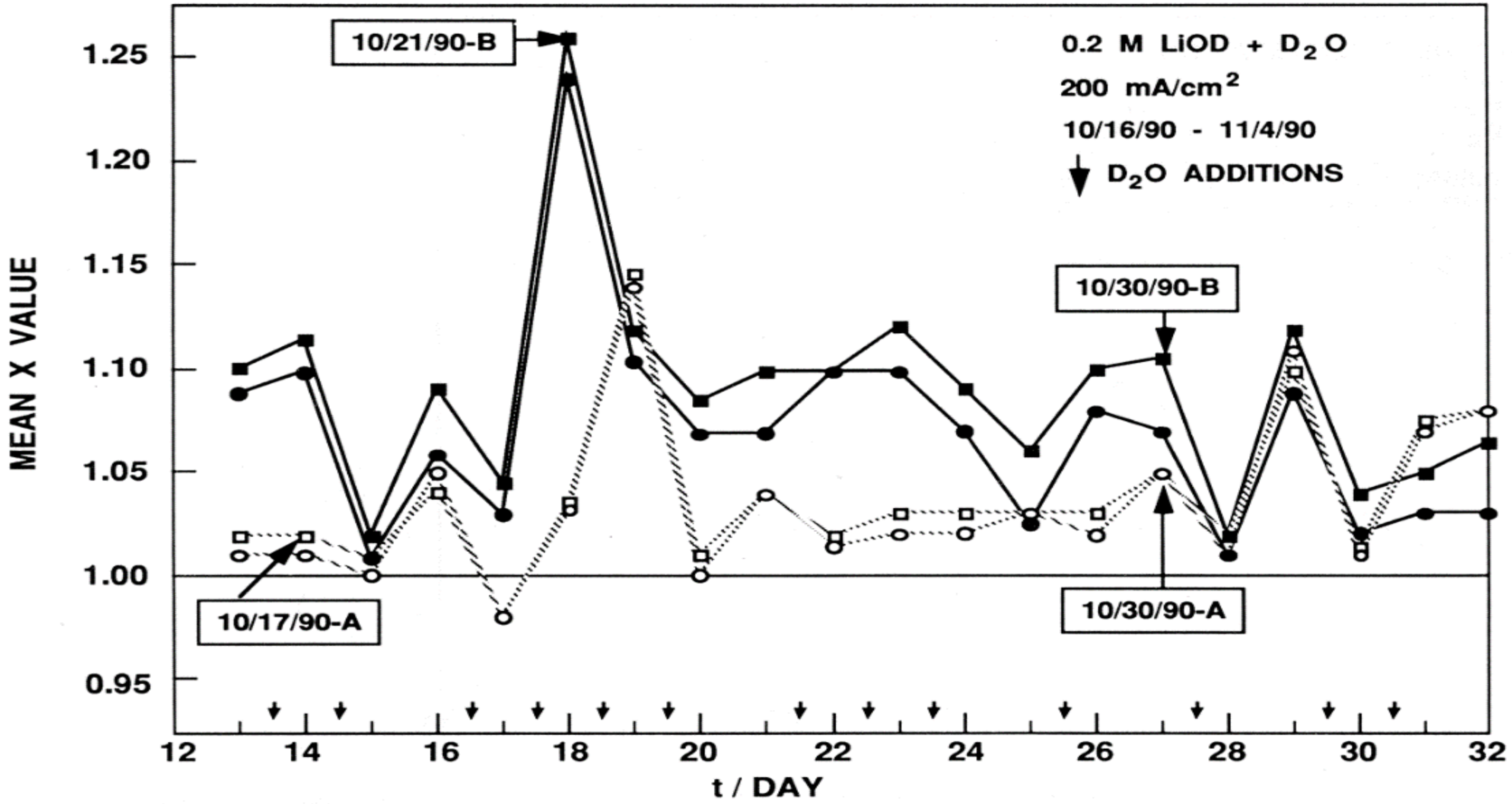


Fig. 3. Calorimetric measurements and effluent gas collection dates in D_2O + LiOD for cell A (○, □) and cell B (●, ■).

Theoretical Calculations Of Expected Helium-4 Amounts
(Based on Experimental Cell Current and Excess Power)

$$D + D \rightarrow He\text{-}4 + 23.85\ MeV\ (Lattice)$$

$$\Delta E = \Delta mc^2 = 23.846478\ MeV$$

$$[(23.85 \times 10^6\ eV/He\text{-}4)(1.602 \times 10^{-19}\ J/eV)]^{-1} = \boxed{2.617 \times 10^{11}\ He\text{-}4/W.s}$$

(J = W.s)

Theoretical Rate of He-4 Production

$$R_1 = (2.617 \times 10^{11}\ He\text{-}4\ /\ W.s)\ [P_X \text{ in } W]$$

Theoretical Rate of D_2 + O_2 Molecules Produced By Electrolysis

$$R_2 = (0.75\ I/F)N_A \qquad \text{(for I in Amps)}$$

Helium-4 Amount

$$\text{Ratio} = R_1 / R_2 = (\text{He-4 atoms} / (D_2 + O_2) \text{ molecules})$$

$$\boxed{\text{He-4 (ppb)} = R_1 / R_2 = 55.91\ (P_X / I) \text{ in ppb}}$$

NOTE: He-4 = 0 ppb IF $P_X = 0$ (See CalTech and MIT publications).

China Lake Results In 1990 / Helium-4 Measured At University of Texas
Excess Power and Helium-4

Theoretical He-4 (ppb) = 55.91 (P_X / I)

Sample	P_x(W)	Theoretical He-4 (ppb)[c]	Measured He-4
12/14/90-A	0.52[a]	44.1	Large Peak
10/21/90-B	0.46	48.7	Large Peak
12/17/90-A	0.40	42.4	Medium Peak
11/25/90-B	0.36	38.1	Large Peak
11/20/90-A	0.24	25.4	Medium Peak
11/27/90-A	0.22	23.3	Large Peak
10/30/90-B	0.17	18.0	Small Peak
10/30/90-A	0.14	14.8	Small Peak
10/17/90-A	0.07	7.4	No Peak
12/17//90-B	0.29[b]	30.7[b]	No Peak

[a]I = 0.660 A. For All Others I = 0.528 A.

[b]Calorimentric Error Due to Low D_2O Solution Level.

[c]University of Texas Detection Limit was About 5 ppb He-4 based on Table.

<u>Publications:</u>   **J. Electroanal. Chem., Vol. 304, 1991, pp. 271-278**
Proceedings of ICCF-2, 1991, pp. 363-372
J. Electroanal. Chem., Vol. 346, 1993, pp. 99-117

<u>Corrections:</u>   **Large / Medium / Small Peaks Differ By Factor of About Three for ppb He-4**
University of Texas Detection Limit For He-4 Was About 5 ppb.

Rate of Atmospheric Helium-4 Diffusion Into The Glass Flasks (Effect of D_2 or H_2 Fill)

Conditions	Laboratory[a]	He-4 Atoms/Day	ppb/Day[b]
Theoretical	q=KxP/d	2.6×10^{12}	0.23
N_2 Fill	HFO	2.6×10^{12}	0.23
N_2 Fill	HFO	3.4×10^{12}	0.30
N_2 Fill	RI	3.7×10^{12}	0.32
D_2+O_2 Fill[c]	RI	$1.82 \pm 0.01 \times 10^{12}$	0.160
D_2+O_2 Fill[d]	RI	$2.10 \pm 0.02 \times 10^{12}$	0.184
D_2+O_2 Fill[e]	RI	$2.31 \pm 0.01 \times 10^{12}$	0.202
H_2 Fill[f]	RI	$1.51 \pm 0.11 \times 10^{12}$	0.132
Vacuum[f]	RI	$2.09 \pm 0.04 \times 10^{12}$	0.183

He-4 Diffusion Rate Slower When Flasks Contain D_2 or H_2
(Outward Diffusion of D_2 Slows Inward Diffusion of He-4)
Flask Storage Time of 28 Days Required to Reach 5 ppb He-4 Detection Limit.
[a]HFO (Helium Field Operations, Amarillo, Texas, [b]Using 1.41×10^{22} $D_2 + O_2$ Molecules per Flask, [c]Glass Flask #5, [d]Glass Flask #3, [e]Glass Flask #4, [f]Both Experiments Used Glass Flask #2.

Second Set of Excess Power and Helium-4 Measurements
(He-4 Measurements By Rockwell International: Brian Oliver)
Error Less Than ± 0.1 ppb

- **Effect of Atmospheric He-4 Diffusion Eliminated**
- **Double Blind Experiments**
- **Most Accurate He-4 Results (but P_X was small)**

Table 3. Results for the Second Set of Experiments (1991-1992)

Sample	P_x (W)	Theoretical He-4 (ppb)	Experimental He-4 (ppb)[c]
12/30/91-B	0.100[a]	10.65	11.74
12/30/91-A	0.050[a]	5.32	9.20
01/03/92-B	0.020[b]	2.24	8.50

[a]**I = 0.525 A**
[b]**I = 0.500 A**
[c]**Reported Rockwell error was equivalent** to ±0.09 ppb

Second Set of Helium-4 Experiments Corrected For Background He-4 (- 4.5 ppb)

Table 4. Results For the Second Set of Experiments With Corrections For the Background Helium-4 (4.5 ppb)

P_X (W)	Theoretical He-4 (ppb)	Corrected He-4 (ppb)	He-4/sW[c]	MeV/He-4[d]
0.100[a]	10.65	7.24	1.8×10^{11}	35
0.050[a]	5.33	4.70	2.3×10^{11}	27
0.020[b] (0.040)*	2.24 (4.47)*	4.00 ———	4.7×10^{11} (2.4×10^{11})*	13 (25)*

[a]I = 0.525 A

[b]I = 0.500 A

[c]Theoretical Value: 2.617×10^{11} He-4/sW

[d]Theoretical Value: 23.85 MeV/He-4

- Possible significant Error For P_X = 0.020 W.s based on He-4 Results.
- Using P_X = 0.040 W yields 2.4×10^{11} He-4 / W.s and 25 MeV / He-4*.

* At low P_X values, He-4 data is likely more accurate than calorimetric Data.

*(P_X = I (4.00) / 55.91 = 0.036 W)

Third Set of Helium-4 Measurements Using Metal Flasks
(He-4 Measurements By U.S. Helium Field Operations Laboratory, Amarillo, Texas)
Error About ±1.3 ppb

Small Excess Power Effects

Table 5. Helium-4 Measurements Using Metal Flasks

Flask/Cell (Date)	P_X (W)	Theoretical He-4 (ppb)	Experimental He-4 (ppb)
3/B (9/13/94)	0.120[a]	13.4	9.4±1.8
2/A (9/13/94)	0.070[a]	7.8	7.9±1.7
2/D 5/30/93)	0.060	8.4	6.7±1.1
3/A (5/31/93)	0.055	7.7	9.0±1.1
4/B (5/21/93)	0.040	5.6	9.7±1.1
1/C (5/30/93)	0.040	5.6	7.4±1.1
1/A (7/7/93)	0.030[a]	3.4	5.4±1.5

[a]I = 0.500 A. For all others I = 0.400 A

Third Set of Helium-4 Experiments Corrected For Background He-4 (-4.5 ppb)
Metal Collection Flasks Used For Gas Samples

P_X (W)	Corrected He-4 (ppb)[a]	Percent of Theoretical %	Electrode Volume (cm^3)	Helium-4 S.W
0.120	4.9	37	0.57	1.0×10^{11}
0.070	3.4	43	0.63	1.1×10^{11}
0.060	2.2	26	0.04	0.7×10^{11}
0.055	4.5	59	0.51	1.5×10^{11}
0.040	5.2	93	0.02	2.4×10^{11}
0.040	2.9	52	0.01	1.4×10^{11}
0.030	0.9	27	0.29	0.7×10^{11}

[a]4.5 ppb subtracted from reported He-4 measurements

Background Helium-4 Measurements Using Metal Flasks (No Excess Power)

- **Main Source of Atmospheric He-4 Was Rubber Vacuum Tube Connectors (Not Glass Cell)**

Electrode	Flask / Cell, (Date)	He-4, ppb	He-4 Atoms / 500 mL
Pd Rod[a] (0.4 x 1.6 cm)	1/C (2/24/93)	4.8 ± 1.1	5.5×10^{13}
Pd-Ag Rod[a] (0.4 x 1.6 cm)	2/D (2/24/93)	4.6 ± 1.1	5.2×10^{13}
Pd Rod[a] (0.4 x 1.6 cm)	3/C (2/28/93)	4.9 ± 1.1	5.6×10^{13}
Pd-Ag Rod[a] (0.4 x 1.6 cm)	4/D (2/28/93)	3.4 ± 1.1	3.9×10^{13}
Pd Rod[b] (0.1 x 1.5 cm)	3/C (7/7/93)	4.5 ± 1.5	5.1×10^{13}
Pd Rod[c] (0.41 x 1.9 cm)	3/D (3/30/94)	4.6 ± 1.4	5.2×10^{13}
(Mean)		(4.5 ± 0.5)	$(5.1 \times 0.6 \times 10^{13})$

Helium Analysis by U.S. Helium Field Operations Laboratories

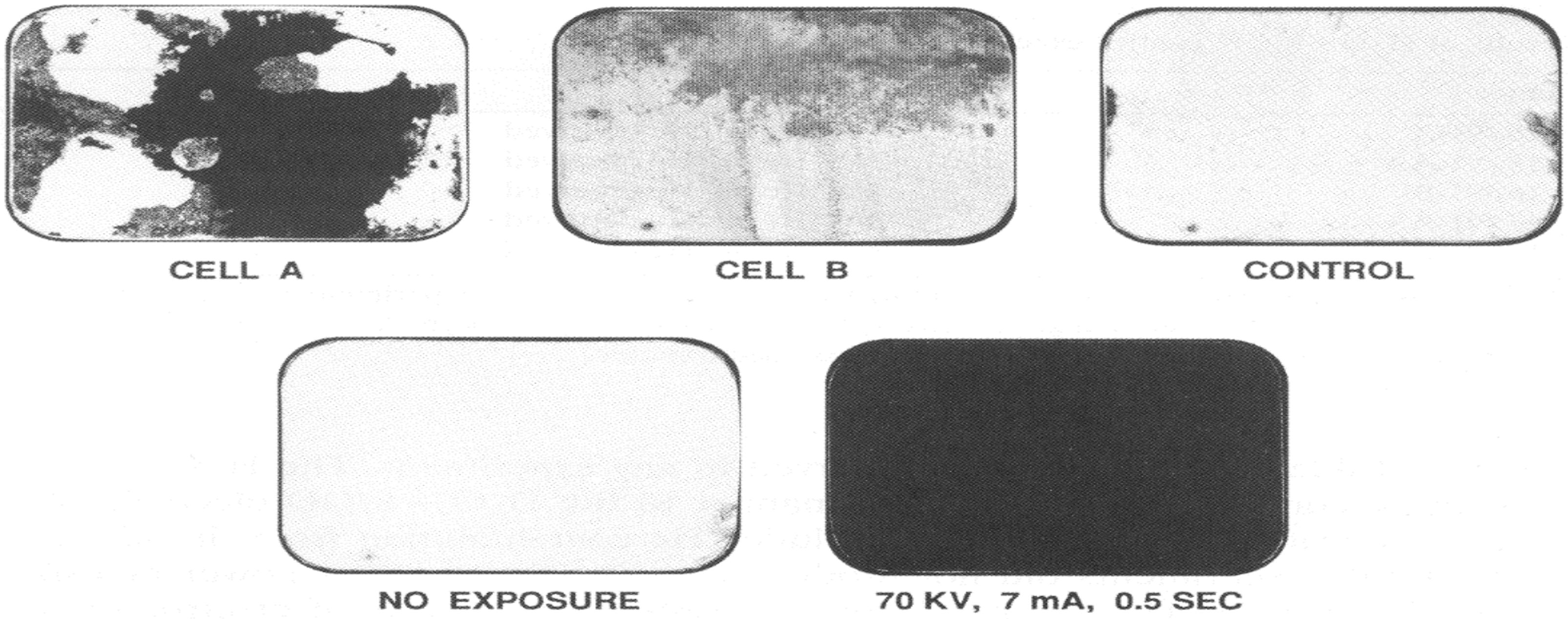
[a] D_2O + LiOD (I = 0.500 A)

[b] H_2O + LiOH (I = 0.500 A)

[c] D_2O + LiOD (I = 0.600 A)

Additional Evidence For A Nuclear Process
(First Set of China Lake Experiments, 1990)

- **Highest Excess Power Measured at China Lake**
- **High Count Rates With a Geiger-Mueller Detector**
- **Dental Film Exposure In Both Cell A and Cell B**



- **Tritium Increased 78% For Cell A and 63% For Cell B (Significant?)**
- **<u>H_2O + LiOH Control</u> No Excess Power, No Helium-4 Production, No High Radiation Count Rates, No Dental Film Exposure.**

See: Correlation of Excess Power and Helium Production During D_2O and H_2O Electrolysis Using Palladium Cathodes", J. Electroanal. Chem., Vol. 346, 1993, pp. 99-117.

Experimental Errors in Excess Power and Helium-4 Measurements (I = 0.500 A)

He-4 (ppb) = 55.91 (P_X / I)

P_X (W)	He-4 (ppb)	He-4 Error (%) [a]	PX Error (%) [b]
0.020	2.24	44.6	100.0
0.050	5.59	17.4	40.0
0.100	11.18	8.9	20.0
0.200	22.36	4.4	10.0
0.500	55.91	1.8	4.0
1.000	111.82	0.9	2.0
5.000	559.10	0.2	0.4
10.000[c]	1118.20[c]	0.1	0.2

[a]Assuming ± 1.0 ppb He-4 error.
[b]Assuming ± 0.020 W Calorimetric error
[c]Most Cells Would Boil before P_X = 10 W

- **Larger excess power results in smaller errors**

NOTE: N. Lewis (CalTech) and D. Albagli (MIT) reported He-4 detection limit of 1 ppm (1000 ppb) in their 1989-1990 publications.

- **He-4 detection limit of 1000 ppb would be useless for these experiments.**

What About Other Possible Fusion Reactions Producing He-4 ? (And No Neutrons)

- **Possible Fusion Reactions**

  I. D + D → He-4 + 23.85 MeV (2.617 x 10^{11} He-4/W.s)

  II. D + Li-6 → 2 He-4 + 22.4 MeV (5.57 x 10^{11} He-4/W.s)

  III. D + B-10 → 3 He-4 + 17.9 MeV (10.46 x 10^{11} He-4/W.s)

- **Compare Best Experimental Result**

  (P_X = 0.100 W, I = 0.525 A, Measured He-4 = 7.2 ppb)

  I. 10.65 ppb He-4 Predicted For 23.85 MeV/He-4 48% High

  II. 22.67 ppb He-4 Predicted For 11.2 MeV/He-4 215% High

  III. 42.57 ppb He-4 Predicted For 5.97 MeV/He-4 492% High

23.85 MeV/He-4 Agrees Best With Experimental He-4 Measurements

Statistical Analysis For All He-4 Experiments At China Lake (NAWCWD)

- **Experiments With <u>No</u> Excess Power And <u>No</u> He-4 Production**

  (12 / 12 Experiments)

- **Experiments With <u>Both</u> Excess Power And He-4 Production**

  (18 / 21 Experiments)

  Three Exceptions: Calorimetric Error (1), Use of Pd-Ce Cathodes (2, 3)

- **<u>Probabilities For Random Disagreements (3 in 33 Experiments)</u>**

  $P_3 = (33!\ /\ 30!3!)(0.512)^{30}\ (0.488)^{3} = 1.203\text{x}10^{-6}$

  $P_2 = 1.221 \times 10^{-7}$

  $P_1 = 8.009 \times 10^{-9}$

  $P_0 = 2.546 \times 10^{-10}$

  $P = P_3 + P_2 + P_1 + P_0 = 1.333 \times 10^{-6} = 1\ /\ 750{,}000$

  (See NAWCWPNS TP 8302, September 1996, Appendix C, p. 92)

Groups Reporting Helium-4 In Electrochemical Experiments

Miles / Bush	1990 / 1991
Bockris	1992
Gozzi	1993
Liaw / Liebert	1993
McKubre / Tanzella	2000
DeNinno / Del Giudice	2000

MORE (?)

See E. Storms, The Explanation of Low Energy Nuclear Reaction, Infinite Energy Press, 2014, pp. 30 – 40.

SUMMARY
Assumption of D + D → He-4 + 23.85 MeV (Lattice)

- **Derived** Relationship: **He-4 (ppb) = 55.91 (P_X / I)** for Theoretical Helium-4 Amount Expected for Experimental Excess Power and Cell Current.
- **Presented** Theoretical and Experimental Helium-4 Amounts (ppb) for Three Sets of China Lake Experiments.
- **Proved** by Various Measurements that Helium-4 Diffusion into the Glass Collection Flasks was not a Factor in the China Lake Experiments.
- **Confirmed** the Calorimetric Excess Power Results by the Helium-4 Measurements (Especially Useful for Small Excess Power Measurements)
- **Showed** That Other Possible Fusion Reactions do **not** Fit as Well with the Experimental Helium-4 Measurements
- **Established** That Excess Power and Helium-4 Production in Cold Fusion Experiments are Related using Statistical Analysis of the Data.

→ Results Also Suggest That Any Power Carried Outside The Cell By γ-Radiation Is NOT Significant.

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