



The Nature and Control of Excess Heat in Electrolytic Cold Fusion Cells

Peter H. Handel

Department of Physics & Astronomy and
Center for Nanoscience, Univ. of Missouri-
St. Louis, MO 63121, USA



- Introduction: Phenomenology of Excess Heat
- Types of Electrolytic Cells Showing Excess Heat
- Thermoelectrochemical,
Thermoelectromechanical Effect
- In Electrons and Out Electrons Differ
- Literature
- Excess Heat Formula vs Experiment
- Discussion
- Conclusions



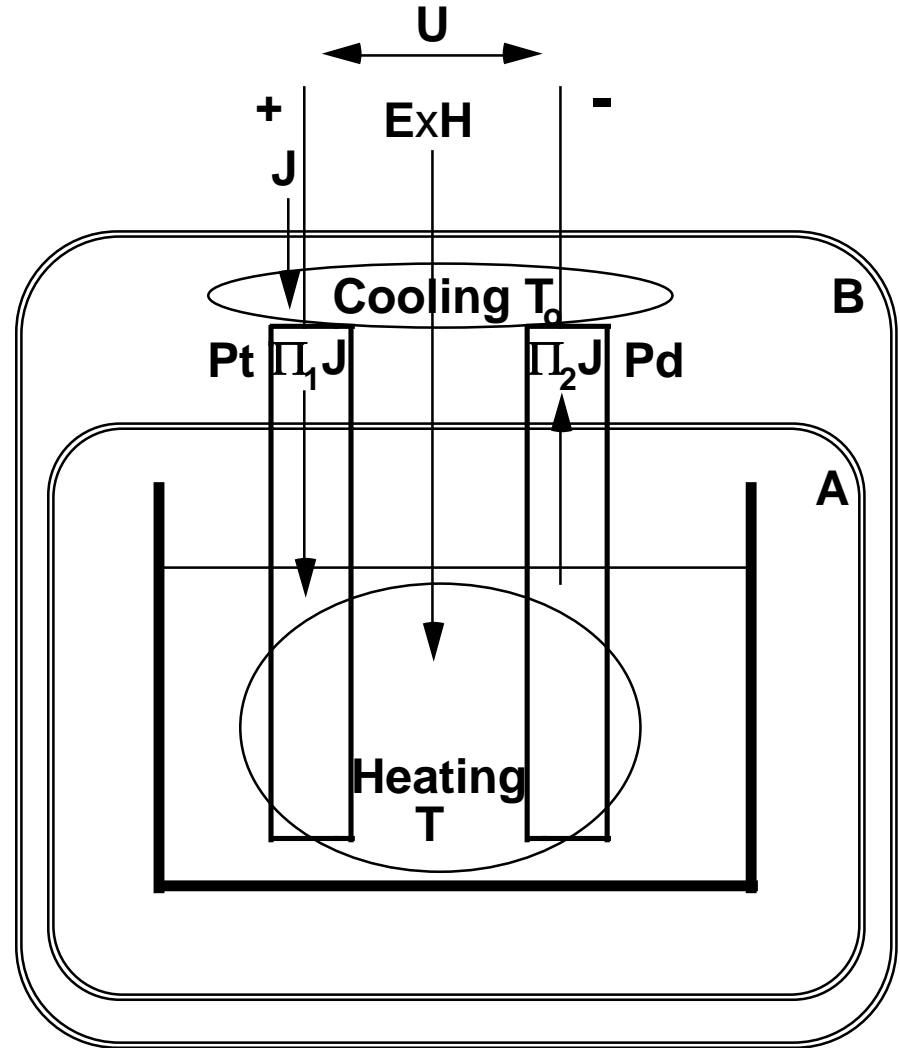
Phenomenology of Excess Heat

- In general, excess heat power is proportional to the current
- Some non-uniformity due to exothermic and endothermic sections of loading characteristic and run-away effects
- Often the excess heat is not observed; Why?

Electrolytic Cell



Thermo-electrochemical effect in a Pt/Pd cell: The work input $UJ = \int \mathbf{E} \times \mathbf{H} da$ and the heat transport ΠJ from the environment into the electrolytic cell. U is the applied voltage, J the current, and $\Pi = \Pi_1 - \Pi_2$ a Peltier coefficient. Excess heat is observed if no enclosure is used, or if enclosure A is used. No excess heat is observed when enclosure B is used, encompassing both the hot and cold source. This helps us understand why many laboratories were unable to reproduce the excess heat.



In Electrons and Out Electrons Differ

Literature



R.T. Schneider and P.H. Handel: "Neutron Emission by Plasma Cavities", *Fusion Technology* 7, 316-319 (1985).

P.H. Handel and R.T. Schneider: "Nature of Resonances Leading to High-Pressure Cavities", *Fusion Technology* 7, 320-324 (1985).



R.T. Schneider and P.H. Handel: "Fusion Reactions in RF Plasma Cavities", Proc. V Topical Conf. on RF Plasma Heating, Madison WI, Febr. 21-23, 1983, p.109-112 (Univ. of Wisconsin Press).

P.H. Handel: "Intermittency, Irreproducibility and the Main Physical Effects in Cold Fusion". Fusion Technology 18, 512-517 (1990).

125. P.H. Handel: "Reformulation of the Cold Fusion Problem: Heterogeneous Nucleation - A likely Cause of the Irreproducibility and Intermittency of Cold Fusion Observations". I. Annual Conf. on Cold Fusion, Salt Lake City, Utah, March 28-31, 1990.

Literature



P.H. Handel: "Subtraction of a New Thermo-Electrochemical Effect from the Excess Heat, and the Emerging Avenues to Cold Fusion", Proc. 4th Conf. on Cold Fusion, Maui, Hawaii, Dec. 1993, Electric Power Research Institute Press, 3412 Hillview Ave., Palo Alto, CA 94304, EPRI TR-104188, (July 1994), Vol. 2, pp. 7-1 to 7-8..

P.H. Handel: "Thermoelectric Excess Heat Effect in Electrolytic Cells", Zeitschr. für Physik B 95, 489-492 (1994).

Heat Charge and Current Density



The energy current density \mathbf{w} and electric current density \mathbf{j} in the electrodes are given by

$$\mathbf{w} = (\Pi - \mu/e)\mathbf{j} - \kappa\nabla T; \quad \mathbf{j} = \sigma\nabla\mu - \sigma S\nabla T,$$

where σ , κ are the electrical and thermal conductivities, μ the electrochemical potential, Π the Peltier coefficient, S the Seebeck coefficient (thermopower) and $e > 0$ the elementary charge⁵⁻⁷.

Types of Cells; Consensus



Types of Electrolytic Cells Showing Excess Heat

- Open Cells: Thermoelectrochemical Effect
- Closed Cells: Thermoelectrochemical Effect
- Cells with Circulating Electrolyte: Thermoelectrochemical Effect & Thermo-Electromechanical Effect
- Theoretical models of the excess heat are no longer encountering the difficulty of explaining the largest excess heat observed experimentally
- Critics ridiculing the experimentalists who reported excess heat had better be looking for explaining the phenomenon
- Understanding the excess heat correctly, unifies the scientific community again

Elementary Derivation of the Thermo-electrochemical Excess



Heat Open Cells

- $U = U_0 + TS + JR + \Delta U$; $U_0 = 1.45 \text{ V}$
- $\Delta W = Jt(U - 1.54 \text{ V}) = \text{net work}$
- $\Delta U = U - JR - 1.54 \text{ V} = \text{Overpotential}$
- The Tafel law in the implicit form given by Erdey-Gruz and Volmer, See Zeitschr. Phys. Chem. **150**, 203 (1930): $j = C\{\exp[-\alpha e\Delta U/kT] - \exp[(1-\alpha)e\Delta U/kT]\} \approx -Ce\Delta U/kT$

$$\eta_1 = W_1/Q_1 = \frac{(T - T_0)\langle S \rangle + JR + \Delta U}{T\langle S \rangle + JR + \Delta U} \quad S = S_1 - S_2$$

$$\varepsilon' = 1/\eta_1 - 1 = \frac{Q_0}{W_1} = \frac{T_0 \langle S \rangle}{T\langle S \rangle + JR + \Delta U} = \frac{T_0 \langle S \rangle}{U - U_0} = (\text{What is there})/(\text{what should be there})$$

be there). **Thermo-electrochemical Effect**

In the limit of small current densities (ΔU and JR negligible), and small temperature differences $T-T_0$, *the excess heat fraction ε' goes to infinity.*

$$\varepsilon'_{\text{reversible}} \rightarrow \infty \quad \text{for } T \rightarrow T_0.$$

Note that, ignoring the existence of the thermo-electrochemical effect introduced in this paper, this infinite *excess heat per Coulomb* of electricity transported could have been attributed to nuclear reactions by default, as long as no other explanations for its existence were available. Its cumulative amount *is once more infinite* when the amount of charge allowed to pass through the cell goes to infinity. This is the suspect excess heat fraction on which the scientific community was focusing, with a controversial, less objective, but very divisive effect.

Discussion



In the case of closed cells the gases released in electrolysis recombine catalytically in the cell, and the work $W=W_1+U_0Jt=UJt$ as well as the heat $Q=Q_1+U_0Jt$ released into the calorimeter will now include the corresponding energy of recombination U_0Jt . Therefore, one is tempted to define closed cell thermo-electrochemical excess heat fraction as

$$\varepsilon_2 = \frac{Q_0}{W} = \frac{T_0 \langle \bar{S} \rangle}{U} = \frac{T_0 \langle \bar{S} \rangle}{T_0 \langle \bar{S} \rangle} = (\text{What is there}) / (\text{what should be there}).$$

This expression remains finite even in the limit of small currents and temperature differences, because the “what should be there in the calorimeter” term was increased by definition by a finite amount, that is actually recoverable, replacing the more logical “what should be there over and above the recoverable amount that’s available in the oxygen and hydrogen generated by the cell”. If we recover the energy of these gases, e.g, in a fuel cell, ε' proves to be the true measure of the excess heat, while ε_2 is a fake measure.

Indeed, one could feed back the energy obtained from the gases into the power plant supplying the incoming energy UJt , which reduces the denominator of Eq. (7) for ε_2 to the denominator of Eq. (6) and (6') for ε' . Note that ε_2 is much smaller than ε' only because U_0 is very large, which has nothing to do with the absolute value of the "excess heat" $Q_0 = T_0 \langle S \rangle Jt$, or with its relative value ε' , correctly evaluated only in Eqs. (6) and (6'). The excess heat fractions are calculated in Table I for three examples of cells at $j = 100 \text{ mA/cm}^2$.

Table 1

Cell Electrodes	T °K	T ₀ °K	S ₁ μV/K	S ₂ μV/K	<S> μV/K	Π mV	ΔU+JR mV	ε' %
I. 1)Pt ; 2)Pd	301	299	-5.14	-10.7	5.56	1.666	<u>2.96</u>	
II. 1)Fe; 2)Ni	301	299	15	-19.4	34.4	10.3	30	<u>34.3</u>
III. 1)Pt; 2)Ni	301	299	-5.14	-19.4	13.9	4.28	16	<u>26.7</u>

Table 1.: Thermo-electrochemical excess heat for Pt/Pd, Fe/Ni and Pt/Ni cells.

Discussion



Comparing with the experiments, we note the similarity between the data for the 0.1x10 cm rods presented by Pons and Fleischmann¹, and data one would expect from the thermo-electrochemical effect introduced in this paper. In Table 2 below we list the current densities j , the measured excess heat percent ε' , the corresponding cell voltages U implied by the latter, and the effective Peltier coefficient $\Pi = T_o \langle S \rangle = (U - U_o) \varepsilon' / 100$ obtained from Eq. (6) above.

Table 2

Current Density j mA/cm ²	Excess Heat ¹ ε' %	Cell voltage U V	Eff. Peltier Coefficient $\Pi = T_o \langle S \rangle$ mV
8	23	3.22	390
64	19	3.65	390
512	5.5	8.9	400

Table 2.: Measured¹ values of the excess heat percent and cell voltage for various current densities, indicate the presence of a constant effective Π .

Discussion



A considerable increase of Π may be due to the presence of impurities in the electrode materials, for example, hydrogen in Pd. Another source of an increased coefficient is the possible connection of the Pt lead to a copper wire before it leaves the calorimeter together with the Pd lead. Copper has a positive Seebeck coefficient which yields a larger difference $S=S_1-S_2$. Direct measurement of the effective S and Π is the best method of accounting for the thermo-electrochemical effect.

The proportionality of excess power with the constant current applied to the cell is evident in most if not all excess heat measurements to date. An example is on page 15 of the last Cold Fusion Conference Proceedings⁹, which allows to define $\Pi = 150 \text{ mV/K}$. ***More research is needed to practically separate the real fusion heat, if present, in all past experiments.***

Conclusions



- Open Cells: Subtract Thermoelectrochemical Effect
- Closed Cells: Subtract Thermoelectrochemical Effect
- Cells with Circulating Electrolyte: Subtract Thermoelectrochemical Effect & Thermo-Electromechanical Effect
- Theoretical models of the excess heat are no longer encountering the difficulty of explaining the largest excess heat observed experimentally
- Critics ridiculing the experimentalists who reported excess heat had better be looking for explaining the phenomenon: Huizenga
- Understanding the excess heat correctly, unifies the scientific community again
- Legitimate Field of Science, From Now on Recognized
- Better Funding Needed Urgently