



## NOTES ON TWO PAPERS CLAIMING NO EVIDENCE FOR THE EXISTENCE OF EXCESS ENERGY DURING THE ELECTROLYSIS OF 0.1 M LiOD/D<sub>2</sub>O WITH PALLADIUM CATHODES

A problem popularly known as “cold fusion” was brought, although in an unusual way, to the attention of the scientific community. Although much discussion was (and is still) devoted to whether this effect is connected with any *known* nuclear reactions, the latter being widely questioned, there is no doubt that the general interest in the problem was provoked by the claim of the possibility of producing excess energy, i.e., energy surmounting the energy breakeven value. Unlike the clearly negative indications so far in terms of known nuclear processes taking place, however, careful analysis reveals that the claims in the principal negative papers published so far with respect to the existence of excess energy are in disagreement with the raw experimental data whenever such is presented in those papers. This is very surprising indeed in view of the wide publicity these negative results have been given. An example of an improper analysis of their own experimental data by the authors is Ref. 1, which we have already discussed.<sup>2</sup> Other examples of inappropriate method and improper interpretation of their own experimental data are Refs. 3 and 4.

For convenience, denote by A the palladium/platinum (Pd/Pt) circuit working alone, that is, in the *absence* of a working resistor heater, and denote by B the combination of the Pd/Pt circuit working *together* with a resistor heater. Define  $E_A$  and  $E_B$  as the cell voltages of systems A and B,  $E_m$  as the thermoneutral voltage corresponding to temperature  $T_1$ ,  $P_h$  as the resistor heater power, and  $\alpha(I_A)$  and  $\alpha(I_B)$  as the *possible* excess powers  $\alpha(I)$  produced by systems A and B, respectively, corresponding to the electrolysis currents  $I_A$  and  $I_B$  flowing through the Pd/Pt circuits of systems A and B.

In Refs. 3 and 4, to decide whether or not excess energy exists, electrolysis of D<sub>2</sub>O was carried out with a palladium cathode and a platinum anode in the absence (case A) and the presence (case B) of a working resistor heater in the electrolysis cell, the temperature of the cell in both cases being maintained the same. This method leads to the following pairs of experimental data (see, e.g., Table 3 of Ref. 3, data couples

A through E): time of electrolysis (in case A and in case B), current ( $I_A$  and  $I_B$ ) or current density, electrolysis power ( $P_A$  and  $P_B$ ), heater power (0 and  $P_h$ ), total power [ $P_{tot(A)} = P_A$  and  $P_{tot(B)} = P_B + P_h$ ], temperature of the electrolysis cell [ $T_{c(A)} = T_{c(B)}$ ], and heating coefficient ( $HC_A$  and  $HC_B$ ), which is calculated on the basis of the data for the temperature of the cell  $T_c$ , temperature of the bath  $T_b$ , and total power  $P_{tot}$  [ $HC = (T_c - T_b)/P_{tot} = \Delta T/P_{tot}$ ].

During isothermal calorimetry, according to Newton's cooling law in its general form,

$$P = AK(T_{cell} - T_{sur}) = AK\Delta T, \quad (1)$$

the heating coefficient  $HC = \Delta T/P$  is given by

$$\frac{\Delta T}{P} = \frac{1}{AK}, \quad (2)$$

where

$P$  = power input to the calorimeter or cell (output from calorimeter to the surroundings)

$A$  = Newton's cooling constant

$K$  = heat capacity of the calorimeter

$T_{cell}$  (or  $T_c$ ) = temperature of the calorimeter

$T_{sur}$  = temperature of the surroundings =  $T_{bath}$  or  $T_b$ .

If during the electrolysis of D<sub>2</sub>O, in addition to the electrical power  $P_A$  and  $P_B$  for the electrolysis, some other power  $\alpha(I_A)$  and  $\alpha(I_B)$  would have contributed to the temperature increase, then from Eq. (2) for system A [when  $P = P_A + \alpha(I_A)$ ],

$$\frac{\Delta T}{P_A + \alpha(I_A)} = \frac{1}{AK} \quad \text{or} \quad \frac{\Delta T}{P_A} = \frac{1}{AK - \frac{\alpha(I_A)}{\Delta T}}, \quad (3)$$

and for system B, if the power of the resistor heater  $P_h$  is additionally considered [ $P = P_B + P_h + \alpha(I_B)$ ],

$$\frac{\Delta T}{P_B + P_h + \alpha(I_B)} = \frac{1}{AK} \quad \text{or} \quad \frac{\Delta T}{P_B + P_h} = \frac{1}{AK - \frac{\alpha(I_B)}{\Delta T}}. \quad (4)$$

If only the resistor heater remains working in case B (this common case, disregarded in Refs. 3 and 4, we denote differently from A and B as  $A_0$ ), then instead of Eq. (4), Eq. (2) would be valid:

$$\Delta T/P_h = 1/AK \quad \text{or} \quad AK = P_h/\Delta T .$$

In case  $A_0$ ,  $\Delta T$  (equal to  $\Delta T$  in case A) and  $P_h$  (the resistor power value necessary to maintain the same difference  $\Delta T = T_c - T_b$ ) are directly observable quantities. Thus, when  $P_A$ ,  $\Delta T$ , and  $AK$  obtained with systems A and  $A_0$  are known, the value of the excess power  $\alpha(I_A)$ , if any, can easily be determined according to Eq. (3), and conversely, if no  $\alpha(I_A)$  was produced, this also can easily be determined for sure.

However, in Refs. 3 and 4, case A, in which  $\alpha(I_A) > 0$  is sought, is not juxtaposed with case  $A_0$ , in which only the resistor works in the electrolysis cell and it is *guaranteed* that  $\alpha(I) = 0$ . In Refs. 3 and 4, case A is juxtaposed with case B in which, as in case A, the same quantity  $\alpha(I_B)$  is also to be determined since a Pd/Pt electrode is used in case B as well as in case A and in which Eq. (4), similar to Eq. (3), is used and not Eq. (2). As is seen, during what would be a proper juxtaposition of system A with system  $A_0$ , the quantity  $HC$  in Eq. (2) ( $HC = \Delta T/P = 1/AK$ ) enables one to definitively answer the question as to whether excess power  $\alpha(I)$  is obtained during the electrolysis of  $D_2O$  and, if any, what its quantity is. On the contrary, during the juxtaposition of system A with system B, accepted in Refs. 3 and 4, Eqs. (3) and (4) are obtained, comprising a system of two equations with three unknowns (and that only if the product  $AK$  is observed as a single quantity). This shows that when the particular method in Refs. 3 and 4 is applied, it is not possible to judge the value of  $\alpha(I)$  from the data for the quantity  $HC$  [i.e., the data for the left sides of Eqs. (3) and (4) referring to  $HC$ ]. There is, however, a way to use Eqs. (3) and (4) (referring to  $HC$ ) even after finding out the obvious uselessness of  $HC$  for the purpose of determining excess energy. After some algebraic operations from Eqs. (3) and (4), Eq. (5) is obtained:

$$\frac{1}{AK - \frac{\alpha(I_A)}{\Delta T}} - \frac{1}{AK - \frac{\alpha(I_B)}{\Delta T}} = \frac{\Delta T}{P_A} - \frac{\Delta T}{P_B + P_h}$$

or

$$\alpha(I_A) - \alpha(I_B) = \Delta\alpha(I) = P_B + P_h - P_A$$

or

$$\alpha(I_A) - \alpha(I_B) = \Delta\alpha(I) = P_{tot(B)} - P_{tot(A)} , \quad (5)$$

where  $P_{tot(A)}$  and  $P_{tot(B)}$  are the total power in cases A and B. The pairs of  $HC$  given in Refs. 3 and 4, however, are not needed to obtain Eq. (5); it is enough only to observe the very pairs of total powers themselves. One can compare the measured total power of system A,

$$P_{tot(A)} = I_A(E_A - E_{in}) , \quad (6)$$

with the corresponding total power of system B,

$$P_{tot(B)} = I_B(E_B - E_{in}) + P_h , \quad (7)$$

as the same temperature  $T_1$  is maintained in both cells. Further, as systems A and B maintain the same temperature  $T_1$  in the cell, we may write

$$P_{tot(B)} + \alpha(I_B) = P_{tot(A)} + \alpha(I_A) , \quad (8)$$

or, substituting Eqs. (6) and (7) in Eq. (8),

$$I_B(E_B - E_{in}) + P_h + \alpha(I_B) = I_A(E_A - E_{in}) + \alpha(I_A) . \quad (9)$$

From Eq. (9), one obtains

$$\begin{aligned} I_B(E_B - E_{in}) + P_h - I_A(E_A - E_{in}) \\ = P_{tot(B)} - P_{tot(A)} = \alpha(I_A) - \alpha(I_B) = \Delta\alpha(I) . \end{aligned} \quad (10)$$

It is Eq. (10), identical to Eq. (5), on which the analysis of whether excess energy exists or not has to be based because from the data in Refs. 3 and 4, it is in fact only  $\Delta\alpha(I)$  and not  $\alpha(I_A)$  and/or  $\alpha(I_B)$  that the authors' method can ensure and on which the authors rely entirely when drawing their conclusion of "no evidence" for excess power (enthalpy<sup>3,4</sup>). The authors consider that they have experimentally found this  $\Delta\alpha(I)$  to be negligible (within their experimental error limits). Therefore, according to these authors, the two terms on the left side of Eq. (10) are said to be in agreement. They consider this agreement to be the ultimate proof for the nonexistence of excess power.

However, this conclusion is incorrect because even if  $\Delta\alpha(I)$  were zero, it still would leave the question of the existence of excess power undetermined. The result  $\Delta\alpha(I) = \alpha(I_A) - \alpha(I_B) \approx 0$  (within the error limits) is sure proof that  $\alpha(I_A) \approx \alpha(I_B)$ , but not that  $\alpha(I_A) \approx 0$  and  $\alpha(I_B) \approx 0$ . The truth is that when  $\Delta\alpha(I) = \alpha(I_A) - \alpha(I_B) \approx 0$ , the quantities  $\alpha(I_A)$  and  $\alpha(I_B)$  are unknown. This result also shows that the calibration procedure applied in Refs. 3 and 4 is inappropriate—in effect, two unknown quantities are compared.

The method in Refs. 3 and 4 is unable to answer whether  $\alpha(I_A)$  and  $\alpha(I_B)$  were actually produced in the  $D_2O$  cell and, if they were, of what order of magnitude they might be. Therefore, to understand whether there really was any  $\alpha(I)$  in Refs. 3 and 4, we must somehow rely only on the available data in those papers and compare them with the data from previous studies. Since the experiments in Ref. 3 (and Ref. 4) are "[i]n response to claims . . ." in Ref. 5, it is quite natural to refer the considerations mentioned to the latter studies. Let us see whether the only available data in, e.g., Ref. 3 concerning excess power, namely, the data for  $\Delta\alpha(I)$ , are in agreement with similar data in Ref. 5. From the data in Table 1 of Ref. 5 is seen that for a palladium cathode of 0.079-cm<sup>3</sup> volume (similar to the palladium cathode volume of 0.073 cm<sup>3</sup> in Table 3 of Ref. 3; note that although the correct comparison is at similar *volumes*, a similar conclusion is obtained when data at similar cathode diameters are compared) and for a similar current (a comparison at similar currents is the correct one; however, a comparison at similar current densities gives similar results!) range, an eightfold change of electrolysis current brings 0.0715 W of excess power. Therefore, since the excess power in Table 1 of Ref. 5 is at least proportional to the current density, 1.2 to 1.5 times the applied current, which is typical for Ref. 3, should be expected to bring 0.01 W of excess power. Let us compare this expected value of excess power according to Ref. 5 with the data in Ref. 3. From Table 3 of Ref. 3, the quantity  $\Delta\alpha(I) = P_{tot(B)} - P_{tot(A)}$  can be found in five separate cases, and the values are, indeed, of the order of 0.01 W. The 0.01-W value may seem to be a small number. The authors of Ref. 3 even consider it within the error limits. There is, however, no more to be expected if their data are to reproduce those in Ref. 5, despite the authors' impression. The results in Ref. 5 are even more impressive when one considers that the  $\Delta\alpha(I)$  is only

a part of the real amount of excess power that might have been produced in the D<sub>2</sub>O cell.

This discussion shows that the experimental results in Ref. 3 (similar arguments can be given for Ref. 4) replicate rather than disprove the calorimetric findings in Ref. 5. The latter conclusion, however, is insufficient to provide a *decisive* answer in Refs. 3 and 4 to the question of whether  $\alpha(I)$  is real or not.

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