

## THE PRESENT STATUS OF RESEARCH IN COLD FUSION

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### EDITORIAL NOTE:

Martin Fleischmann has recently been asked by the Royal Society of Chemistry to give an account of the II Annual Conference on Cold Fusion for the Newsletter of the Electrochemistry Group of the Society. The editors thought it would be a very useful addition to the Conference Proceedings. We thank Martin Fleischmann and the Royal Society of Chemistry for having agreed to publish this text in these Proceedings.



In the development of any new area of research (and especially in one likely to arouse controversy!) it is desirable to achieve first of all a qualitative demonstration of the phenomena invoked in the explanation of the observations. It is the qualitative demonstrations which are unambiguous: the quantitative analyses of the experimental results can be the subject of debate but, if these quantitative analyses stand in opposition to the qualitative demonstration, then these methods of analysis must be judged to be incorrect<sup>1</sup>.

Research in the area of Cold Fusion affords an excellent illustration of this principle. Contrary to popular belief it is relatively easy to show qualitatively that Pd cathodes polarized in LiOD solutions in  $D_2O$  generate excess enthalpy over and above that of the enthalpy input to the electrochemical cell. All that is required is that a sufficient number of electrodes of sufficiently well-controlled properties be polarized for a sufficiently long time in  $D_2O$  having a sufficiently low content of  $H_2O$  and using calorimeters of sufficient sensitivity (signal:noise) in a sufficiently well-controlled environment<sup>2</sup>. It will then be found that a proportion of the experiments will show temperature-time and cell potential-time plots of the form illustrated in Fig. 1. We also make the following observations about this particular type of experiment:

- (i) the current efficiency for the electrolysis of  $D_2O$  is virtually 100%: there is no additional chemical source of enthalpy in the system;
- (ii) heat transfer from the cell to a surrounding thermostat is controlled by radiation and the heat transfer coefficient for the particular cell is virtually independent of time;
- (iii) our experiments in  $H_2O$  do not show these effects.

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<sup>1</sup> This principle, which should be self-evident, is usually overlooked in the unseemly haste to develop research. It may come to be known as Pons' and Fleischmann's first principle (designed to irritate the scientific public in general and nuclear physicists in particular). We have some even more irritating principles but will save these for a later discourse.

<sup>2</sup> The explanation of the term "sufficient" in each of these contexts is beyond the scope of this article; these points can be taken up by correspondence.



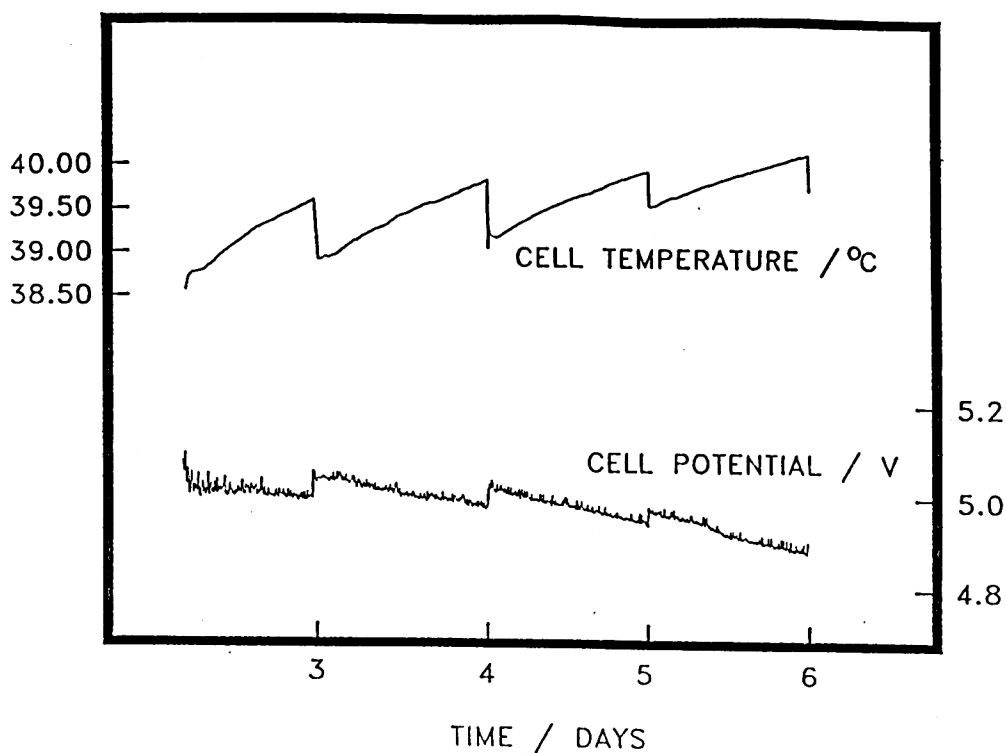


FIG. 1. Cell temperature (upper) and cell potential (lower) vs. time since cell was started for the electrolysis of  $D_2O$  in 0.6M  $Li_2SO_4$  solution at pH 10 at a palladium rod cathode ( $0.4 \times 1.25$  cm). The cell current was 400mA, the water bath temperature was  $30.00^\circ C$ , and the room temperature was  $21^\circ C$ . The rate of excess enthalpy generation at the end of each day was 0.045W (day 3), 0.066W (day 4), 0.086W (day 5), and 0.115W (day 6). The accumulation of excess enthalpy for this period was on the order of 26KJ.

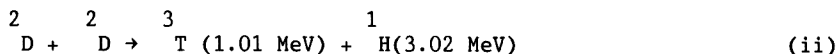
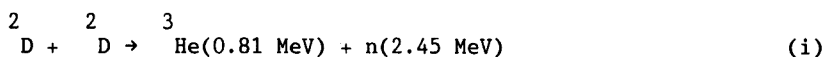
How then are we to explain an increasing thermal output of the cell coupled to a decreasing thermal input? The first law of thermodynamics requires that there be a source of enthalpy in the system and the strength of this source increases with time during the period illustrated. Such observations were valid in 1989 (they were valid



before then!), they were valid in 1990 and they are valid now.

The next step naturally is to seek a quantitative interpretation of such data. The last two years have seen the development of something akin to a cottage industry whose objective appears to be to explain away the reality of the phenomena by a combination of using incorrect (or inappropriate) methods of data analysis and invalid methods of overestimating the errors of the calorimetry (10% is the target figure). There is in truth scope for the former because the experiment is complex; the latter will come as a surprise to chemists who have hitherto relied on calorimetric methods as the main plank of thermodynamics. In judging the validity of such methods of calculation and of such estimates it is important to bear in mind the qualitative information conveyed by the experiments: any quantitative evaluation which removes or obscures the qualitative information must be judged to be invalid. Equally, failure to observe comparable qualitative effects when using other calorimetric methods must be judged to be due to inadequacies of the experimental methods<sup>3</sup> or, possibly, erroneous interpretation of the results.

Our own interpretation of the data in Fig. 1 gives the values of the rates of excess enthalpy generation and of the total excess enthalpy also shown on the Figure. Over the period shown the specific excess enthalpy amounts to 172 kJ cm<sup>-3</sup> corresponding to 1.52 MJ (g mole Pd)<sup>-1</sup>. It is our view that enthalpies of this magnitude can only be attributed to the operation of nuclear processes. The most rudimentary measurements of the generation of tritium and of the neutron flux (or rather the lack of it!) show that the nuclear reaction paths




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<sup>3</sup> These include: failure to control the H<sub>2</sub>O content of the electrolyte, inadequate experiment times and other factors such as cracking of the electrodes (repeated use of the cathodes?) or lack of symmetry of the disposition of the anodes around the cathodes leading to low D/Pd ratios; excessive sophistication of the instrumentation (which obscures the significance of the results) and incorrect choices of the experimental protocols.



which are dominant in high energy fusion (and which have roughly equal cross-sections under those conditions) contribute to only a very small extent to the observed phenomena.

We reach the conclusions:

- (i) the lattice has an important influence on the nuclear processes;
- (ii) the observed processes are substantially aneutronic;
- (iii) the generation of excess enthalpy is the main signature of these new nuclear processes.

These conclusions were valid in 1989, they were valid in 1990 and they are valid now. As chemists we are naturally interested in the main signature of the processes-side reactions can give important information but, in the end, one always has to investigate the major reaction route. Research in Chemistry teaches one that an understanding of the major processes normally leads also to an understanding of the side reactions<sup>4</sup>. This dictum has not been followed in most of the research carried out during the last two years.

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<sup>4</sup> This principle is so well understood by Chemists that it doesn't qualify for Pons' and Fleischmann's second principle of research in Chemistry; it could, however, qualify as the second principle of research in Nuclear Physics. As the saying goes: Chemists are interested in making Chemicals but Physicists are not interested in making Physicals.



## Conclusions

This short account has been based on only a small part of the information available. It is probably too soon, for example, to attempt a comprehensive explanation of the formation of high energy tritons ( $\sim 5\text{MeV}$ ) and neutrons ( $3\text{--}6\text{ MeV}$ ) except to say that they certainly cannot arise in simple two-body collisions. We also note that other explanations of the phenomena have been put forward: we have simply chosen the one which at this time is most free from objections and which also has the essential advantage that it leads to predictions for the outcome of novel experiments. Future surveys will have to cover the much wider range of observations already to hand and may well have to include the strange patterns of behaviour of compressed deuteron plasmas which are being reported in related fields of research such as in the application of Plasma Focus devices.

It is our view that the scientific interest of the subject has now been amply established; the scope for technological applications remains to be evaluated. However, to date, it has certainly been true that all aspects of electrochemistry, no matter how esoteric, eventually find some practical use.

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<sup>12</sup> The information about the system is in the macroscopic wave-functions. Neglect of this fact leads to paradoxes of the Einstein-Rosen-Podolsky type.

<sup>13</sup> This argument should not come as a surprise to electrochemists since there is some analogy between the deuteron-electron plasma coupling and the dipole fluctuation induced activation of outer sphere redox reactions. Indeed, it is our view that the latter processes would best be described by the relevant macroscopic wave functions of that superradiant system.