

Electrochemically-Induced Solid-State Fusion

The 1989 Spring Meeting of the Electrochemical Society was held in Los Angeles, California, from 7th to 12th May. Without doubt the major talking point among the 1,626 delegates concerned the prospects of nuclear fusion being achieved by the simple electrolysis of heavy water, between a palladium cathode and a platinum anode.

Since the first announcement by Professor Martin Fleischmann, of Southampton University, England, and Professor B. Stanley Pons, of the University of Utah, U.S.A., on 23rd March, 1989, there has been a frenzy of activity in laboratories around the world as scientists of different disciplines have attempted to repeat their fusion experiments. Due to the importance attached to this new area of research, the Electrochemical Society convened a Special Session on 8th May, at which leading electrochemical groups were invited to present their findings on the new fusion phenomenon.

Most groups had, at this early stage, concentrated mainly on calorimetric measurements made in their cells. Some had, however, carried out analysis of fusion products and two reported on mass spectrometric detection of hydrogenic species. Many of the principal speakers reported positive results with respect to the generation of quantities of excess heat from their electrolysis experiments. However, of those equipped to carry out measurement of fusion products, none presented conclusive evidence of any significant quantities of neutrons and tritium. It was apparent that it was still far too early for any consensus to be reached concerning the nature of the observations. Professor John O'M. Bockris, of Texas A & M University, stated that the reason why

many other groups had reported no effects was due to the fact that the nature of the palladium electrode has a crucial effect on its ability to absorb deuterium species.

Generation of Excess Heat

The results reported in their recent publication (*J. Electroanal. Chem. Interfacial Electrochem.*, 1989, 261, (2A), 301-308) were reaffirmed by Fleischmann and Pons. These were essentially that, dependent on the applied current density, excess enthalpy generation of over 10 W/cm^3 of the palladium cathode was measured. The electrodes consisted of rods 1, 2 and 4 mm diameter \times 10 cm long. Heat in excess of 4 MJ/cm^3 of electrode volume was measured over time intervals up to 120 hours. This heat was not continuous but occurred in bursts throughout the duration of the experiments. Questions concerning the positioning of the thermistor in the Dewar flask used for the calorimetry experiments were answered by a video film which revealed that complete mixing took place in twenty seconds. It was suggested that other workers should use larger volume palladium electrodes to observe these excess heat effects more readily.

A dual-cell, isoparabolic calorimeter, in which the hydrogen-palladium and deuterium-palladium systems were compared side by side, under identical conditions was described by R. A. Huggins, of Stanford University. A coin shaped palladium electrode was used. Excess heat was generated in the lithium deuterioxide-heavy water-containing cell, which was proportional to the applied power and also increased with time. Huggins reported that in the short term, over a 3.5 hour experiment, 67.5 kJ was supplied, to provide 9.8 kJ excess heat. He further commented that no differences between the hydrogen-palladium and deuterium-palladium systems were observed when the palladium was uncharged with the hydrogenic

species. Also, due to the possibility of exchange of deuterium with hydrogen from atmospheric moisture, excess heat gain disappeared when experiments were carried out with the "lid off".

The work carried out at Case Western Reserve University, U.S.A. was reported by U. Landau. This group had set up four cells involving palladium wires (1.0 mm diameter \times 3 cm long) in heavy water and in normal (light) water, and control experiments with similar platinum wires. Power balance measurements showed that, at 255 mA/cm², excess power of 0.144 W was obtained in the palladium-heavy water experiment, compared to only 0.013 W in the palladium-light water cell.

The results of a microcalorimetric study were presented by S. Srinivasan, of Texas A & M University. Palladium wires 0.5 mm and 1.0 mm diameter \times 1.0 cm long, and 2.0 mm diameter palladium spheres were compared with similar platinum materials in both heavy and light water. No excess heat was observed with either the platinum-heavy water or the palladium-light water systems, after up to 140 hours measurement. However, palladium-heavy water did show excess heat generation after being held at 600 mA/cm² for 60 hours. The excess was 10 to 25 per cent of the input to the cell, and reached a maximum of 30 mW. On allowing the cells to go to open circuit, an immediate decay in the heat output was observed. The excess heat corresponded to 16 to 18.5 W/cm³ palladium.

Another Texas A & M group, headed by Bockris, reported that of twenty electrodes studied, five had given excess heat. One electrode which showed an increased neutron count, was a 1.0 mm diameter \times 4.0 cm long palladium wire, of 99.9 per cent purity. No excess heat was seen for the first ten hours, but was measured for the following twenty hours, before decaying.

Detection of Fusion Products

Professor Steven Jones, of Brigham Young University, Utah, warned of the dangers of placing too much reliance solely on calorimetric evidence, and emphasised that the identifica-

tion of fusion products was the only valid experimental approach. His own work had revealed that the use of either titanium or palladium cathodes (large surface area foil) generated an increased neutron count above baseline, at 2.5 MeV.

In order to avoid effects caused by cosmic rays, recent work had been carried out in the Gran Sasso Tunnel, Bologna, Italy. An increased neutron count was observed over a three hour period. However, the increases were of a very low level, corresponding to about 0.4 fusion/s, and were calculated as only leading to 10^{-13} W heat generation. Jones concluded that the measurements of excess heat made by other workers were due to processes other than electrochemical fusion. Increased levels of 2.45 MeV neutrons and tritium accumulation were measured by Fleischmann and Pons, but, although consistent with each other, the quantities were at too low a level to account for the observed enthalpy changes. Landau also measured low level increases of neutron emission ($2.5 \times$ background), in bursts, and tritium generation ($2 \times$ background), but was cautious in relying heavily on these data. Bockris reported that one palladium electrode, of the many examined, produced an increased neutron count. This cycled up and down, and generally decreased with increased current density. Increases in tritium levels were also recorded. N. Lewis, of the California Institute of Technology expressed some doubt on the conclusion of increased neutron levels reached by some workers. He suggested that these observations might be more correctly interpreted by other processes such as chemiluminescence from lithium deuterioxide.

Mass spectrometric analyses of products formed during electrolysis, in 99.95 per cent heavy water, with both new and used palladium diffusion tubes as the cathodes, were outlined by E. Stuve, of the University of Washington. 10 volts were required to pass 10 mA, and the cell was open to air. Atomic mass numbers 2, 3, 4, 5 and 6 were detected in heavy water, while mass number 6 was absent in control experiments with water. Although numbers 5

and 6 could be interpreted as due to the existence of DT and T₂ species, respectively, the presenter suggested that the more likely interpretation was that they were caused by triatomic species DDH and DDD. Equipment limitations prevented a more detailed analysis. Neutron and fusion product analysis was reported by J. Jorne, of the University of Rochester, New York. The neutron count of 0.6/s and gamma-ray count of 16/s were not significantly higher than baseline. Mass spectrometry revealed atomic masses 3 and 4, but again it was impossible to establish with their equipment whether tritium formation was responsible for these.

The Role of Palladium

An explanation of the current irreproducibility of results from one group to the next, both from the point of view of observing the effect in the first place, and then establishing the magnitude of the effect, was put forward by Bockris. His results indicated that the effect was dependent on the nature of the electrode. He suggested that increases in stress near to edge dislocations caused increases in solubility of deuterium species. Annealing to remove hydrogen from the lattice, to enable deuterium absorption, was also an important factor. Huggins also commented that the microstructure of the palladium was a major issue, and that cast or wrought materials could behave differently. The influence of carbon impurities was alluded to, in that the impurity could cause methane formation, thereby leading to reduced charging of the palladium by hydrogen.

During the subsequent discussion session, D. T. Thompson, of Johnson Matthey, corrected statements that had appeared in the media concerning the requirements of palladium for successful fusion results. The most usual Johnson Matthey manufacturing process for rods was stated to involve three principal, successive operations, namely casting, forging and drawing down to size. It was also mentioned that palladium may be the optimum metal for this process, due to its large "appetite" for absorbing hydrogen/deuterium and that application of an electrical potential to the palladium enhances this ability to absorb hydrogen.

Conclusions

While it was clear that phenomena apparently similar to that first reported by Fleischmann and Pons have now been observed in several other laboratories, it was equally clear that much work remains to be done, both to identify the crucial factors leading to the effects noted and to establish an explanation for them. At this meeting no conclusive proof was available that these early experimental observations were indeed due to fusion. However, it is certain that the ultimate possibility of a cheap, inexhaustible and environmentally acceptable energy source will continue to stimulate much research in the coming months. Along with others working in this exciting area, Martin Fleischmann strongly encouraged the publication in the scientific literature of all results, whether positive or negative, in order that a proper evaluation of the phenomenon can be made.

G.A.H.

The Chemistry of the Platinum Group Metals

Continuing the successful series of triennial conferences on the above named topic, the Fourth International Conference is to be held at Cambridge from 9th to 13th July, 1990.

Organised by the Dalton Division of the Royal Society of Chemistry, the topics to be covered include: activation of small molecules; bio-inorganic and medical chemistry; compounds with metal-metal bonds and clusters; co-ordination chemistry; heterogeneous catalysis and surface studies; homogeneous

catalysis; new electronics materials, sensors and electrode systems; organic synthesis; organometallic chemistry; photochemistry and related methods of molecular activation; and regio- and stereo-selective reactions.

People wishing to contribute or to receive further information about this important international meeting, should contact Dr. John F. Gibson, Secretary (Scientific), Royal Society of Chemistry, Burlington House, Piccadilly, London W1V 0BN, England.