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Detection Of Energetic Charged Particles During Electrolysis

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By the use of Cr-39 particle track detectors immersed in the electrolyte, we confirm that a nuclear reaction of as-yet unknown nature can take place during electrolysis. With Li_2SO_4 dissolved in D_2O or H_2O and either Pd or Ni as cathodes, a very large statistical difference in nuclear track generation is found between detector chips immersed during electrolysis and the control chips immersed in similar solutions not subjected to electrolysis. The probability that the electrolysis tracks and the control tracks could have by chance arisen from a common population is 2.5×10^{-5}, 1.2×10^{-6}, and 5.8×10^{-4} for the systems Pd/D_2O, Pd/H_2O, and Ni/D_2O, respectively. We conclude that there is a causal relationship between electrolysis and energetic charged particles and that neither Pd nor D_2O is essential for the generation of a nuclear reaction. Some implications for theoretical considerations are presented.

INTRODUCTION

The 1989 announcement by Fleischmann and Pons[1] that a nuclear reaction can be generated by electrolysis of a D_2O solution of Li_2SO_4 upon a palladium cathode has been followed by many investigations of the generation of excess thermal power[2-5], of ^4He[6], and of tritium[7]. These studies have convinced a number of people of the reality of what has become known as "cold fusion" but have left a far larger number unconvinced and quite scornful of the investigations, claiming difficulties of calibration, existence of unrecognized artifacts, or outright fraud or self-delusion. The present work was motivated by the perceived need to apply as simple a technique as possible yielding unambiguous evidence so that the results would be convincing to the scientific community. We believe that the use of CR-39 charged particle detectors offers the best vehicle for achieving that goal.

EXPERIMENTAL PROCEDURE

Energetic charged particles that impinge upon a Cr-39 plastic detector damage the chemical bonds of the polymer molecules and leave a trail that is made visible by etching the plastic in 6.5 N KOH solution at 60 to 75°C. The energies necessary to create the trail of damaged bonds is far greater than can be produced by any chemical reaction, so that tracks observed in these plastic detectors are unambiguous evidence that a nuclear reaction of some kind has taken place. The CR-39 plastic employed in this work is BARYOTRAK obtained from the Fukuvi Chemical Industry Company, Japan. It is received as chips about 15 x 8 mm in area and about 0.8 mm in thickness. They are coated with a plastic film on both sides to prevent formation of alpha tracks by radon in the air. The chips come with laser-inscribed numbers on one side for easy identification. The chips are halved, additional identifying symbols are scratched on them if necessary, and small holes are drilled to enable the suspension of the chips by fine platinum wires in the electrolytic solution (Fig. 1) during electrolysis.

We wish to determine the number of nuclear tracks that are produced during electrolysis, and therefore it is necessary to record the tracks already present in the chips. After removing the protective plastic films, the chips are etched, then examined at 100X magnification. Ten or more areas of the chips are photographed, each of which includes a portion of the inscribed numerals. Two to four chips are then suspended either between the anode and the cathode or above the anode. Electrolysis is carried out usually over three days at various current densities, after which the chips are again etched and photographed at exactly the same areas as identified by the portions of the inscribed numerals included in the photographs made prior to electrolysis. For each of the ten or more images from a chip the number of nuclear tracks produced by the electrolysis and by radon in the air during handling is obtained by counting the tracks found after electrolysis and subtracting from that count the tracks observed prior to electrolysis. The net numbers of tracks for each of the images are added and the sum is divided by the number of areas examined to yield the average number of new tracks per image on a chip. By dividing this number by 0.008, the approximate cm^2 per image, one obtains the average number of new tracks per cm^2. To account for nuclear tracks caused by radon in the atmosphere during preparation and photography another set of chips is prepared to accompany each experiment. These control chips are handled in exactly the same way as are the experimental chips except that they are suspended without electrolysis within bottled solution, of the same concentration as the electrolysis solution, for the same length of time as the duration of the electrolysis.

For photography a digital camera coupled to a computer and printer is used. Microscope magnification of 100X in bright field is employed, although 500X magnification and dark field are also employed to help identify features as nuclear tracks. In this connection comparison is made to the tracks produced by exposing CR-39 chips to the radiation from pitchblende. The output of the digital camera is processed by the computer by a "Find Edges" program to yield high-resolution, high-contrast images. We have found that hard contacts of the detector ships with tweezers or glass can produce surface damage, often linear arrays of pits. Hence great care was exercised to avoid such contacts, and pits in linear arrays were not counted.

The electrolysis apparatus consists of a cylindrical tube of about 15 mm internal diameter. Its upper end terminates in a taper joint that contains a tungsten wire seal-through to which is spot-welded a platinum wire whose lower portion is a flat spiral that serves as the anode. A later version replaces the seal-through with a perforated rubber stopper (Fig. 1). The lower end of the glass tube terminates in a flanged joint between whose O-rings is clamped the cathode plate. The palladium cathodes are 25 x 25 mm sheets of 1 mm thickness obtained from Dr. E. Storms, Los Alamos National Laboratory (retired). The nickel cathodes are of 99.9% purity sheet, about 0.2 mm in thickness.

Preparation of the cathodes consists only of sanding and washing. The electrolytic solutions of Li_2SO_4 in either D_2O or H_2O were of various concentrations near 0.025 g/cm^3. Electrolyses were carried out at current densities between 0.1 and 0.4 A/cm^2 with the evolved gases released to the environment.

RESULTS AND DISCUSSION

Figure 2 shows a typical example of nuclear tracks before and after electrolysis. These digital images are processed with the "Find Edges" program and the appearance of the tracks can be seen to be similar to the appearance of tracks produced by exposure to pitchblende (Fig. 3). The results for new tracks after electrolysis and for the control chips are displayed in the Tables for the three systems investigated. It may be seen that in each case there is overlap between the distribution for chips that were not subject to electrolysis (the control chips) and those that were exposed to electrolysis (the "active" chips), although the latter show significantly larger track densities than do the controls. To quantify the degree of significance of these differences we apply the Mann-Whitney test[10], which is not affected by deviations from Gaussian behavior. The test yields the mere-chance probability, p, that the two data sets, that for the controls and that for the actives, could belong to a common population. The results from the statistical analyses are given in Table 4. Each of the analyses for the three systems provides overwhelming evidence that the active chips are in distinct and significantly different populations from the control chips. We can conclude with very high probability that the excess track densities in the active chips were caused by a physical agent that was not operative in the controls. Clearly, the physical agent is associated with electrolysis.

Electrolysis produces bubbles of hydrogen some of which impinge upon the surface of the plastic detectors, and it may be thought that such impingement is the cause of the etch pits that we construe as nuclear in origin. We note firstly that theses bubbles do not undergo cavitation with consequent generation of very high pressures and temperatures. Secondly, in several experiments we exposed detector chips to streams of bubbles of deuterium gas or hydrogen gas in a solution of Li_2SO_4 in D_2O for several days. The bubbles were produced by passing pressurized gas through a fritted glass sparger. In no instance were etch pits produced at levels above background. Another unlikely source of artifacts was considered, that uranium or thorium impurity in the platinum anode accumulates in the electrolyte during electrolysis causing the nuclear tracks that we observe. In addition to noting that neither Th or U appears in the chemical analysis of the platinum that was used in our experiments, we placed chips for five days in the residual electrolyte left after an experiment that concluded 13 days previously. New nuclear tracks were not found in the detector chips. The radiation from U and Th has very long half-life so that if these elements had indeed accumulated in the electrolyte during the previous experiment, nuclear tracks would have been produced.

Our results corroborate those of other workers showing that a nuclear reaction can accompany electrolysis. We note that despite the resemblance of the tracks in our experiments to alphas caused by radon from pitchblende we cannot assert that our tracks arise from alpha particles rather than from some other highly energetic nuclei. Nor do we know whether the nuclear reaction responsible for the tracks is the cause of the generation of thermal energy in excess of the normal production of energy in electrochemical processes.

The fact that the H_2O as well as D_2O can be used in the production of nuclear tracks means that the often considered D-D fusion reaction can be ruled out as the operative nuclear reaction. Since nickel is as effective a cathode material as palladium and the hydrogen concentration achievable in nickel by cathodic deposition in non-acidic solutions is very small, the possibility of a coherent nuclear reaction involving large concentrations of hydrogen in the lattice is also ruled out. The generation of energetic charged particles by a nuclear reaction occurring on the surface of the cathode appears unlikely because the plastic detector chips are at distances from the cathode much larger than the very short mean-free path of charged particles in a liquid medium. It is therefore quite probable that nuclear reactions detected by the CR-39 occurred in the electrolyte very near the surface of the plastic. By the same token a nuclear reaction may occur in the electrolyte at greater distances from the chip and consequently remain undetected. This may be the reason for the overlap between the lower portion of the track density values of the actives with those of the controls. In some of the experiments the reverse side of the detector chips was examined to find that whereas the front side had a large population of new tracks, the reverse side showed only background values. It is clear that a detector chip records tracks generated only by charged particles produced very close to its surface, so that absence of an excess of nuclear tracks does not necessarily imply that a nuclear reaction somewhere else in the electrolyte did not occur.

CONCLUSIONS

A nuclear reaction of as-yet unknown nature can accompany the electrolysis of either D_2O or H_2O using Li_2SO_4 in solution and either palladium or nickel as cathode material. Because of the short mean-free path of charged particles in liquids, the nuclear reaction that produced the observed nuclear tracks must have taken place in the electrolyte very near the detector chips. What other ions in the electrolyte and what other metals as cathodes may be employed to produce nuclear tracks are as yet unknown.

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Table 1. System: $Pd/D_2O/Li_2SO_4$[8]

Tracks/cm²			
Actives		Controls	
3760	578	541	143
2756	543	260	143
2375	318	260	118
1733	315	221	108
1138	260	204	95
962	225	195	95
962	177	177	75
897	161	165	59
757	156		
676			

Table 2. System: $Pd/H_2O/Li_2SO_4$[9]

Tracks/cm²			
Actives		Controls	
1950	520	377	100
1745	485	367	95
1737	437	228	83
1418	413	179	72
1300	400	177	70
1219	378	108	43
1080	361	108	23
922	295	107	12
845	260		
693	213		
682	204		
676	195		
606	173		
595	107		

Table 3. System: $Ni/D_2O/Li_2SO_4$[9]

Tracks/cm²			
Actives		Controls	
1405	325	364	130
1355	307	338	130
1202	283	272	107
993	272	260	95
982	237	260	95
922	221	160	83
898	221	143	78
741	213	142	35
532	202		
532	185		
510	141		
402	120		
390	107		
390	98		
335	95		
332	83		

Table 4. Results of the Mann-Whitney Statistical Analyses

System	Mann-Whitney p-value
	p
Pd/D_2O	2.5×10^{-5}
Pd/H_2O	1.2×10^{-6}
Ni/D_2O	5.8×10^{-4}

Note: p = probability that the data from the experimental chips and the control chips constitute a single population.

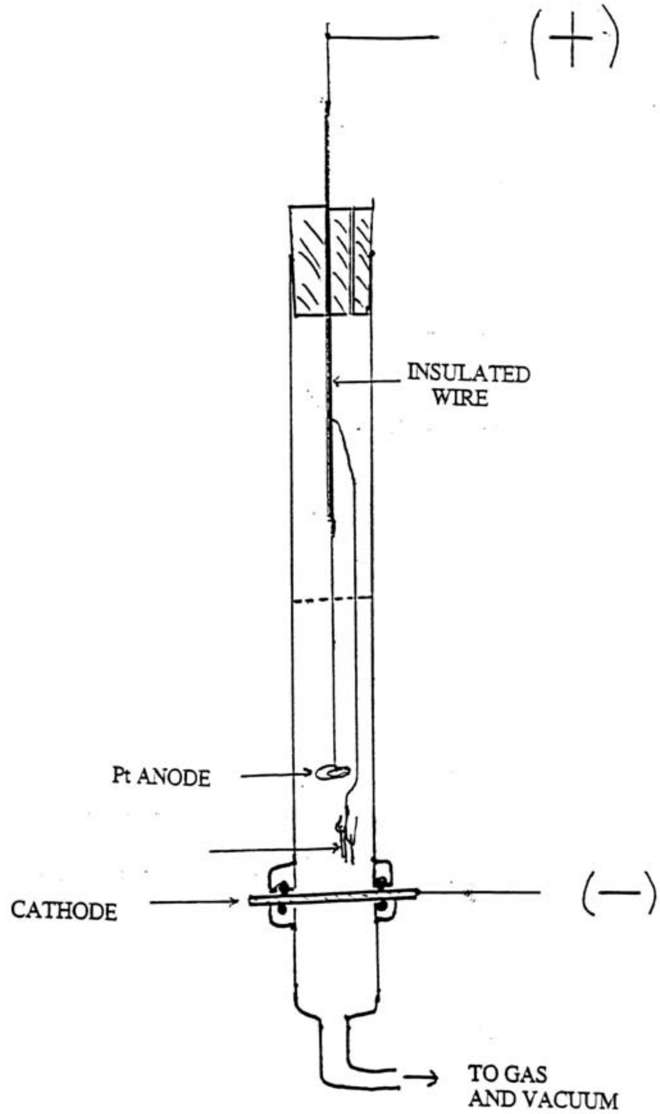
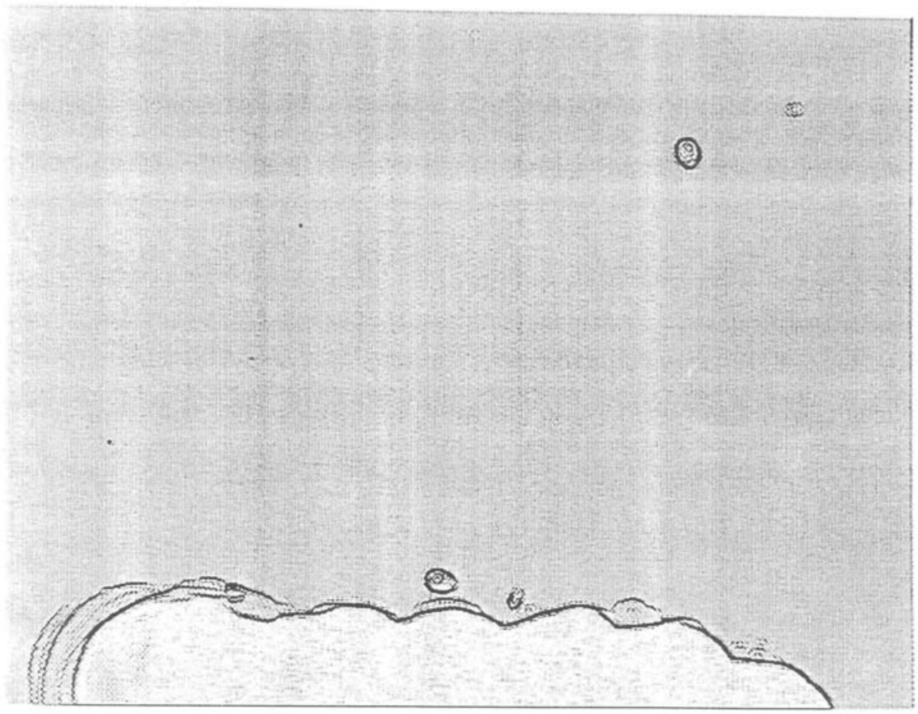


Figure 1. Schematic diagram of the electrolysis apparatus.



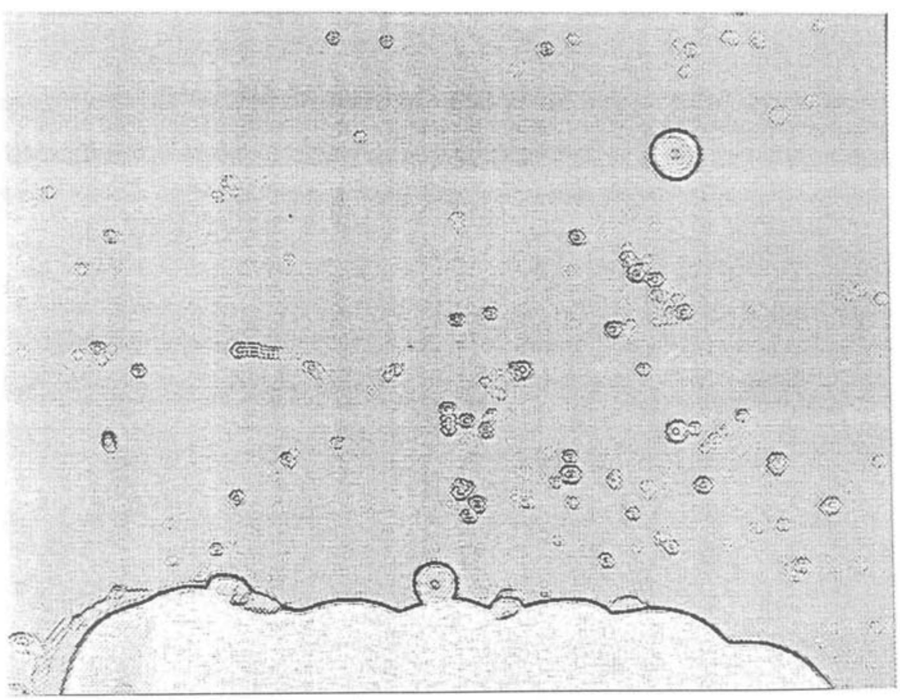


Figure 2. Bright-field image, original magnification 100X of a region of a detector chip after the first etch prior to electrolysis. The contoured feature in the lower portion of the image is a part of a small hole drilled into the plastic chips.

2B. The same region of the detector chip after electrolysis and re-etching the chip.

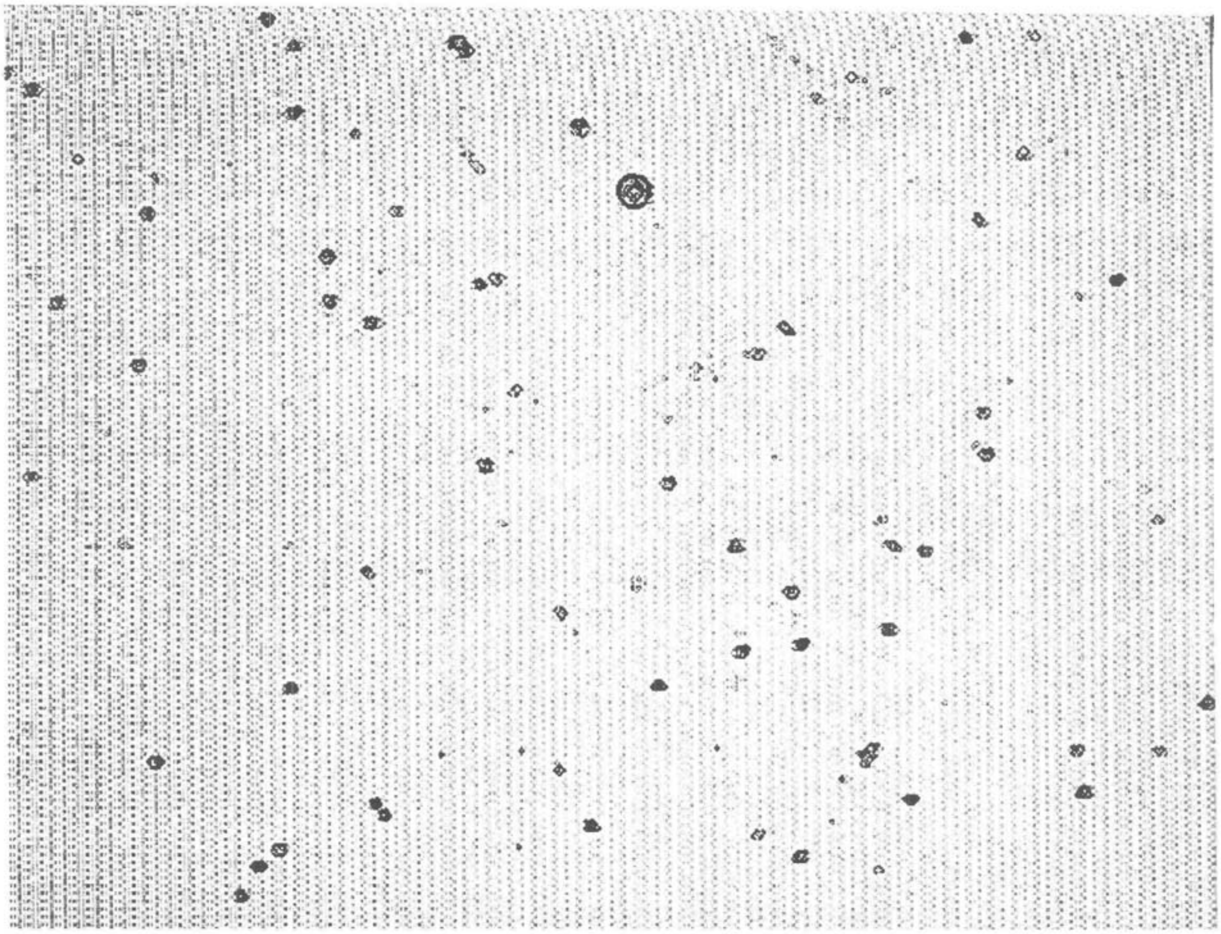


Figure 3. Bright-field image of alpha tracks produced by exposure of a detector chip to radiation from pitchblende.