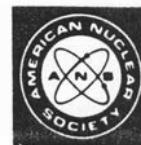


COMMENTS



The following two technical notes, "Anomalous Reactions During Arcing Between Carbon Rods in Water" and "Verification of the George Oshawa Experiment for Anomalous Production of Iron from Carbon Arc in Water," are unique among the various papers that have been published in *Fusion Technology* in the area of cold fusion and nuclear reactions in solids. The first discusses experiments intended to prove or disprove earlier reports of anomalous production of iron in a carbon arc, while the second discusses a variety of possible related nuclear transmutations. Both studies are directly, or indirectly, related to the subject of nuclear reactions under non-hot-plasma conditions, i.e., closely related to the field of possible nuclear reactions in electrodes during electrolysis in materials like palladium with deuterium implanted by high gas pressure, plasmas, or electrical discharges. Both studies imply that reactions might occur under electron volt background conditions that are even further removed from hot-plasma reaction conditions than those encountered in electrolytic cells. (However, even in electrolytic cells, there have been sporadic reports of the measurement of various product elements that imply nuclear transmutations can occur under these conditions. [See V. A. Tsarev and D. H. Worledge, "Cold Fusion Studies in the USSR," *Fusion Technol.*, **22**, 138 (1992) and R. T. Bush, "A Light Water Excess Heat Reaction Suggests That 'Cold Fusion' May Be 'Alkali-Hydrogen Fusion,'" *Fusion Technol.*, **22**, 301 (1992).])

By anyone's standards, these results seem bizarre—indeed, the authors themselves stress the need for much more work. Because of this, four referees, with widely varying backgrounds, were used to review each of these technical notes. The decision to publish came down to the fact that the referees were mostly "neutral" in their assessments, saying that they could find no egregious errors but that the studies were not definitive and, hence, may be premature. Still, based on the responsibility for a journal to disseminate information to the community in a timely way so that further work is fostered or that pertinent issues are raised, the majority recommendation was to publish these technical notes now. Readers should keep in mind the purpose of these technical notes, namely, to provide provocative observations about a possible new field involving fusion-like nuclear reactions.

George Miley

VERIFICATION OF THE GEORGE OSHAWA EXPERIMENT FOR ANOMALOUS PRODUCTION OF IRON FROM CARBON ARC IN WATER

NUCLEAR REACTIONS
IN SOLIDS

TECHNICAL NOTE

KEYWORDS: *anomalous nuclear reactions, nuclear transmutation, iron formation*

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A direct current arc was run between ultrapure graphite electrodes dipped in ultrapure water for 1 to 20 h. The graphite residue collected at the bottom of the water trough was analyzed for iron content by a conventional spectrographic method. It was found, in the first few experiments, that the iron content in the graphite residue was fairly high, depending on the duration of the arcing. The experiment was repeated initially six times, and the results showed large variations in iron content [50 to 2000 parts per million (ppm)] in the carbon residue. In the second series of experiments, which were done with the water trough fully covered, the amount of iron in the carbon residue decreased significantly (20 to 100 ppm). Here also there were large variations in the iron concentration in the residue, although the experiments were performed under identical conditions. Whether iron is really being synthesized through transmutation from carbon and oxygen as suggested by George Oshawa or is getting concentrated to different degrees through some other phenomenon is not currently clear. The iron in the carbon residue was also analyzed mass spectrometrically for the abundance of its various isotopes, and the results were more or less the same as that of natural iron. Besides iron, the presence of other elements like silicon, nickel, aluminum, and chromium was also determined in the carbon residue, and it was found that the variation of their concentrations followed the same pattern as that of iron.

INTRODUCTION

Oshawa,¹ Monti,² and others³ have suggested that nuclear transmutation can take place by methods other than conventional fission, fusion, or radioactive decay. For example, it was claimed that if a carbon arc is struck in water, a part of the carbon combines with the oxygen of the water and is converted into iron, based on the experiments conducted by Oshawa and his associates first in 1964 in Japan. As claimed by Monti,² the quantity of iron produced was so much that one could collect it by moving a magnet over the carbon residue. Since direct current (dc) arc excitation is routinely employed in our division and the graphite rods are also

used frequently for trace analysis of various samples, carrying out this experiment to check the stated results was felt to be necessary. The results of our studies, presented in this technical note, show that the presence of iron in the carbon residue is marginally high. Recently, Diodati⁴ performed similar experiments and did not find the production of iron from the carbon arc in water. Sundaresan and Bockris⁵ have also reported anomalous formation of iron from carbon as a result of arcing in water.

EXPERIMENTAL DETAILS

A Pyrex trough of ~1.5-l capacity was filled with demineralized water (iron content < 5 µg/l) to about three-fourths of its volume. Two ultra-high-purity Ultra Carbon Corporation (UCC) carbon electrodes^a [iron content < 2 parts per million (ppm)] each with a 30-cm length and a 6-mm diameter were dipped in the water at roughly right angles to each other and clamped to the electrode holders. The electrode holders were connected to a dc power supply.^b Inside the water, the electrodes were first made to touch each other at the tips and then slightly separated to get the arc started. The carbon electrode, used as the anode, had a rack and pinion arrangement (Fig. 1) for moving it along its length to compensate for its rapid consumption. Initially, the current was maintained at ~15 to 18 A, and the voltage across the electrodes was 30 to 35 V. The dc arc was run intermittently because if it were run continuously for more than a few minutes, the water heated up. Also, one cannot run the arc continuously for a long time because the gap between the tips of the electrodes increases with arcing, and the arcing stops by itself. To restart the arcing, the electrode tips are once again made to touch each other and then slightly taken apart. The experiment was continued for a few hours, but the actual arcing time was < 1 h. After the termination of the experiment, the suspended carbon particles settled at the bottom of the trough. The carbon residue collected was only 5 mg in the first experiment, and it was analyzed for the iron content as described in Sec. III. The results of the iron content, given in

^aUltra Carbon Corporation, Bay City, Michigan.

^bJarrell-Ash Custom Varisource.

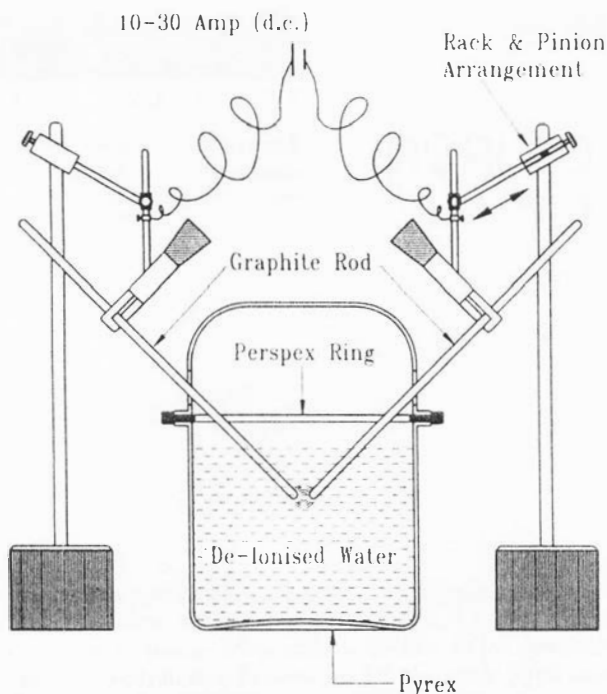


Fig. 1. Experimental setup of carbon arc in water.

Table I, showed a high concentration of iron (≈ 2000 ppm) in the residue. So, the experiment was repeated as discussed below.

In the second experiment, the fresh UCC carbon electrodes were weighed before and also after the experiment. One litre of demineralized water was poured into the trough, and the electrodes were clamped to the electrode holders as in the previous experiment. The electrode tips were well dipped in water, and the dc arc was struck intermittently. The experiment was conducted throughout the day. The water, when heated up, was allowed to cool by itself. In this experiment also, the actual arcing time was ~ 1 h. The carbon residue settled at the bottom of the trough was again analyzed spectrographically for the iron content, and the results are given in Table I. This time also, a very high value of iron (1000 ppm, experiment 2) was found in the residue as compared with the values of the blanks (given in footnote c of Table I).

We decided that the iron content in the graphite residue should be analyzed mass spectrometrically for the isotopic abundances of the various isotopes of iron. Therefore, the experiment was repeated once more. Since we wanted a large quantity of the residue sample for the isotopic analysis of iron, this time we used a double-walled Pyrex trough so that the water in the trough could be continuously cooled by the circulation of water. The results of this experiment (experiment 3), also given in Table I, again showed a fairly high concentration (2000 ppm) of iron in the residue. The results of the isotopic analysis of iron by the mass spectrometric method were more or less the same as that of the natural iron, which was also analyzed each time with the sample (see Table II, experiment 3). It was suggested that more accurate data on the mass spectrometric analysis could be obtained if the quantity of the residue was further increased. Therefore, the experiment was repeated a fourth time for collecting still larger quantities of the residue. This time, the single-wall Pyrex

trough was cooled by surrounding it with dry ice. Experiment 4 ran for a few days with the total arcing time being ~ 20 h. However, the arc current was reduced to 10 to 11 A because of the problem of running the arc at large currents over prolonged periods. The results of this experiment (number 4), given in Table I, showed a somewhat lower concentration of iron (only 450 ppm). The results of the isotopic analysis were again more or less the same as that of natural iron (see Table II, experiment 4).

The experiment was repeated a fifth time with a higher current, i.e., 25 A, and the water in the trough was cooled more efficiently by surrounding the trough with cold water, which was cooled continuously by pouring liquid nitrogen in it from time to time. The results of the experiment, given in Table I, showed a further downward trend of iron concentration (100 ppm) in the graphite residue. The mass spectrometric analysis results of the iron contained in the graphite residue of this experiment are given in Table II. The experiment was repeated a sixth time at a 22-A current, and the iron concentration in the residue further decreased (50 ppm), as shown in Table I.

All the experiments mentioned earlier used a Pyrex trough partially covered with a glass plate leaving some open space. To avoid any possibility of contamination of the water from the atmosphere, we made two Pyrex troughs with a perspex collar to hold them in position when one of them is kept inverted on the other, thus completely isolating the arcing space from the outside atmosphere. Only two small slots were cut in the upper trough to create some opening for the insertion of the graphite electrodes. A schematic diagram of this arrangement is shown in Fig. 1. Under identical conditions, four more experiments were done with a current as high as 28 A without cooling the water. This time, the consumption of the graphite rod was very fast, and in one day itself, we could collect a large residue of the carbon, which was analyzed spectrographically. The results of these analyses are given in Table I as experiments 7 through 10. Here again, the iron concentration in the carbon residue dropped further and its value varied from 20 to 100 ppm.

SPECTROGRAPHIC ANALYSIS OF THE RESIDUE

To carry out the spectrographic analysis of the carbon powder, collected at the bottom of the trough, we dried the residue under an infrared lamp and then on a Bunsen burner after decanting the water with the help of a siphon after each experiment. The carbon powder residue weighed only 5 mg in the first experiment. The spectrographic determination of the iron and other trace elements in the residue was done by using a dc arc method. Initially, a set of synthetic standards ranging from 10 to 500 ppm was prepared by using the spex mixture containing 1.28% of each of 49 elements. The residue obtained by arcing the graphite electrodes in water was thoroughly ground and mixed with an equal quantity of the spec-pure graphite to make up a charge of 10 mg (in the first experiment since the residue was small). The sample charge and the standards were loaded in the cavity of $\frac{1}{4}$ -in.-diam graphite electrodes. The spectrum of the sample and the synthetic standards was photographed on a Hilger large quartz spectrograph on Kodak SA-1 plates at 10 A and for 35 s of exposure. A 10% filter was also incorporated at the slit of the spectrograph to increase the range of the standards. Later on, another set of standards was prepared that contained only the persistently present elements in the graphite residue like

TABLE I
Results of the Iron Content in the Carbon Residue When Carbon Arc Is Struck in Water

Experiment Number	Type of Water Used (Quantity)	Approximate Arcing Time	Arc Current (A)	Amount of Carbon Consumed (g)	Carbon Residue Collected (mg)	Carbon Collected (%)	Iron Concentration in Carbon Residue (ppm)	Iron Content in Blank (μg) Water/Carbon	Excess Iron Content in Residue (μg)	Excess Iron in Residue per Gram Carbon Consumed (ppm)
1	Demineralized ^d (1 ℓ)	<1 h (without cooling)	15 to 18	^a	5		2000	^b	10	
2	Demineralized ^d (1 ℓ)	1 h (without cooling)	15 to 18	0.600	46	7.7	1000	5/<2 ^c	39	65
3	Demineralized ^d (1 ℓ)	6 h (cooling by water in double-walled trough)	15 to 18	4.755	127	2.7	2000	5/10	239	50
4	Deionized ^e (4 ℓ)	20 h (cooling by dry ice surrounding the trough)	10 to 11	15	850	5.7	450	8/30	345	23
5	Deionized ^e (4 ℓ)	15 to 20 h (cooling by water surrounding the trough, cooled by liquid nitrogen)	25	26	4800	18.5	100	8/52	420	16
6	Deionized ^e (2 ℓ)	2 to 3 h (cooling by water surrounding the trough, cooled by liquid nitrogen)	22	13.33	2076	15.6	50	4/26	74	5.6
7	Deionized ^e (2 ℓ)	2 to 3 h (without cooling)	28	5.215	1755	33.7	50	4/10	74	14.2
8	Deionized ^e (2 ℓ)	2 to 3 h (without cooling)	28	5.378	1990	37.0	20	4/10	26	4.8
9	Deionized ^e (2 ℓ)	2 to 3 h (without cooling)	28	5.648	2240	39.7	20	4/11	30	5.3
10	Deionized ^e (2 ℓ)	2 to 3 h (without cooling)	28	4.145	1377	33.2	100	4/8	126	30

^aNot measured.^bNo blank was run for this experiment.^cThe electrodes are supposed to contain <2 ppm of iron.^dIron content in the demineralized water approximately equal to 5 $\mu\text{g}/\ell$.^eIron content in the deionized water approximately equal to 2 $\mu\text{g}/\ell$.

TABLE II

Mass Spectrometric Analysis Results of the Iron Recovered from the Graphite Residue in the Carbon Arc in Water Experiments Along with the Analysis of Natural Iron (Spec Pure)

Experiment Number	Atom Ratios of Iron Isotopes		
	$^{54}\text{Fe}/^{56}\text{Fe}$	$^{57}\text{Fe}/^{56}\text{Fe}$	$^{58}\text{Fe}/^{56}\text{Fe}$
3	^a	0.0231 ± 0.0007	^a
Natural iron (Spec pure)	0.0636 ± 0.0005	0.0230 ± 0.0002	0.00310 ± 0.00004
4	^a	0.0230 ± 0.0002	^a
Natural iron (Spec pure)	0.0635 ± 0.0005	0.0233 ± 0.0002	0.00308 ± 0.00004
5	0.0635 ± 0.0010	0.0232 ± 0.0002	^a
Natural iron (Spec pure)	0.0638 ± 0.0005	0.0233 ± 0.0002	0.00310 ± 0.00004

^aIn the sample, because of isobaric interference of $^{54}\text{Cr}^+$ and $^{58}\text{Ni}^+$, the respective iron isotope results of $^{54}\text{Fe}/^{56}\text{Fe}$ and $^{58}\text{Fe}/^{56}\text{Fe}$ could not be reported.

silicon, iron, nickel, chromium, aluminum, and manganese and also incorporating gallium (0.01%) as the internal standard to account for the variations in the experimental conditions. In all the cases, the intensity of the elemental line of the sample was compared with that of the standards to estimate the concentration. The inaccuracy of the spectrographic analysis is expected to be within 15 to 20%.

RESULTS AND DISCUSSION

In the first experiment, the concentration of the iron found in the carbon residue was very high (2000 ppm) while, according to the certification supplied by UCC, it is expected to be <2 ppm in the carbon rods used in the experiment (see Table I). Of course, the carbon residue was only 5 mg in the first experiment, which went up to 46 mg in the second experiment by consuming 600 mg of the carbon rod. The percentage of carbon captured (in the residue) was $2.7\% [46/600] \times 100$ as given in column 7 of Table I. The iron concentration in this residue was found to be 1000 ppm. Thus, the excess iron content (after subtracting the blank of the carbon rod and also of the water) was 39 μg , as given in column 10 of Table I. The excess iron in the residue per gram of the carbon consumed was 65 ppm $[39/0.600]$, as given in the last column of Table I.

In the third experiment, the percentage of carbon collected was $2.7\% [127/4755] \times 100$, and the iron concentration was 2000 ppm, which was 239 μg after subtracting the blank. The excess iron per gram of the carbon consumed was 50 ppm. In experiments 4, 5, and 6, the percentage of carbon collected ranged from 5.7 to 18.5% wherein the water in the trough was cooled. The iron concentration in the residue varied from 50 to 450 ppm, but the excess iron per gram of the carbon consumed varied from 5.6 to 23 ppm. In the first series of experiments, these values, as given in Table I, varied from 65 to 5.6. In the second series of experiments wherein the trough was completely covered and the water in the trough was not cooled, the consumption of the graphite was much faster, and the percentage of carbon captured was also more, i.e., 33.2 to 39.7%. The iron concentration in the residue dropped to low values of 20 to 100 ppm. The excess iron in the residue per gram of the carbon consumed varied

from 4.8 to 30 ppm (last column of Table I). There is a large variation in the values despite the facts that these last four experiments were done under identical conditions and the water trough was fully covered.

In the first six experiments, the iron concentration in the carbon residue was significantly high in the beginning but dropped to low values in the later experiments. In the last four experiments, which were performed under identical conditions, the iron concentration further decreased, and here also there were large variations in the concentration. This observation suggested looking for other commonly occurring elements also in the spectrum of the graphite residue. We looked back into the spectrum on the plates and determined the concentration of the commonly occurring elements by comparison with the standards, and the results are given in Table III. It appears that in the first few experiments when iron was found to be high, other elements like silicon, chromium, and nickel were also high and dropped to lower values in the subsequent experiments.

CONCLUSIONS

It was found that the iron concentration in the carbon residue was as high as 2000 ppm in the beginning and dropped to lower values (20 ppm) in the later experiments, which were done by taking more precautions. However, even the lower values cannot be accounted for on the basis of the preconcentration of the carbon powder alone. Whether iron is really being synthesized through transmutation from carbon and oxygen, as suggested by the experiments of Oshawa, or by some other phenomenon is not currently clear. We have shown that iron is detected only in small amounts and not in large amounts as claimed by Monti² and Oshawa.¹ Second, it has been mentioned¹⁻³ that the iron so produced is different from the natural iron. The mass spectrometric analysis, done three times for the samples, gave the results (Table II) that the isotopic abundances are the same as those in the natural iron. We recommend that since the results, especially of the last four experiments, which were done under identical conditions and also with the fully covered trough, are not sufficiently reproducible and the values are differing, such experiments should preferably be very carefully done in a

TABLE III

The Concentration of a Few Commonly Occurring Elements Found in the Graphite Residue*

Experiment Number	Cover	Iron	Silicon	Nickel	Aluminum	Chromium	Manganese
1	Partial	2000	1500	400	300	100	<10
2	Partial	1000	500	500	200	500	50
3	Partial	2000	300	400	200	50	50
4	Partial	500	400	<10	200	<10	<10
5	Partial	100	100	<10	50	<10	<10
6	Complete	70	20	<10	15	<10	<10
7	Complete	50	15	<10	15	<10	<10
8	Complete	20	15	<10	15	<10	<10
9	Complete	20	15	<10	15	<10	<10
10	Complete	100	15	<10	15	10	<10

*Values given in parts per million.

completely dustproof laboratory, to say with certainty that the marginal increase in the iron content in the graphite residue by transmutation of carbon and oxygen is a myth or a reality.

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