J. Condensed Matter Nucl. Sci. 19 (2016) 281–286

Research Article

Is the Abundance of Elements in Earth's Crust Correlated with LENR Transmutation Rates?

Felix Scholkmann*
Research Office for Complex Physical and Biological Systems (ROCoS), Mutschellenstr. 179, 8038 Zurich, Switzerland

David J. Nagel
The George Washington University, Washington DC, 20052, USA

Abstract

Nuclear transmutations are reported in many low-energy nuclear reaction (LENR) experiments. We showed in a previous study (Scholkmann and Nagel, *J. Condensed Matter Nucl. Sci.* **13** (2014) 485–494) that (i) the transmutation data of three independent experiments have a similar pattern and (ii) this pattern correlates with a model-based on the prediction of Widom and Larsen (WL). In the present study, we extended our analysis and investigated whether the abundance of elements in Earth's crust is correlated with either (i) the WL-prediction, or (ii) the three LENR transmutation data sets. The first analysis revealed that there is no statistically significant correlation between these variables. The second analysis showed a significant correlation, but the correlation only reflects the trend of the data and not the peak-like pattern. This result strengthens the interpretation that the observed peak-like pattern in the transmutation data sets does not originate from contamination. Further implications of our study are discussed and a recommendation is given for future transmutation experiments.

Keywords: Elements in Earth's crust, Low-energy nuclear reactions (LENR), Neutron scattering strength, Statistical analysis, Transmutation, Widom–Larsen theory

1. introduction

Over the last decades, many studies reported transmutations of elements induced by chemical energies (see for review [1–3]). These processes are taken to be the results of low-energy nuclear reactions (LENR).

In a previous study [4], we found that (i) the transmutation data of three independent experiments (Miley et al., [5–7], Mizuno et al. [8,9], Little and Puthoff [10]) show a similar pattern and (ii) this pattern correlates with a model-based prediction of Widom and Larsen (WL) [11] Both correlations were statistically significant.

---

*Corresponding author. E-mail: felix.scholkmann@gmail.com

There are two possible interpretations of these results: the correlations are results of LENR transmutation process, or they are artifacts originating from impurities of these used materials, which contain traces of elements present in nature.

The goal of the present study was to investigate this issue. In detail, our aim was to analyze whether the abundance of elements in Earth's crust is correlated with (i) WL-prediction, and/or with (ii) any of the three LENR transmutation data sets The results of this analysis will indicate if the observed pattern in the transmutation data is an artifact (originating from impurities of the probed material due to natural abundances of elements in Earth's crust) or not. To the best of our knowledge, such an analysis was not performed so far.

2. Material and Methods

2.1. Experimental data

As in the previous analysis [4], the following transmutation data sets from electrolysis experiment were selected from publications and used in the present analysis: data obtained by (i) Miley (*Miley data set*), (ii) Mizuno (*Mizuno data set*), and (iii) Little and Puthoff (*Little-Puthoff data set*). More detailed description of these data sets can be found in [4].

2.2. Data about Earth's elemental abundance

The data for the abundance of elements in Earth's crust was obtained by [12], which include the abundance for elements with atomic number (Z) ranging from 1 to 92 from several references.

2.3. Data analysis

Two types of analysis were performed: we analyzed whether the abundance of elements in Earth's crust is correlated with (i) the WL-prediction and/or (ii) the three LENR transmutation data sets (see Fig. 1).

For the first correlation analyses, the $f(A)$ function, with A the atomic mass number, given by the WL-prediction had first to be transformed to a $f(Z)$ function, since the abundance data of the elements in the Earth's crust are given according to their atomic number Z value. For more information about the $f(A)$ function and the WL-prediction please refer to [4,11]. The new $f(Z)$ function was derived by the following steps: (i) defining an approximate relation

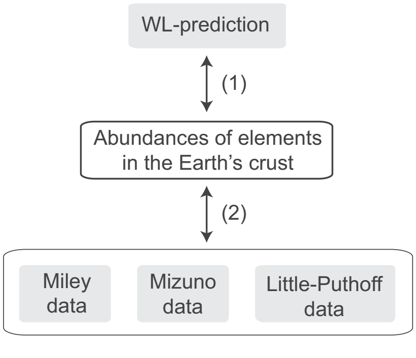

Figure 1. The two types of correlation analysis performed.

between A and Z as (a) $A = 1 \rightarrow Z = 1$ (hydrogen) and (b) $A = 238 \rightarrow Z = 92$ (uranium), (ii) finding the new values of the complex parameter z in Eq (1) of [4] by rescaling the $f(A)$ function such that the two constraints (a and b) were fulfilled. The derived z value is $4.89 + 0.5$ i. (iii) Manual adjustment of two values of the $f(Z)$ function to Z(5, 1.8) and Z(12, 1.8) was necessary since the fitting procedure at these important points gave a poor result The peak-like structure of the obtained $f(Z)$ function is identical to that of the $f(A)$ function, except the y-axis scaling (Z instead of A).

2.3.1. *Comparison of the Earth's elemental abundance with the WL-prediction*

The data set for the abundances of elements in Earth's crust was normalized to the range [0,1] to simplify the next data processing steps. The $f(Z)$ function was then fitted to the normalized abundances of elements in Earth's crust by using a classical least squares optimization method. The fitting was performed by multiplying the $f(Z)$ function with a scaling factor (θ), which then was changed until the sum of squared errors between the $f(Z)$ function and the data was minimized. Then the data sets of the normalized abundances of elements in Earth's crust was segmented into intervals corresponding to the peaks and troughs of the $f(Z)$ function. Thus, ten intervals were determined. The borders of the intervals were chosen to cover the peak and troughs position of the $f(Z)$ function optimally. The borders for the peak intervals were (given in Z): 4–6, 12–13, 23–27, 42–48, and 69–79. The borders for the trough intervals were (given in Z): 7–9, 15–21, 29–39, 50–68, and 80–92. To test whether the mean values of the new data set in the peak and trough intervals are significantly different statistically, a t-test was used for each interval pair. To account for the multiple comparison situation a Bonferroni-correction was used, leading to the new level of significance: $p<0.05/N=0.01$, with $N=5$ for the five t-tests performed. Thus, a p-value of <0.01 was used to indicate a statistically significant difference. The data processing cascade for this analysis is visualized in Fig. 2(a).

2.3.2. *Comparison of the earth's elemental abundance with LENR transmutation data sets*

For this analysis, the correlation between the $f(Z)$ function and each of the three LENR data sets as well as the combined data sets were computed. For each data set, the θ value was determined separately. The correlation strength was quantified by calculating the Pearson correlation coefficient (r), ranging from –1 to 1 where 0 indicates that no linear correlation between the variables exists. On the other hand, a value of –1 or 1 implies a perfect negative or positive, respectively, correlation. In order to test if the correlation is due to chance, the statistically significance (p-value) of the correlation was calculated. A p-value of < 0.05 was chosen as a threshold value for statistical significance. A limitation of this analysis is that it only provides an indication of the trends if the variables agree A correlation of the fine-structure cannot be quantified with this analysis.

3. Results

3.1. Comparison of the Earth's elemental abundance with the WL-prediction

The analysis gave the following p-values corresponding to the significance of the difference between the values in the intervals 1–10: (i) interval 1 vs 2: $p = 0.2600$, (ii) interval 3 vs 4: $p = 0.0296$, (iii) interval 5 vs. 6: $p = 0.0522$, (iv) interval 7 vs. 8: $p = 0.0063$ (v) interval 9 vs. 10: $p = 0.1486$ (see Fig. 2) Thus, only the difference between interval 7 and 8 was statistically significant ($p < 0.05/5 = 0.01$). Since the sign of the difference is opposite to the expectation (i.e., the WL-prediction gives a peak at this interval instead of a trough), this single significant correlation is not a proof for a general correlation between the Earth's elemental abundance and the WL-prediction.

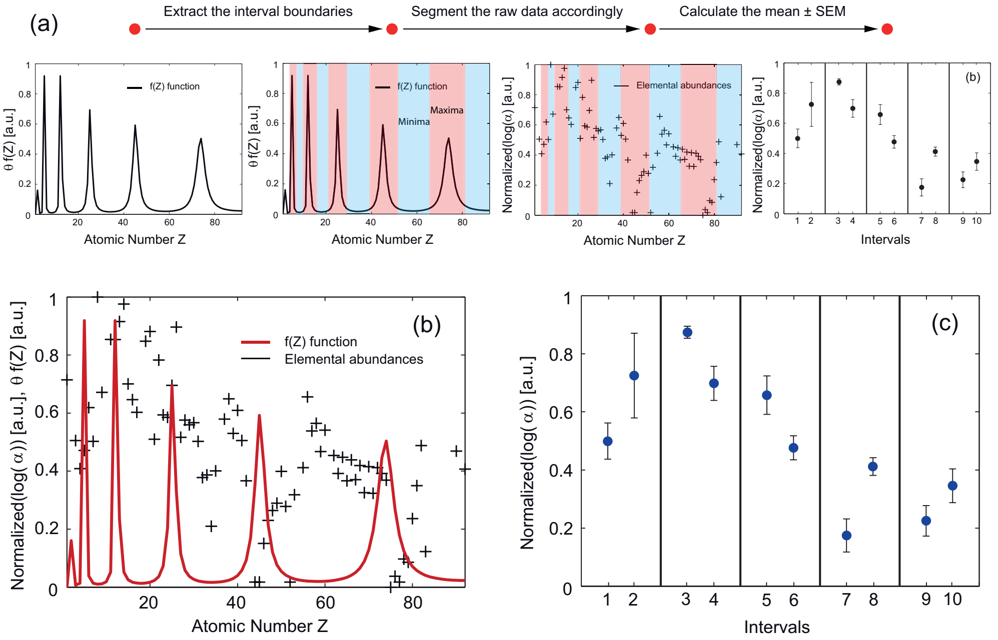

Figure 2. (a) Shows the signals processing cascade for the first type of data analysis performed. (b) Shows the comparison between the abundances of elements in Earth's crust (α) and the $f(Z)$ function based on the WL-prediction. θ: scaling coefficient ($\theta = 0.5102$, estimated using least squares fitting). (c) Interval-wise comparison between the abundance data and the WL-prediction. Interval definition: (i) intervals with maxima: (1): 4–6, (3): 12–13, (5): 23-27, (7): 42–48, (9): 69–79; (ii) intervals with minima: (2) 7–9, (4) 15–21, (6) 29-39, (8) 50–68, (10) 80–92. The interval boundaries are defined according to the $f(Z)$ function. Data are given as the mean ± standard error of the mean (SEM) .

3.2. Comparison of the Earth's elemental abundance with LENR transmutation data sets

The analysis showed a statistically significant correlation between these data sets ($p < 0.5$). For the obtained $p$values and the values of the correlation coefficient (r) please refer to Fig. 3.

4. Discussion and Conclusion

The first analysis (*comparison of the Earth's elemental abundance with the WL-prediction*) showed clearly that the peak-pattern of the WL-prediction does not correlate with the Earth's elemental abundance. The correlation was not statistically significant, apart from the difference between interval 7 and 8. However, as already explained, since the sign of the difference is opposite to the expectation (i.e., the WL-prediction), this single significant correlation is not a proof for a general correlation between the Earth's elemental abundance and the WL-prediction. In short, this test does not find a proof that there is an association between the Earth's elemental abundance and the WL-prediction.

The second analysis (*comparison of the Earth's elemental abundance with LENR transmutation data sets*) revealed that, on the one hand, the LENR transmutation data are significantly correlated with the Earth's elemental abundance data. However, on the other hand, this correlation is caused by the global trend of the data sets and not of their fine structure (i.e., the peak-pattern). What could be the cause for the same global trend (i.e., higher abundance values at low Z values and vice versa) in the data? The global (decreasing) trend in the Earth's elemental abundance data can be explained by the cosmic nucleosynthesis processes that created them [13]. An explanation for the same decreasing

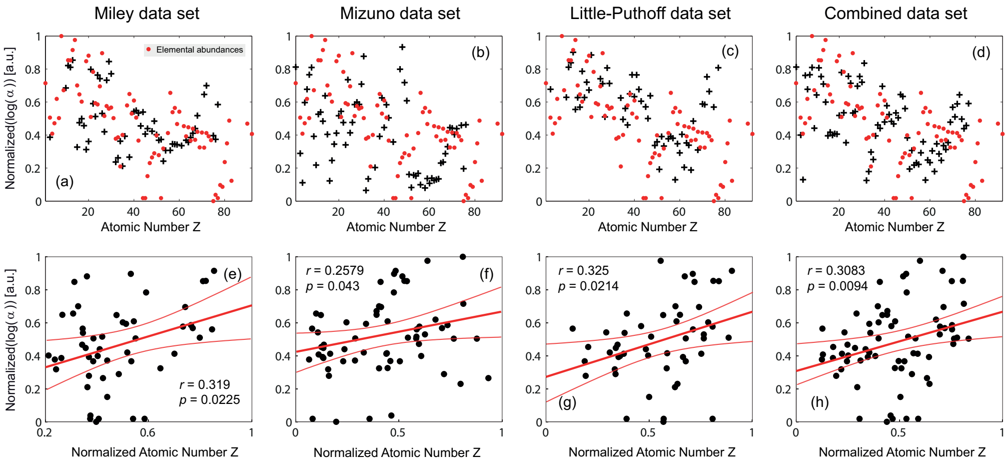

Figure 3. Results of the correlation analysis. Shown are the abundances of the Earth's elements and the three different LENR transmutation data sets (a–c, e–g) as well a combination of all these data sets (d,h). Subfigures e–h show the scatter plots of the Earth's elemental abundances vs. the LENR transmutation data sets. r: correlation coefficient, p: p-value corresponding to the significance of the correlation. In figures e–h the normalized atomic number Z is given which is defined as $Z \in [0\ 1]$.

trend present in the LENR transmutation data sets is missing, as far as we know. We can speculate that production of heavier elements requires sequential LENR. However, there is neither experimental nor theoretical evidence for that possibility at present.

How should our analysis be interpreted regarding the question of whether or not the observed and correlated patterns in the three LENR transmutation data sets are simply an artifact? The present analysis seems to strengthen the opinion that the experimental patterns cannot be explained by the distribution of the Earth's elemental abundance. However, there remain two significant concerns. We consider them each, and conclude they are not likely.

First, our analysis cannot rule out the possibility that contamination did play a role in the LENR transmutation experiments analyzed. In general, there might be two sources of contamination: (i) dirt in the laboratories that has an elemental abundance different from that of the Earth's crust, and (ii) other materials that are in contact with the experimental materials and also have specific elemental distributions. However, it is highly unlikely that the distributions of contaminations in all three of the laboratories would have been as similar as reported, whatever the origin of possible contaminations.

Second, there is concern over the sequence of events needed to link elements from the outdoor environment to those found in the three LENR experiments. The transport path involves three steps: (a) from the environments into the laboratories, (b) from the laboratories into the experiments, and (c) deposition within the experiments onto the surfaces that were later analyzed. We believe that it is very unlikely for the starting distribution of environmental contaminations and the selectivity of all three steps to be so identical that very similar final reported distributions of elements resulted. Even less likely is the possibility that the starting environmental distributions were really different, but the selectivity in the three transport steps happened to lead to the same end results. A simpler conclusion is that the three LENR experiments, despite their great differences, all yielded similar results because of the still unknown nature of LENR.

Since the analyzed experimental data in the three experiments were obtained years ago, and no samples of external or indoor dirt and other materials involved in the experiments were obtained, analyses of these elemental distributions are not possible. Thus, for future LENR transmutation experiments, we recommend collecting samples from different materials that are in the outdoor and laboratory environments and in the materials used for the experiments. This will allow subsequent data analyses as discussed in our previous study [4] and in this paper. Extensive consideration of other desirable aspects of future transmutation experiments is available in [4].

References

[1] E. Storms, *The Science Of Low Energy Nuclear Reaction ,* World Scientific, Singapore, 2007

[2] M. Srinivasan, G.H. Miley and S. Storms, *Low Energy Nuclear Reactions: Transmutations*, in *Nuclear Energy Encyclopedia: Science, Technology and Applications*, S.B. Krivit, J.H. Lehr and T.B. Kingery (Eds.), Wiley, New York, 2011, pp. 503–540.

[3] D. Nagel, The status of 'cold fusion', *Radiation Phys. Chem.* **51**(4–6) (1998) 653–668.

[4] F. Scholkmann and D. Nagel, Statistical analysis of transmutation data from LENR experiments and comparison with a model-based prediction of Widom and Larsen, *J. Condensed Matter Nucl. Sci.* **13** (2014) 485–494.

[5] G.H. Miley, *Reaction product and heat correlation for LENRs*. 2000. Lerici (La Spezia), Italy.

[6] G.H. Miley, Possible evidence of anomalous energy effects in H/D-loaded solids – Low energy nuclear reactions (LENR), *J. New Energy* **2**(3–4) (1997) 6–13.

[7] G.H. Miley and J.A. Patterson, Nuclear transmutations in thin-film nickel coatings undergoing electrolysis, *J. New Energy* **1**(3) (1996) 5-3.

[8] T. Mizuno, Isotopic changes of elements caused by various conditions of electrolysis, in *The 237th ACS National Meeting*, 2009, Salt Lake City, UT, USA.

[9] T. Mizuno, T. Ohmori and M. Enyo, Isotopic changes of the reaction products induced by cathodic electrolysis in Pd, *J. New Energy* **1**(3) (1996) 31–45.

[10] S. Little and H.E. Puthoff, Search for Evidence of Nuclear Transmutations in the CETI RIFEX Kit. http://www.earthtech.org/experiments/rifex/rifex.pdf, 1998.

[11] A. Widomand and L. Larsen, *Nuclear Abundances in Metallic Hydride Electrodes of Electrolytic Chemical Cells.* arXiv:cond-mat/0505026, 2006.

[12] Jefferson-Lab., *It's Elemental — The Periodic Table of Elements,* 2013; Available from: http://en.wikipedia.org/wiki/Abundance_of_elements_in_Earth%27s_crust.

[13] E.M. Burbidge et al., Synthesis of the elements in stars, *Rev. Mod. Phys.* **29**(4) (1957) 547–650.