Nuclear Abundances in Metallic Hydride Electrodes of Electrolytic Chemical Cells

A. Widom† and L. Larsen‡

† Physics Department, Northeastern University
110 Forsyth Street, Boston MA 02115
‡ Lattice Energy LLC, 175 North Harbor Drive, Chicago IL 60601

Abstract. Low energy nuclear transmutations have been reported in experimental chemical electrolytic cells employing metallic hydride electrodes. Assuming that the nuclear transmutations are induced by ultra-low momentum neutron absorption, the expected chemical cell nuclear abundances are discussed on the basis of a neutron optical potential model. The theoretical results are in satisfactory agreement with available experimental chemical cell data. Some implications of these laboratory nuclear transmutations for r- and s-process models of the neutron induced solar system and galactic nuclear abundance are briefly explored.

1. Introduction

It has been theoretically asserted[1], for surfaces of fully loaded metallic hydrides saturated with protons, that the collective electron and proton surface plasma modes give rise to the production of ultra-low momentum neutrons. The reaction proceeds in accordance with the weak interaction model,

$$(\text{radiation energy}) + e^- \rightarrow \tilde{e}^{\,-},$$
$$\tilde{e}^{\,-} + p^+ \rightarrow n + \nu_e, \tag{1}$$

wherein e^- is an electron, $\tilde{e}^{\,-}$ is a "dressed" or heavy electron localized near the metal hydride surface, p^+ is a proton, n is a neutron and ν_e is an electron neutrino. The resulting hydride surface product ultra-low momentum neutrons have an extraordinarily high absorption cross section. These neutrons in turn yield successive nuclear transmutations into higher and higher values of the atomic mass number A. At appropriate values of A, a resulting unstable nucleus may beta decay so that the values of the nuclear charge number Z then also rises. From such energy nuclear reaction kinetics, most of the periodic table of chemical elements may be produced, at least to some extent. Such nuclear transmutations do not require the high Coulomb energy barrier penetration implicit in low energy fusion models.

It has been previously reported[2], for experimental electrolytic chemical cells employing metallic hydride electrodes, that a variety of nuclear transmutations have

indeed been observed and that the resulting abundances of various nuclei have been reliably measured. Our purpose is to describe the experimental abundances of nuclear transmutations in strongly driven electro-chemical cells in terms of theoretical ultra-low momentum neutron absorption cross sections.

In Sec.2, a simple neutron optical potential model for a spherical well is reviewed and the complex scattering lengths for describing the ultra-low momentum neutron absorption cross sections are derived[3]. In Sec.3, we discuss the experimental distribution in atomic mass number A of the low energy nuclear reaction products measured in laboratory chemical cells[4]. Very remarkably, the product yield in a chemical cell is in some ways qualitatively similar to nuclear abundances found in our local solar system and galaxy[5]. The local maxima and minima in these abundances are strongly correlated to the local maxima and minima in the ultra-low momentum neutron absorption cross sections. This strong similarity serves as an indicator of the potential importance of ultra-low energy neutrons in nuclear reaction kinetics as briefly discussed in the concluding Sec.4.

2. Optical Potential Theory

Let us consider the following *optical potential model* for the effective (added to a nucleus) neutron amplitude $\psi(\mathbf{r})$. The complex potential probed by the neutron has the form of a spherical well. The well radius for a given atomic mass number A is modeled by

$$R = aA^{1/3} \quad \text{wherein} \quad a = 1.2 \times 10^{-13} \text{ cm.} \tag{2}$$

In detail, we assume a complex spherical step potential well

$$U(r < R) = -\left(V + \frac{i\hbar\Gamma}{2}\right),$$
$$U(r > R) = 0. \tag{3}$$

From the Scrödinger equation for the neutron amplitude

$$\left(-\frac{\hbar^2}{2M}\Delta + U(r)\right)\psi(\mathbf{r}) = E\psi(\mathbf{r}) = \frac{\hbar^2 k^2}{2M}\psi(\mathbf{r}), \tag{4}$$

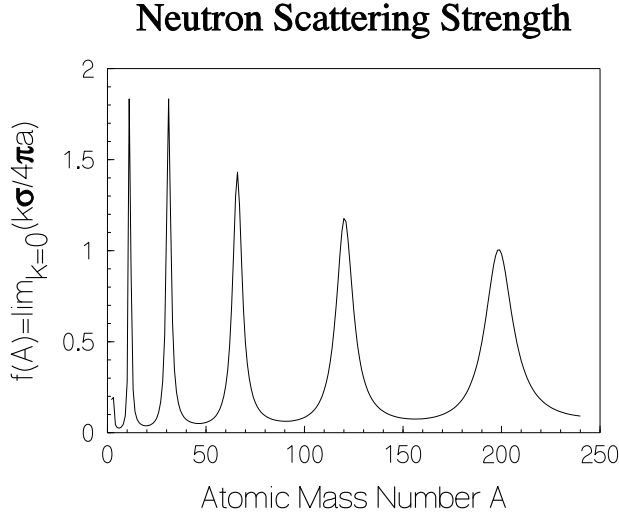one finds the scattering amplitude $\mathcal{F}(k,\theta)$,

$$\psi(\mathbf{r}) \to e^{ikz} + \mathcal{F}(k,\theta)\frac{e^{ikr}}{r} + \dots \quad \text{as} \ r \to \infty, \tag{5}$$

and thereby the total neutron cross section

$$\sigma(k) = \frac{4\pi}{k}\Im m\mathcal{F}(k,0). \tag{6}$$

In the ultra-low momentum limit, one may compute the neutron scattering strength

$$f(A) = \lim_{k\to 0}\left(\frac{k\sigma(k)}{4\pi a}\right) = \lim_{k\to 0}\left(\frac{\Im m\mathcal{F}(k,0)}{a}\right). \tag{7}$$

Neutron Scattering Strength

Figure 1. In the ultra-low momentum limit $k \to 0$, the total cross section is given by $\sigma(k, A) = (4\pi a/k)f(A)$. The scattering strength $f(A)$ is plotted as function of atomic mass number A.

The exact analytic form of the limiting Eq.(7) is given by

$$f(A) = \Im m \left\{ \frac{\tan\left(zA^{1/3}\right)}{z} \right\},$$

$$\frac{\hbar z}{a} = \sqrt{2M\left(V + i\frac{\hbar\Gamma}{2}\right)}. \tag{8}$$

Employing this optical potential model with $z = 3.5 + 0.05i$, the total neutron cross section in the long wavelength limit may be analytically computed,

$$\sigma(k, A) = \left(\frac{4\pi a}{k}\right) f(A) \quad \text{as} \quad k \to 0, \tag{9}$$

as plotted in Fig.1. The peaks in the neutron cross section correspond to comfortably fitting the neutron wave within the spherical model optical potential wells of the nuclei. The well radius R varies with A in accordance with Eq.(2).

While the model solved above refers the absorption of one neutron by one spherical nucleus, when the model is applied an ultra-low momentum neutron in a condensed matter electrode of a chemical cell, the very long neutron wave length spans many nuclei. This gives rise to collective quantum coherent effects in the neutron-nuclei interaction.

3. Nuclear Reactions in a Chemical Cell

The following experimental nuclear transmutations have been previously reported using light water solutions of one Molar Li_2SO_4 in electrolytic cells. Small plastic micro-spheres were coated with thin films of Nickel which were then employed to construct electrodes. The granular thin film structure of the electrodes allowed for large effective surface areas for the nickel hydride. If there exists sufficiently large flux of protons moving through the nickel and if the surface of the nickel hydride film is saturated with
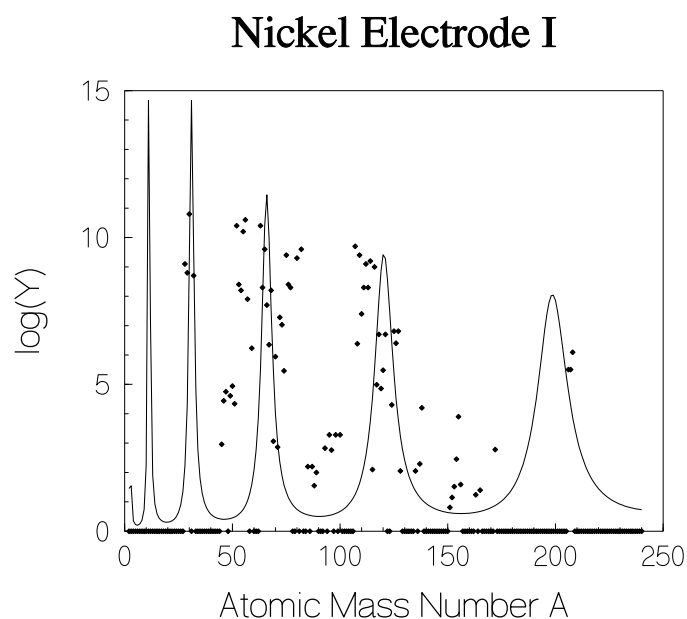
Nickel Electrode I

Figure 2. Shown is the experimental yield Y in parts per million Nickel electrode atoms of nuclear transmutation products during a moderately productive run. The experimental points were produced employing chemical electrolytic cells with a Nickel hydride cathode. Points exactly on the A-axis are those below detectable experimental resolution. Also plotted is a smooth theoretical curve of $8 \times f(A)$ which is proportional to the neutron absorption cross section.

Nickel Electrode II
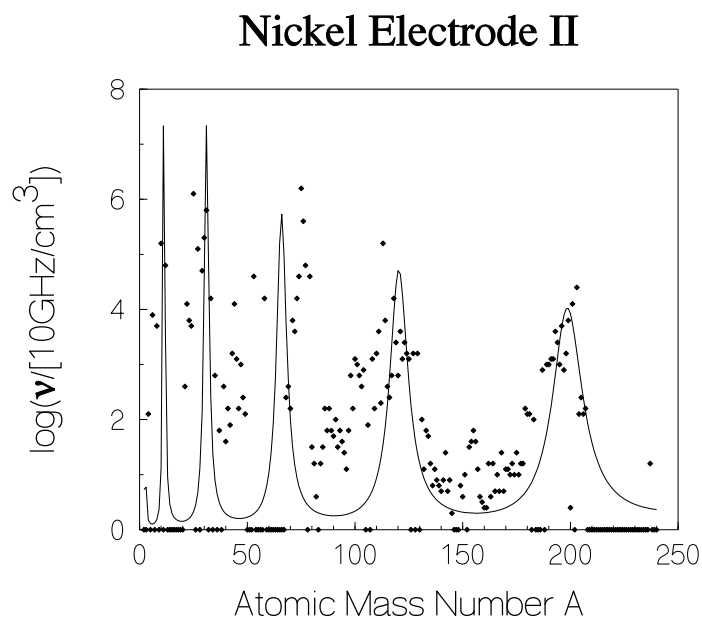
Figure 3. Shown is the experimental yield ν measured in transmutation events per second per cubic centimeter of Nickel electrode during a very productive run. The experimental points were produced employing chemical electrolytic cells with a Nickel hydride cathode. Points exactly on the A-axis are those below experimental resolution. Also plotted is a smooth theoretical curve of $4 \times f(A)$ which is proportional to the neutron absorption cross section.

hydrogen atoms and thereby protons, then nuclear transmutations could be measured to take place with a yield that is plotted as functions of A. The magnitude of the transmuted nuclear yields varies from one experimental run to to another. The variations will depend on the isotopic composition of the metallic hydride cathode and anode, various ions found in solution and the nano-scale uniformity of the electrode fabrication processes. However, the distribution of the yields versus atomic number appear to be understandable in terms of the total cross sections for neutron absorption in the ultra-low momentum limit, i.e. in terms of the above calculated neutron scattering strength.

In Fig.2, we plot the reported transmutation yield versus atomic mass number for a moderately productive run[6] employing a Nickel cathode and compare the observed shape of the yield function and the shape of the ultra-low momentum neutron scattering strength. In Fig.3 we plot the reported transmutation yield versus atomic mass number for a very productive run[7] employing a Nickel cathode and again compare the observed shape of the yield function and the shape of the ultra-low momentum neutron scattering strength. Similar experimental results[2][4][6][7] have been found employing titanium hydride, palladium hydride, and layered Pd-Ni metallic hydride electrodes. In all such experimental runs, the agreement between the multi-peak transmutation yields and the neutron scattering strength is quite satisfactory.

4. Conclusions

Let us conclude with some comments on the nature of the peaks in the theoretical neutron scattering strengths shown in Fig.1. In varying the atomic mass number A, we are in reality varying the radius $R = aA^{1/3}$ of the optical potential well. When the neutron wavelength within the well reaches resonance with the radius of the well[8] a peak appears in the scattering strength. If we associate resonant couplings with the ability of the neutron to be virtually trapped in a region neighboring the nucleus, then for intervals of atomic mass numbers about and under the resonant peaks we would expect to obtain neutron halo nuclei[9][10]. The spherical optical potential well[11] predicts the halo nuclei stability valleys[12] and thus the peaks in observed nuclear transmutation abundances. Finally, the neutrons yielding the abundances in our local solar system and galaxy have often been previously assumed to arise entirely from stellar nucleosynthetic processes and supernova explosions. However, such assumptions may presently be regarded as suspect[13][14]. It appears entirely possible that ultra-low momentum neutron absorption may have an important role to play in the nuclear abundances not only in chemical cells but also in our local solar system and galaxy.

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