ECE Theory of Low Energy Interaction from the Fermion Equation and Carbon Arc Induced Nuclear Fusion
by

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Abstract

The fermion equation is used to produce a generally covariant relativistic quantum theory of low energy nuclear reaction. The theory produces the energy levels of the fused nucleus and describes spin orbit interaction responsible for the nuclear structure. The mass of the fused nucleus is governed by considerations of relativity, and is not constant. The mass changes in low energy nuclear reaction produce energy. Experimental evidence is given for low energy nuclear reaction produced by a carbon arc.

KEYWORDS:ECE theory, fermion equation, carbon arc induced low energy nuclear reaction.

1 Introduction

In the course of development of Einstein Cartan Evans (ECE) unified field theory [1–11] it has been shown that the Dirac equation may be developed into a fermion equation which eliminates negative energy states, a well known failing of the Dirac equation. The fermion equation is generally covariant and is developed from Cartan geometry, whose tetrad postulate is the basis for the ECE wave equation. In UFT172 and UFT173 on www.aias.us the wave equation was developed into the fermion equation, whose wave-function is a two by two tetrad matrix. Therefore the use of four by four matrices by Dirac is no longer needed. The fermion equation may be expressed as two equations in spinors, equations which may be applied to a wide range of problems. In Section 2 the fermion equation is applied to low energy nuclear reaction (LENR) to find the energy levels of the fused nucleus and to describe its spin orbit structure. The development starts on the classical relativistic level in order to define the mass M used in the fermion equation. The mass is in general defined by relativistic considerations and in the non relativistic limit reduces to the sum of reactant masses. Otherwise M is less than the sum of the reactant masses, leading to energy released by fusion using well known arguments of nuclear fusion theory. The attractive nuclear strong force is modelled with a Woods Saxon [11] potential, and the repulsive force between protons of the nucleus by a Coulombic potential. The fermion equation is solved using a straightforward method based on a non-relativistic approximation. In general the fermion equation must be solved numerically for nuclear energy levels. The fermion equation produces fused nuclear features such as the nuclear Landé and Thomas factors, nuclear magnetic resonance, and several phenomena of nuclear spin orbit coupling, including the nuclear Darwin term of the fused nucleus. The Woods Saxon potential is used in an approximation designed to give an analytical solution. It is well known that this potential may also be approximated by a harmonic oscillator, giving the magic numbers of the fused nucleus. The mass difference between the fused nucleus and the sum of the reactant masses leads to energy released in the form of heat and light - low energy nuclear reaction (LENR).

In Section 3, experimental evidence is presented of carbon arc induced nuclear fusion producing several transmuted elements, indicating a variety of fusion processes involving the plasma electrons and ions and carbon. In future work these spectra will be analysed with the fermion equation.

2 The Fermion Equation and Low Energy Nuclear Fusion Reaction

In order to define the mass M of the fused nucleus consider two reactants 1 and 2 producing two products 3 and 4. Total energy momentum is conserved as follows:

$$p_1^\mu + p_2^\mu = p_3^\mu + p_4^\mu \tag{1}$$

This equation applies to scattering, annihilation, chemical and nuclear reactions. Total energy momentum is conserved in the theory by definition. In the limit of special relativity [12] the relativistic momentum is:

$$\mathbf{p} = \gamma m \mathbf{v} \tag{2}$$

where m is the mass of a given reactant, $\mathbf{v}$ is its linear velocity, and where

$$\gamma = \left(1 - \frac{v^2}{c^2}\right)^{-1/2} \tag{3}$$

is the Lorentz factor where c is the speed of light in vacuo. From Eq. (2):

$$p^2c^2 = \gamma^2 m^2 v^2 c^2 = \gamma^2 m^2 c^4 \left(\frac{v^2}{c^2}\right) \tag{4}$$

From (3)

$$\frac{v^2}{c^2} = 1 - \frac{1}{\gamma^2} \tag{5}$$

so:

$$p^2c^2 = \gamma^2 m^2 c^4 \left(1 - \frac{1}{\gamma^2}\right) = \gamma^2 m^2 c^4 - m^2 c^4 = E^2 - E_o^2 \tag{6}$$

Therefore the Einstein energy equation is obtained:

$$E^2 = p^2c^2 + m^2c^4 \tag{7}$$

It is simply a rewriting of the definition of the relativistic momentum, a definition which originates in conservation of momentum [12]. The total relativistic energy E and rest energy E_o are

$$E = \gamma mc^2, E_o = mc^2 \tag{8}$$

Consider the sum of the relativistic momenta of the reactants 1 and 2, it follows that:

$$(\mathbf{p}_1 + \mathbf{p}_2) \cdot (\mathbf{p}_1 + \mathbf{p}_2) = p_1^2 + p_2^2 + 2p_1p_2cos\theta \tag{9}$$

where θ is the angle between the vectors $\mathbf{p}_1$ and $\mathbf{p}_2$. Therefore:

$$c^2\,(\mathbf{p}_1+\mathbf{p}_2)\cdot(\mathbf{p}_1+\mathbf{p}_2) = E_1^2+E_2^2-(m_1^2+m_2^2)c^4+2p_1p_2cos\theta \tag{10}$$

and rearranging gives:

$$E_1^2+E_2^2 = c^2\,(\mathbf{p}_1+\mathbf{p}_2)\cdot(\mathbf{p}_1+\mathbf{p}_2)-2p_1p_2cos\theta+(m_1^2+m_2^2)c^4 \tag{11}$$

The relativistic momenta can be expressed as:

$$p_1^2 = \frac{1}{c^2}(E_1^2-m_1^2c^4) = (\gamma_1^2-1)m_1^2c^2 \tag{12}$$

$$p_1^2 = \frac{1}{c^2}(E_2^2-m_2^2c^4) = (\gamma_2^2-1)m_2^2c^2 \tag{13}$$

so

$$E_1^2+E_2^2 = c^2(\mathbf{p}_1+\mathbf{p}_2)\cdot(\mathbf{p}_1+\mathbf{p}_2)+(m_1^2+m_2^2)c^4-2(\gamma_1^2-1)^{1/2}(\gamma_2^2-1)^{1/2}(m_1m_2)c^4cos\theta \tag{14}$$

which can be expressed in terms of the mass M of the fused nucleus by:

$$(E_1+E_2)^2-(\mathbf{p}_1+\mathbf{p}_2)\cdot(\mathbf{p}_1+\mathbf{p}_2) = M^2c^4 \tag{15}$$

where

$$M^2 = m_1^2+m_2^2+2m_1m_2(\gamma_1\gamma_2-(\gamma_1^2-1)^{1/2}(\gamma_2^2-1)^{1/2}cos\theta) \tag{16}$$

This classical equation can be quantized into a fermion equation. The mass M is the sum of the masses m_1 and m_2 only in the non relativistic limit:

$$v_1 << c, v_2 << c \tag{17}$$

when Eq.(16) becomes:

$$M^2 = m_1^2+m_2^2+2m_1m_2 = (m_1+m_2)^2 \tag{18}$$

Otherwise there is a mass difference:

$$\Delta m = (m_1^2+m_2^2-M^2)^{1/2} \tag{19}$$

which gives rise to the energy released in nuclear fusion as heat and light. Consider the fermion equation for the fusion of two atoms 1 and 2. The attractive nuclear strong forces are denoted V_1 and V_2. The sum of these potentials is:

$$V = V_1+V_2 \tag{20}$$

The total relativistic energy of nuclei 1 and 2 is:

$$E = E_1+E_2 \tag{21}$$

and their fused mass is M. The vector sum of their relativistic momenta is:

$$\mathbf{p} = \mathbf{p}_1 + \mathbf{p}_2 \tag{22}$$

The fermion equation for this nuclear fusion process consists of two simultaneous equations (UFT172, 172 and 226 on www.aias.us):

$$((E - V) + c\boldsymbol{\sigma} \cdot \mathbf{p})\phi^L = Mc^2\phi^R \tag{23}$$

$$((E - V) - c\boldsymbol{\sigma} \cdot \mathbf{p})\phi^R = Mc^2\phi^L \tag{24}$$

where the wave functions are spinors:

$$\phi^L = \begin{bmatrix} \psi_L^1 \\ \psi_L^2 \end{bmatrix}, \phi^R = \begin{bmatrix} \psi_R^1 \\ \psi_R^2 \end{bmatrix} \tag{25}$$

From Eqs. (23) and (24):

$$(E - V)^2\phi^L = (c^2\boldsymbol{\sigma} \cdot \mathbf{p}\boldsymbol{\sigma} \cdot \mathbf{p} + M^2c^4)\phi^L \tag{26}$$

where:

$$(E - V)^2 - M^2c^4 = (E - V - Mc^2)(E - V + Mc^2) \tag{27}$$

So:

$$(E - V - Mc^2)\phi^L = c^2\boldsymbol{\sigma} \cdot \mathbf{p}\left(\frac{1}{E - V + Mc^2}\right)\boldsymbol{\sigma}\mathbf{p}\phi^L \tag{28}$$

The classical relativistic hamiltonian is defined [12] as:

$$H = E + V = Mc^2 + T + V \tag{29}$$

and Eq. (28) can be written as the eigenequation:

$$\hat{H}\phi^L = H\phi^L \tag{30}$$

where H is the relativistic hamiltonian and $\hat{H}$ is the relativistic hamiltonian operator defined by the Schroedinger ansatz:

$$\mathbf{p} = -i\hbar\boldsymbol{\nabla} \tag{31}$$

In general this eigenequation must be solved numerically using the highly developed methods of computational quantum chemistry [1–10]. In order to obtain an analytical result, use the non-relativistic approximation:

$$E \rightarrow Mc^2 \tag{32}$$

in the denominator of the hamiltonian operator, to obtain:

$$E\phi^L = \left(V + Mc^2 + \frac{1}{2M}\boldsymbol{\sigma} \cdot \mathbf{p}\left(1 - \frac{V}{2Mc^2}\right)^{-1}\boldsymbol{\sigma} \cdot \mathbf{p}\right)\phi^L \tag{33}$$

Finally assume that:

$$V << 2Mc^2 \tag{34}$$

to obtain the hamiltonian operator:

$$\hat{H} = V + Mc^2 + \frac{1}{2M}\boldsymbol{\sigma}\cdot\hat{\mathbf{p}}\left(1+\frac{V}{2Mc^2}\right)\boldsymbol{\sigma}\cdot\hat{\mathbf{p}} \tag{35}$$

In parallel with well known methods of atomic and molecular physics (UFT172, 173 and 226) this hamiltonian operator gives a lot of information on the fused nuclear state, notable the nuclear Landé factor of 2, the Thomas factor of 2, and the spin orbit structure of the nucleus. With the reference to note 227(11), posted with this paper, on www.aias.us, the hamiltonian operator $\hat{H}$ can be expressed as the sum:

$$\hat{H} = \hat{H}_1 + \hat{H}_2 \tag{36}$$

where:

$$\hat{H}_1 = Mc^2 + V - \frac{\hbar^2\nabla^2}{2m} \tag{37}$$

and:

$$\hat{H}_2 = \frac{1}{4M^2c^2}\boldsymbol{\sigma}\cdot\hat{\mathbf{p}}V\boldsymbol{\sigma}\cdot\hat{\mathbf{p}} \tag{38}$$

The nuclear energy levels of $\hat{H}_1$ are given by:

$$\hat{H}_1\phi^L = H_1\phi^L \tag{39}$$

and the nuclear energy levels of $\hat{H}_2$ by:

$$\hat{H}_2\phi^L = H_2\phi^L \tag{40}$$

These are the energy levels of the fused nucleus with mass M. The spin orbit coupling term is given by:

$$\boldsymbol{\sigma}\cdot\hat{\mathbf{p}}V\boldsymbol{\sigma}\cdot\hat{\mathbf{p}}\phi^L = (\boldsymbol{\sigma}\cdot\hat{\mathbf{p}}V\boldsymbol{\sigma}\cdot\hat{\mathbf{p}})\phi^L + \cdots \tag{41}$$

Using the Leibnitz Theorem:

$$(\boldsymbol{\sigma}\cdot\hat{\mathbf{p}}V\boldsymbol{\sigma}\cdot\hat{\mathbf{p}})\phi^L = (\boldsymbol{\sigma}\cdot(\hat{\mathbf{p}}V)\boldsymbol{\sigma}\cdot\hat{\mathbf{p}})\phi^L + \cdots \tag{42}$$

so the spin orbit energy levels are given by:

$$\frac{-i\hbar}{4M^2c^4}(\boldsymbol{\sigma}\cdot(\boldsymbol{\nabla}V)\boldsymbol{\sigma}\cdot\hat{\mathbf{p}})\phi^L = E_{so}\phi^L \tag{43}$$

The forces in the nucleus are made up of the strong nuclear attractive force:

$$\mathbf{F}_N = -\boldsymbol{\nabla}V \tag{44}$$

and the Coulombic repulsion between protons:

$$\mathbf{E} = -\boldsymbol{\nabla}\Phi \tag{45}$$

where e is the charge on the proton. the spin orbit hamiltonian du to the attractive strong nuclear force is:

$$\hat{H}_{SO,N} = -\frac{\hbar}{4M^2c^2}\boldsymbol{\sigma}\cdot\mathbf{F}_N\times\hat{\mathbf{p}} \tag{46}$$

and that due to the repulsion between protons is:

$$\hat{H}_{SO,E} = -\frac{e\hbar}{4M^2c^2}\boldsymbol{\sigma}\cdot\mathbf{E}\times\hat{\mathbf{p}} \tag{47}$$

where the electric field on the U(1) level is defined by:

$$\mathbf{E} = -\boldsymbol{\nabla}\Phi = \frac{e}{4\pi\epsilon_o r^3}\mathbf{r} \tag{48}$$

The repulsive spin orbit hamiltonian is therefore:

$$\hat{H}_{SO,E} = -\left(\frac{\hbar e^2}{16\pi M^2c^2\epsilon_o r^3}\right)\boldsymbol{\sigma}\cdot\hat{\mathbf{L}} \tag{49}$$

in which the orbital angular momentum operator is defined as:

$$\hat{\mathbf{L}} = \mathbf{r}\times\hat{\mathbf{p}} \tag{50}$$

So the repulsive nuclear spin orbit hamiltonian operator is:

$$\hat{H}_{SO,E} = -\zeta\boldsymbol{\sigma}\cdot\hat{\mathbf{L}} \tag{51}$$

where

$$\zeta = \frac{\hbar e^2}{16\pi M^2c^2\epsilon_o r^3} \tag{52}$$

is the spin-orbit constant in S.I. units where ϵ_o is the vacuum permittivity. In relativistic quantum mechanics, the spin angular momentum operator is defined as:

$$\hat{\mathbf{S}} = 1/2\hbar\hat{\boldsymbol{\sigma}} \tag{53}$$

and $\hat{\mathbf{S}}\cdot\hat{\mathbf{L}}$ is developed with angular momentum theory as is well known and described in UFT172 and UFT173 on www.aias.us. In nuclear physics, the Woods Saxon potential [11] is used to model, effectively, the main features of the nuclei. It is described by:

$$V = -V_o\left(1+e^{\left(\frac{r-R}{a}\right)}\right)^{-1} \tag{54}$$

where V_o is the potential well depth, a is the surface thickness of the nucleus, and R is the nuclear radius. It can be approximated roughly by the harmonic oscillator potential [11]:

$$V = 1/2kr^2 - V_o \tag{55}$$

where k is the spring constant of Hooke's law, so Eq.(39) becomes:

$$H_1\phi^L = \left(\frac{-\hbar^2\nabla^2}{2m} + 1/2kr^2 + Mc^2 - V_o\right)\phi^L \tag{56}$$

The nuclear energy levels of the fused nucleus in this approximation are well known energy levels of the harmonic oscillator:

$$E = (1+1/2))\,\hbar\omega \tag{57}$$

where:

$$n = 0, 1, 2, \ldots \tag{58}$$

and where:

$$\omega = \left(\frac{k}{M}\right)^{1/2} \tag{59}$$

As described in ref. [11] these give the first two or three magic numbers of the fused nucleus in a rough first approximation. the nuclear strong force dominates in light nuclei, but not in heavy nuclei in which nuclear fission can occur as is well known. Nuclear fusion usually takes place between light nuclei. The nuclear strong force from the radial potential (54) is defined by:

$$\mathbf{F}_N = \frac{1}{a}\frac{e^x}{(1+e^x)^2}\mathbf{e}_r \tag{60}$$

where:

$$x = \frac{r-R}{a} \tag{61}$$

As discussed in ref. [11], the structure of the nuclei of atoms can be understood with this force to good accuracy using computational methods. In order to obtain a rough approximation, consider:

$$r - R << a \tag{62}$$

so:

$$e^x \sim 1 + x \tag{63}$$

and:

$$\mathbf{F}_N \sim \frac{1}{a}\left(\frac{1+x}{(2+x)^2}\right)\mathbf{e}_r \tag{64}$$

where $x << 1$. It follows, using the binomial theorem, that:

$$(1+y)^{-2} \sim 1 - 2y, y = \frac{x}{2} \tag{65}$$

in a rough approximation. This attractive nuclear strong force can be written as:

$$\mathbf{F}_N \sim \frac{1}{4a}\left(1 - \frac{r-R}{a}\right)\mathbf{e}_r \tag{66}$$

using Eq. (66) in Eq. (46) gives:

$$\hat{H}_{SO,N} \sim \frac{\hbar}{16M^2c^2a^2}\boldsymbol{\sigma}\cdot\hat{\mathbf{L}} \tag{67}$$

for the spin orbit interaction due to the strong nuclear force. the spin orbit term can be used to explain nuclear physics and is the most important feature. The energy levels of the fused nucleus are in excited states, and the fission of the fused nucleus gives rise to the products 3 and 4 of the fusion reactants 1 and 2, accompanied by energy in the form of heat and light. This energy can be estimated as:

$$\Delta E_o = (m_1 + m_2 - M)c^2 \tag{68}$$

and is due to the relativistic mass difference. This theory can be extended in many directions, for example it can be used to describe absorption of quanta of energy from spacetime as described in detail in the eleven background notes 227(1) to 227(11) accompanying this paper on www.aias.us. The development of this theory will be the subject of future work. It is conceivable that the resonant absorption of spacetime quanta results in an excited fused nuclear state that decomposes into various production accompanied by energy in the form of heat.

3 Low Energy Nuclear Reactions From a Carbon Arc.

3.1 Experimental Evidence

Transmutation of carbon and oxygen in an electrical discharge is one of the so called "low energy nuclear reactions". Simply put, a carbon - carbon pair of electrodes has an electrical arc struck between them in either in a gaseous or water environment; anomalous production of elements, predominantly iron and calcium is reported. The carbon arc process is additionally interesting in that it is a favoured production method for producing carbon nano-tubes and other fullerenes [13,14], some of which display magnetic properties [15]. The technology is thus fairly well developed. Iron is deliberately included in the carbon rods as a catalyst for single walled nanotube production, so special treatment of spectrographs when taken, were necessary, which essentially eliminated all but carbon influences. Plasma temperatures were reported to be 4000-6500K [13]. Although the transmutation of carbon and oxygen in an electric arc was reported by George Oshawa in an esoteric publication [17 - quoted without authentication] and was reported to produce a new iron alloy in potentially economically producible quantities. The metal termed "George Osawa steel" did not become a market success. The discharge between carbon electrodes was performed both in air and under water with the production of iron being noted in both cases. In 2012, Kozima and Tada [16] summarized the work of Sundaresan and Bockris [17] who conducted similar experiments to Osawa, and Singh who performed a repeat of Osawa's work [19] using highly purified water and rigorous control of experimental variables. Water media was used because it was felt that trace amounts of iron present in the carbon electrodes would not diffuse to the arc from a large volume of the electrodes because of the overall lower temperature provided by water cooling. They observed the production of iron in quantities one to two orders of magnitudes higher than were possible from the trace amounts of iron available in the electrodes. They noted that when nitrogen gas was dissolved in the water (replacing oxygen), elemental iron was not observed as a reaction product. Spectroscopic evidence [22] indicates the presence of Mg, Pd, Ca, Al, Zn, and Cu. Typical voltages for the carbon arc were 10 volt drawing a very noisy 5 to 15 amps of current. Ogura, et. al. [20] in the same time frame performed similar experiments and found Ca and Fe elements present. Hanawa [21] found Cr, Mn, Fe, Co, Ni, Cu, and Zn. Recently, Esko [23] performed a similar discharge finding the following elements, Fe, Si, Mg, Cu, Al, Ti, S, and K. Several reaction schemes have been proposed of which the following are suggested [24, 25];

$$2_6C^{12} + 2_8O^{16} \rightarrow intermediaries \rightarrow {}_{26}Fe^{56} \tag{69}$$

or

$$2_6C^{12} + 2_8O^{16} \rightarrow {}_{26}Fe^{56} + {}_2He^4 + 56.55MeV \tag{70}$$

with

$${}_6C^{12} + {}_8O^{16} \rightarrow {}_{14}Si^{28} \tag{71}$$

as an intermediate step.

A second reaction that falls into the LENR category is the reaction of Nickel with hydrogen nucleus. Experimental evidence is strongly suggestive that the reaction is not a normal exothermic reaction [26]. Energy outputs far exceed normal reactions, and lie in the range expected for nuclear phenomena [27]. Spectroscopic data indicates the presence of copper and zinc in the reacted mixture [27,28]. Manufactured technology exist in the marketplace under the trade name E-Cat [29] for this process. The energy claims made by the E-Cat reports are somewhat contradictory to an earlier NASA solicited study that although it demonstrated excess energy, was inconclusive about the mechanism [30].

The most recent model [31] postulates the following reaction for the Nickel hydrogen process

$$Ni^{a} + p \rightarrow Cu^{a+l} + MeV \rightarrow Ni^{a+l} + e^{+} + \nu + MeV \tag{72}$$

The chain starts with Ni^{58} and ends with Cu^{63} for reasons of stability. The energy release is illustrated in the following table [27].

Table 1: Reaction Energies

Nucleus	$Ni^{a} + p \rightarrow Cu^{a+l}$	$Cu^{a+l} \rightarrow Ni^{a+l} + e^{+} + \nu$
Ni^{58}	3.41	4.80
Ni^{59}	4.48	6.13
Ni^{60}	4.80	2.24
Ni^{61}	5.86	3.95
Ni^{62}	6.12	—

The total reaction energies from this table are 41.79 MeV as opposed to the atomic mass calculation of Bettine [31] which gives 37.36 MeV.

Reactions involving antineutrinos [27] are also postulated. To overcome the high improbability of quantum tunnelling of a proton into a Nickel nucleus, a short-lived proton electron combination is speculated to occur allowing electron shielding of the high repulsive force [27].

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