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Possible Role of the Gailitis Resonance in Low Energy Nuclear Fusion Experiments

By Chi-Yu Hu

California State University Long Beach, United States

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Possible Role of the Gailitis Resonance in Low Energy Nuclear Fusion Experiments

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Abstract- The physical mechanism for the formation of the Gailitis resonances has been established in a recent precision calculation. According to the condition described in the low energy nuclear fusion experiments, the likelihood of Gailitis resonance induced low energy nuclear fusion exists. In this note, the properties of Gailitis resonance, the compound nuclear resonances, the conservation laws of energy, parity and the nuclear angular momentum will be used to support the possibility of Gailitis resonance induced low energy nuclear fusion.

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I. Introduction

Resonances are universal phenomena. They are well known to appear in numerous mechanical or electrical systems, large or small. Here their effects are easily recognizable. Their origin in microscopic systems are much more subtle and diverse. There are only a few well known and well understood resonances in atomic and nuclear systems, such as Feshbach resonances, nuclear magnetic resonances, only recently, the Gailitis resonances. The six-body resonance in muoncatalyzed fusion, typically represented by:

$$(t\mu)_{00} + (D_2)_{\nu_i,k_i} \longrightarrow [(dt\mu)_{11}, dee]_{\nu_f,k_f}, \tag{1}$$

where $(t\mu)_{00}$ is muon atom in ground state, $(D_2)_{\nu_i k_i}$ is a deuterium molecule in rot-vibrational state represented by the quantum number ν_i, k_i, d is the nucleus of deuterium (deuteron), and e represents the electron.

The right hand side of Eq. (1) is a giant complex molecule in rot-vibrational quantum states ν_f, k_f Eq. (1) represents a resonant process where the $(t\mu)_{00} + d$ sub-system on the left-hand side transfers 0:66 eV of energy to the rot-vibrational energy of the large complex molecule and becomes a bounded small molecular ion $(dt\mu)_{11}$ inside the large complex molecule in Eq. (1). Resonant property enables the transferring of energy between two systems differing in size by several orders of magnitudes.

The properties of Gailitis resonance have been revealed only recently [1]. Its lowest quantum states occasionally showed up in atomic calculations. They are called shape resonances. Because of their short-life time, they played little role in most physical processes.

According to [1], in a three-body colliding system the Gailitis resonances occur when the energy of the incoming colliding charged particle satisfies the resonant condition

$$E_m = m|\mu_l|/\langle y^2\rangle_m, \qquad m = 1, 2, 3 \ldots. \tag{2}$$

All quantities are expressed in mass normalized Jacobi coordinate system, energy in atomic units: m is the Gailitis resonance quantum number, $1/y_m^2$ is the Coulomb field of the incoming charged particle at the center of mass of the target, μ_l is the the electric dipole moment of the target system. During the life time of the resonance, the incoming particle is localized in a wave packet centered at a distance y_m from the center of mass of the target.

Clearly, this is a special kind of quantized varying field Stark effect. Similar to Stark effect, it is universal, not limited to three-body scattering systems. Namely, the target can be any atomic system that acquired electric moments from any number of internal or environmental conditions. For example, when heated some of the atomic electrons can be excited to higher orbitals [2], the atom becomes deformed and acquired electric moments.

There exists conditions in the E-cat reactor [3] that could produce deformed targets, namely ^7Li has nuclear electric quadrupole moment, in addition, it is possible to have deformed atomic ions inside the large molecular complex, for example, ^7Li in the molecule $LiAlH_4$. The low energy proton released after heating is ideal for the formation of Gailitis resonances.

For long-lived Gailitis resonances $E_m << 1$ keV, which is within the experimental error of nuclear mass data. The explicit inclusion of E_m in the energy of the Gailitis resonances is not necessary. To simplify the equations, the energy of the Gailitis resonance are defined by:

$$(^7Li + p) = {}^7Li + p + E_m > {}^7Li + p = S_p \text{ of } {}^8Be, \tag{3}$$

$$(^ANi + p) = {}^ANi + p + E_m > {}^ANi + p = S_p \text{ of } {}^{A+1}Cu, \tag{4}$$

Author: Department of Physics and Astronomy, California State University Long Beach, Long Beach, California, USA.
e-mail: chiyu.hu@csulb.edu

where S_p is the proton separation energy measured from the ground state of atom with mass number $A+1$. Section II presents the fusion process

$$({}^{7}Li + p) \xrightarrow{\text{fusion}} {}^{8}Be^{*} \xrightarrow{\text{decay}} 2\alpha + \text{kinetic energy}. \quad (5)$$

Section III will discuss the possibility of the fusion process

$$({}^{A}Ni + p) \xrightarrow{\text{fusion}} {}^{A+1}Cu^{*} \xrightarrow{\text{decay}} {}^{A+1}Ni + \beta^{+} + \bar{\nu} + \text{kinetic energy}. \quad (6)$$

II. Gailitis Resonance Induced Fusion into the Giant Overlapping Compound Nuclear Resonances ${}^{8}Be^{*}$ with Angular Momenta and Parities $I = 0^{+}$ and $I = 2^{+}$

The ${}^{8}Be$ nuclear energy levels have been investigated extensively (see refs [4] and [5] and specific experimental references herein). We are interested in the compound nuclear energy region above the energy level ${}^{7}Li + p = S_p$. There are two sharp resonances located at 0:44 MeV and 2:22 MeV above S_p. The decay of the first resonance are accompanied by two separate γ -rays with energies 14:8 MeV and 17:6 MeV, respectively. The second decays only into ${}^{7}Be + n$. The energy levels of the these resonances lie much too hight above S_p to overlap with the energy of a Gailitis resonance.

Eq. (3) shows that it is only slightly above S_p. The much investigated [5] giant overlapping resonances with angular momentum and parities $I = 0^{+}$ and $I = 2^{+}$ cover the whole region above and even below the S_p energy level according to Ref. [5]. The energy of the Gailitis resonance Eq. (3) can only overlap with that of these Giant resonances investigated in Ref. [5]. The giant resonances can only decay directly into two α particles.

Furthermore, it is easy to demonstrate that the angular momentum coupling of the ${}^{7}Li$ nuclei with $I = 3/2^{-}$ and a p-state proton with $l = 1$, spin 1/2 can produce Gailitis resonances with both $I = 0^{+}$ and $I = 2^{+}$. Despite the vast difference in sizes between the Gailitis resonance and the giant nuclear resonances, the process represented by Eq. (5) conserve energy, angular momentum and parities. The α particle produced by (5) has kinetic energy slightly larger than half of S_p, that is 8:63 MeV. This energy is much too low to penetrate any nuclei or match any of the energies of the compound nuclear resonances in Ni [6]. These results are consistent with the experimental data from the E-cat reactor.

III. Gailitis Resonances Induced Fusion Involving ${}^{A}Ni$ Isotopes

Eq. (6) shows that the complete information of the compound nuclear resonances above proton separation energy of ${}^{A+1}Cu$ are needed in order to satisfy all conservation requirements for these fusion processes. Despite of incomplete information, such as angular momenta and parity of nuclear resonances, the accurate tables of atomic mass energies for all ground states needed in Eq. (6) are readily available in the vast tables of Ref. [7]. From these tables the possibility of Gailitis resonance formation similar to that discussed in Sec. II can be asserted. The conservation of energy in the process represented by Eq. (6) can be established. Of course, it is important to keep in mind that if more nuclear energy levels becomes available, there could be more processes in between or more selection rules must be applied.

The tables provide atomic masses (that's including all the electron as well as nuclear masses) in terms of mass excess $\Delta = M - A$, A is the mass number. That is $A = Z + N$, Z the number of proton, N is the number of neutron with $\Delta(C_{12}) = 0$, the unit of Δ is MeV.

$$ {}^{A+1}S_p = {}^{A}\Delta + \Delta_H - {}^{A+1}\Delta \quad (7)$$

is the proton separation energy of ground state atom with $A + 1$.

$$ {}^{A+4}S_\alpha = {}^{A}\Delta + \Delta_{{}^{4}He} - {}^{A+4}\Delta \quad (8)$$

is the α particle separation energy of ground state atom with $A + 4$.

In table I, S_p and S_α for a number of ground states Cu isotopes are listed. They are calculated using Eqs. (7) and (8), respectively. They are the energy levels in MeV measured from the ground states copper isotopes respectively.

Table I displays the striking closeness between the two energy levels of S_α and S_p for all copper isotopes listed and $S_\alpha - S_p$ changes sign at ${}^{62}Cu$. This is unparalleled by other elements in the neighborhood of copper [7], suggesting overlapping compound nuclear resonances similar to that found in Section II. That in turn, suggests the possibility of Gailitis resonances induced fusion of Eq. (6).

Table 2-5 present the details of the energy conservation process following the fusion induced by the Gailitis resonances ($p + {}^{A-1}Ni$).

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Had the above process continuing, after emitting numerous low energy γ-rays, $\beta^{\pm}$-rays and neutrinos, the process would terminate at the two stable copper elements ^{63}Cu and ^{65}Cu. However, one notices that significant compound nuclear energy level structure changes beginning for copper after $A \geq 62$ in table I. It is also noticed that the nuclear binding energy per nucleon for ^{62}Ni of 8:564 MeV is the largest among all Ni isotopes, that of the ^{63}Cu of 8:517 MeV is also the largest among the copper isotopes. A more compact nucleus results in a more compact atom.

As a result, the atoms are not as easy to deform under stress. The experiment results in Ref. [3] strongly suggest that the Gailitis resonance formation process $(p + {}^{62}Ni) \to {}^{63}Cu^*$ failed such that the processes beginning from Table II terminate at Table V. Consequently, the isotope Ni^{62} accumulate with time at the expense of all other stable isotopes of Ni.

IV. Discussion

According to one of the E-cat reactor experiment carried out in Ref. [3], after 32 days of run, the most noticeable changes between the initial (fuel) and final (ash) isotopic compositions are listed in table VI. It is noticed that

a) There is a drastic % decrease in $^{7}Li^{+}$.
b) No stable Zn isotopes in the ash.
c) There is a drastic % increase in $^{62}Ni^{+}$ at the expense of all the other Ni isotopes.
d) No γ-rays are detected 50cm away from the E-cat reactor.

Possible theoretical explanations:

- There are two possibilities that ($^{7}Li+p$) resonance can be supported. First, the atomic electrons can acquire electric moment under external stress. Second, it is known that ^{7}Li nuclei posses electric quadruple moment. Sec. II successfully matched this Gailitis resonance with the giant compound nuclear resonance in $^{8}Be^{*}$. The ($^{7}Li+p$) has much longer life time [1] that facilities the formation of $^{8}Be^{*}$. The only decay path of $^{8}Be^{*}$ is two of α particles, each with an 8.63 MeV. These processes deplete both ^{7}Li and proton in the fuel, replace them with matching number of 8.63 MeV α particles.
- The energy of the α particle produced in part a) is much too low to match that of the compound nuclear resonates in Ni^{*} [6]. They are unable to penetrate the Ni nucleus. That could explain the lack of stable Zn isotopes in the ash. Thus the energy of the α particle will dispense into heat after multiple collisions.
- The precise condition for the formation of Gailitis resonances in $^{A}Ni+p$ systems is not available at the present time due to the lack of experimental data on compound nuclear resonances above the proton separation energy level in ^{A+1}Cu. The possibility of Gailitis resonance formation is based on circumstantial evidences suggested by the systematics of nuclear masses represented by Table I. Tables II-V evolve using the formation of ($^{A}Ni+p$) and the conservation of energies only. All unknown nuclear energy levels and selection rules due to conservation of parity and nuclear angular momentum are ignored. For example, in Tables II and IV, the γ-rays, direct transition from the compound nuclear resonant states $^{29}Cu^{*}$, $^{31}Cu^{*}$ to the ground states of ^{29}Cu, ^{31}Cu respectively may not even be possible due to selection rules. The theory of accumulation of ^{62}Ni in the ash depends on future experiment data on nuclear energy level measurements both above and below the proton separation energy.
- Based on energy consideration only, it can be summarized as following: The majority of the released energy eventually turns into heat. The majority of the energy escaped the reactor comes from neutrinos and antineutrinos that accompanying each $\beta^{\pm}$ decay. The numerous β^{+} rays eventually annihilate with electrons. They produce most of the γ-rays with an average energy of the order of 0:511 MeV. Can some of the γ-rays escape the reactor? Certainly. Can they be detected outside the reactor 50 cm away? This question can be address with more information on the experiment details [8].

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Table I : The ground states atoms ^{A}Cu, A = 59-65, their life-times, mass excess Δ in MeV, proton separation energy in MeV, and α particle separation energy in MeV are listed, values are taken directly from Ref. [7]

	^{59}Cu	^{60}Cu	^{61}Cu	^{62}Cu	^{63}Cu	^{64}Cu	^{65}Cu
life time	81.1s	23.7m	3.333h	9.67m	stable	12.7h	stable
Δ	-56.357	-58.344	-61.984	-62.798	-65.579	-65.424	-67.264
S_p	3.419	4.477	4.801	5.866	6.122	7.201	7.453
S_α	4.755	4.730	5.064	5.377	5.776	6.200	6.790
$S_\alpha - S_p$	1.336	0.253	0.263	-0.489	-0.346	-1.001	-0.663

Table II : A = 59, $T_{\beta+\nu}$ is kinetic energy of $\beta^{\pm}$ plus the energy carried away by neutrino

Eq. (6)	$(p + {}^{58}Ni)$	$\xrightarrow{\text{fusion}}$	$^{59}Cu^{*}$	$\xrightarrow{\gamma\text{-rays}}$	^{59}Cu	$\xrightarrow{\beta^{+}}$	^{59}Ni
life time	long		short		81.5s		7.6×10^{4}y
Δ	3.419 - 56.357		-52.938		-56.357		-61.156
energy transfer		0		3.419		4.799	
energy distribution		conservation		γ rays		$2m_e = 1.022$	
						$T_{\beta+\nu} = 3.777$	

Table III : A = 60, $T_{\beta+\nu}$ is kinetic energy of $\beta^{\pm}$ plus the energy carried away by neutrino

Eq. (6)	$(p + {}^{59}Ni)$	$\xrightarrow{\text{fusion}}$	$^{60}Cu^{*}$	$\xrightarrow{\beta^{-}}$	^{60}Zn	$\xrightarrow{\beta^{+}}$	^{60}Cu	$\xrightarrow{\beta^{+}}$	^{60}Ni
life time	long		short		2.38m		23.7m		stable
Δ	4.477 - 58.344		-53.867		-54.19		-58.344		-64.472
energy transfer		0		0.323		4.154		6.128	
energy distribution		conservation		$T_{\beta+\nu} = 0.323$		$2m_e = 1.022$		$2m_e = 1.022$	
						$T_{\beta+\nu} = 3.132$		$T_{\beta+\nu} = 5.106$	

Table IV : A = 61, $T_{\beta+\nu}$ is kinetic energy of $\beta^{\pm}$ plus the energy carried away by neutrino

Eq. (6)	$(p+{}^{60}Ni)$	$\xrightarrow{\text{fusion}}$	${}^{61}Cu^{*}$	$\xrightarrow{\gamma\text{-rays}}$	${}^{61}Cu$	$\xrightarrow{\beta^{+}}$	Ni^{61}
life time	long		short		3.333h		stable
Δ	4.801 - 61.984		-57.183		-61.984		-64.221
energy transfer		0		4.801		2.237	
energy distribution		conservation		γ rays		$2m_e = 1.022$ $T_{\beta+\nu} = 1.215$	

Table V : A = 62, $T_{\beta+\nu}$ is kinetic energy of $\beta^{\pm}$ plus the energy carried away by neutrino

Eq. (6)	$(p+{}^{61}Ni)$	$\xrightarrow{\text{fusion}}$	${}^{62}Cu^{*}$	$\xrightarrow{\beta^{-}}$	${}^{62}Zn$	$\xrightarrow{\beta^{+}}$	${}^{62}Cu$	$\xrightarrow{\beta^{+}}$	${}^{62}Ni$
life time	long		short		9.186h		9.67m		stable
Δ	5.866 - 62.798		-56.932		-61.17		-62.798		-66.746
energy transfer		0		4.238		1.628		3.948	
energy distribution		conservation		$T_{\beta+\nu} = 4.238$		$2m_e = 1.022$ $T_{\beta+\nu} = 0.606$		$2m_e = 1.022$ $T_{\beta+\nu} = 2.926$	

Table VI : Changes in isotopic composition

	${}^{6}Li+$	${}^{7}Li+$	${}^{58}Ni+$	${}^{60}Ni+$	${}^{61}Ni+$	${}^{62}Ni+$	${}^{64}Ni+$
fuel	8.6%	91.4%	67%	26.3%	1.9%	3.9%	1%
ash	92.1%	7.9%	0.8%	0.5%	0%	98.7%	0%

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