Photon Induced Low Energy Nuclear Reactions

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Abstract

We propose a new mechanism for inducing low energy nuclear reactions (LENRs). The process is initiated by a perturbation which we assume is caused by an external photon. The initial two body nuclear state absorbs the photon and forms an intermediate state which makes a transition into the final nuclear state with emission of a light particle which in the present paper is taken to be a photon. We need to sum over all energies of the intermediate state. Since the energy of this state is unconstrained we get contributions from very high energies for which the barrier penetration factor is not too small. The contribution from such high energy states is typically suppressed due to the large energy denominators and its matrix element with the initial state. Furthermore the process is higher order in perturbation theory in comparison to the standard fusion process. However these factors are relatively mild compared to the strong suppression due to the barrier penetration factor at low energies. By considering a specific reaction we find that its cross section is higher than the cross section of the standard process by a factor of 10^{41} or more. This enhancement makes LENRs observable in laboratory even for relatively low energies. Hence we argue that LENRs are possible and we provide a theoretical set up which may explain many of the experimental claims in this field.

1 Introduction

The phenomenon of low energy nuclear reactions (LENRs) has now been studied for many decades. The original results presented in [1, 2] were quickly dismissed since several follow up experiments were not able to reproduce them. Several experiments did find confirmation of the results while others disagreed. A major reason for the dismissal was that the phenomenon was thought to be theoretically impossible [3, 4]. However both experimental and theoretical

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research in this field has continued over the years. A useful summary is provided in the collection of articles in Ref. [5] and in the papers [6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18].

Subsequently the experimental work has shown that there is indeed an enhancement of cross sections at low energies [19, 20, 21, 22, 23, 24, 25, 26, 27]. It has been argued that the experimental data is better characterized in terms of production of nuclear particles rather than excess heat [28]. While the experimental results at very low energies require careful further analysis, the results in the energy range of order few keV have consistently shown enhanced cross sections in condensed medium. Some of these experiments involve a beam of high energy deuteron ions impinging on a solid medium [25]. The lower energy experiments use electrolysis at some suitably chosen potential differences. The community has slowly come to an agreement that the nuclear fusion cross sections in this energy regime are much higher than expected theoretically and the ratio of experimental to theoretically predicted cross sections increases rapidly with decrease in energy. There have been many attempts to explain this behaviour by a suitable generalization of the theoretical analysis [11, 12, 14, 16, 20, 27, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44]. Many theoretical models invoke electronic contribution for enhanced cross sections [45, 46, 47, 48, 49]. Other models propose correlated states [50, 51], neutron catalyzed fusion [52], Di-neutron [53], Bose-Einstein condensation [54], electroweak interactions [55, 56] etc. However the LENR phenomena is still not understood completely.

Several theoretical papers have tried to examine the screening due to electrons in a condensed medium [27, 57, 58]. A detailed study of screening has been performed in [27] with the conclusion that by itself it is unable to explain the enhanced cross sections even in the energy range of 1 KeV [20]. There are many other interesting ideas [32, 33]. It has been suggested that the incident particle may be in a superposition of several states and due to destructive interference the reflection coefficient becomes significantly smaller than unity leading to considerable enhancement in transmission [30]. It has also been proposed that the nuclear particles may form clusters due to enhanced electron screening which may lead to smaller Coulomb barrier [31].

We point out that there exist well known situations in which a particle is able to tunnel through a high potential barrier with rather high probability. We consider a text book example of a double hump potential (see page 129 of [59], third edition). Here we assume that the potential barrier is much larger than the energy of the incident particle. Using the WKB approximation, one finds that although the transmission for such a potential is generally small, there exist some special values of energy for which the transmission can be very large. Whether such a mechanism is really realized in nuclear fusion reactions in condensed medium is not clear. Here we use it only to illustrate that high potential does not always mean low transmission. It is also well known that the nuclear fusion rates are rather large if the reaction proceeds by resonance. This arises when the energy of the incident particle is equal or close to one of the nuclear states. In the present paper, however, we shall not consider resonant reactions.

We are interested in explaining the phenomena of LENRs, the energies being of order eV. We point out that LENRs have also been seen experimentally at energies as low as 30-40 meV. In this paper we propose a new process which has so far not been considered in the literature and may be relevant for LENRs. In this case the reaction proceeds by a perturbation in the initial state. This perturbation may be in the form of a real photon or a virtual photon. The virtual photon may be exchanged by an incident flux of electrons, or other charged particles, with the