THE PHYSICAL-CHEMICAL AND NUCLEAR MULTISTAGE REACTION MECHANISM AND THE MULTISTAGE IGNITION CONDITION ON COLD FUSION

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ABSTRACT

Combining the known theories we propose the physical-chemical and nuclear multistage reaction mechanism on cold fusion. Then the multistage ignition condition, which is analogous to the Lawson criterion, and its various forms are obtained, and a concrete threshold value is estimated for the D-Pd system.

Nowadays cold fusion not only has been confirmed by more and more experiments, but also we believe that it is a kind of nuclear reaction. For this purpose we have proposed the multistage nuclear reaction mechanism of cold fusion [1], in which, first D+D→T+p or He^3+n; next p-nuclei reacts; then various nuclei react, etc. Moreover, some results are calculated quantitatively and some predictions are discussed. But the recent theories are unsatisfactory still for cold fusion at very low energy, in which the nuclear reaction probability is too small according to the quantum mechanics, even though the Coulomb screening effect is considered.

So far, the nuclear reaction mechanism of cold fusion is mainly of two types, (1) Deuterons accelerated by an electric field react directly with Pd nuclei or deuterons, etc., on the cathode. The multistage nuclear reaction belongs to this type, and (2) Deuterons accumulate continuously on the cathode, and finally, a plasma is formed. It includes some Coulomb screening theories. But both probabilities at low energy are very small. Therefore, some adhere to the opinion that cold fusion is only a physical or chemical reaction. Of course, they cannot give an explanation for many experimental phenomena of cold fusion.

We combine both mechanisms and extend the multistage nuclear reaction mechanism, then propose the physical-chemical and nuclear multistage reaction mechanism of cold fusion. First, a physical-chemical reaction happens between the cathode material and deuterons, etc., under action of electric current, etc. In this process, on the one hand deuterons accumulate continuously on the cathode, on the other hand the plasma on the cathode is heated. Next, when the time reaches a threshold value, the multistage nuclear reaction may appear.

From the general consideration we propose the ignition condition of cold fusion, which is analogous to the Lawson criterion of thermonuclear fusion [2], and research its various forms.

The total input energy for a system per unit volume

$$E_{in} = E_e + 3n_ikT_i + E_i + E_l , \tag{1}$$

where E_e=IUt/V=ρUt/l is the input electric energy (ρ is the electric current density, U is the voltage, t is the action time of electric current, l should be the action thickness of the electric current on the cathode),

$3n_i kT_i$ is the initial kinetic energy of plasma formed under action of the electric current, etc., in solution, E_i is other input energy (including heated energy, stirring energy, etc.), E_l is various energy loss (including the radiation loss) of system. The total output energy of the system

$$E_{out} = P_R\tau + P_c\tau' \tag{2}$$

where P_R and τ are power and time of nuclear fusion, P_c and τ' are power and time of physical-chemical reaction on the cathode. Then we obtain a form of the general criterion of cold fusion

$$E_{in} \leq E_{out}\ , \tag{3}$$

i.e.

$$\rho Utl^{-1} + 3n_i kT_i + E_i + E_l \leq P_R\tau + P_c\tau'. \tag{4}$$

For a concrete installation the produced energy cannot completely transform to a useful gain in energy. Suppose that the transformation efficiency is η, so the ignition condition of cold fusion, which may keep recirculation and derive a beneficial result of energy, i.e., another form of the general criterion is

$$\eta(E_{in} + E_{out}) \geq E_{in}\ , \tag{5}$$

i.e.

$$\eta(P_R\tau + P_c\tau') / (\rho Utl^{-1} + 3n_i kT_i + E_i + E_l) \geq 1\text{-}\eta. \tag{6}$$

The above criteria may have various concrete forms for those different reaction mechanisms.

In the different processes there are different forms of criterion for the physical-chemical and nuclear multistage reaction mechanism. In the first stage, suppose that the nuclear reaction may be neglected, the cathode plasma is being heated by the physical-chemical reaction, so eqs. (4) and (6) become the first ignition condition

$$P_c\tau' \geq \rho Utl^{-1} + 3n_i kT_i + E_i + E_l\ , \tag{7}$$

and

$$\eta P_c\tau' / (\rho Utl^{-1} + 3n_i kT_i + E_i + E_l) \geq 1\text{-}\eta. \tag{8}$$

In the second stage, the physical-chemical reaction energy is also input for the condition under which the nuclear reaction can be kept, so we obtain the second ignition condition. We assume that the physical-chemical energy heats plasma on the cathode continuously, and finally, the critical temperature T_o of nuclear reaction is reached. In this case, the input energy is $\rho Utl^{-1} + 3n_i kT_i + E_i + E_l$ from (7), while according to the Lawson condition of thermonuclear fusion, the input energy should be $3nkT_o+P_b\tau$. Therefore, suppose that the input electric energy transforms into the physical-chemical energy, which heats the plasma, let the transformation efficiency be η, furthermore, E_i, E_l and $P_b\tau$ are neglected, so

$$3nkT_o = \eta(\rho Utl^{-1} + 3n_i kT_i),$$

i.e.

$$kT_o = \frac{\eta}{3n}(\rho Utl^{-1} + 3n_i kT_i). \tag{9}$$

It is namely an approximate formula of the second ignition condition.

According to the present theory, kT_o should be a limited value, so we may obtain the general conclusion:

the favorable conditions for cold fusion are larger electric current density ρ, higher voltage U, longer time, smaller *l* and n. It is consistent with our prediction based on the quantum theory [1]. But, because $P_R = RE_R$, and

$$R_{DD} = 2.3 \times 10^{-14} n_{DD}^2 (kT)^{2/3} \exp[-18.8/(kT)^{1/3}], \qquad (10)$$

which is directly proportional to n^2 for the D+D reaction, the density n cannot be too small.

By using the D-Pd system as an example, a concrete threshold value may be estimated. Since at present the conditions under which cold fusion can happen are [3]: $n_D/n_{Pd} \geq$ O.9, n_D = O.9n_{Pd} = 6.03 x 10^{22} cm^{-3}; the keeping time of electric current t = 300h = 1.08 x $10^{δ}$s; ρ 200 mA cm^{-2} and U = 220 V, $kT_o = 1.64(\eta/l)$keV + $\eta(n_i/n)kT_i$. If the second term is neglected, let η = ½ and l = 1mm, so kT_o = 8.2keV. Therefore, the nuclear fusion may be produced under above the conditions from this criterion. We can infer that cold fusion may happen, so long as above threshold values may be reached when the experiments fulfill various conditions. Further, combining new experiments and theories, the criterion condition can be corrected and developed.

REFERENCES

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