

COLD FUSION AND SUPERFAST LOW-TEMPERATURE CHEMICAL PROCESSES IN SOLIDS: COMMON BASIS FOR UNDERSTANDING

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ABSTRACT

It is obvious that cold nuclear fusion (CF) [1] isn't similar to the thermonuclear "hot" fusion, etc. There are dozens of theoretical models but their abilities to describe CF qualitatively and quantitatively are poor. Even now, five years after the memorable Utah News Conference, it is not clear what CF is similar to. We claim that there are certain analogies between CF, on one hand, and various fast chemical reactions and physico-chemical processes in solids, on the other hand.

In both classes, the processes do not obey the exponential dependence on activation energy/temperature (Arrhenius's law for chemical reactions) and seem to be a similar but more gently sloped function. The most exciting case of solid state chemical processes under consideration is superfast (explosion-like) cryo-chemical reactions in frozen gas mixtures at phase transition temperatures as has been studied by one of us (V.A.L.) during 1968-1978 [2]. Rates of such reactions differ from extrapolated gas phase reaction rates of the same components by 10-10. [sic]

Both the first and second processes are likely to be described by the synergetic activation model [3]. After this consideration, one more type of cold fusion process, namely CF under chemical detonation of solids, is suggested.

THE NATURAL CLASSIFICATION OF COLD FUSION PROCESSES

Since cold nuclear fusion (CF) was announced (Deryagin, et al., 1986 [4], Fleischmann and Pons, 1989 [1]), the kinetic impossibility of intense nuclear reactions having high potential barriers (E.g., Coulomb barrier) that proceed at low temperatures and pressures has been stressed. A complete explanation of this phenomena is one of the main problems in this field. This problem appears as an unprecedented one and together with poor reproducibility of experiments engenders great skepticism in the scientific community to the existence of the phenomenon itself [5].

There is no common acceptable classification of CF types. Using different methods of classification one may obtain up to 10 or more different types of CF [6]. It is likely that under successful development of the field the number of CF versions would be close to the number of elementary particles. For present consideration we neglect certain kinds of CF objects, methods of action, etc., and will limit our categories to the type of processes in solids or on the surface of the solids that produce CF. Therefore, the number of CF types is reduced to four. These are shown in Table 1.

Assignment of known CF systems to one or another of the above types may be not clear, but can be understood after more extensive study of systems noted. First consider some common regularities of or parallels, also taking into account unavoidable differences due to incommensurable activation energy scales. The first concerns mechano-fusion and mechano-chemistry. These phenomena were observed in a variety of systems under different kinds of action: with single deuteride crystals and with D₂O ice

Table 1. Types of CF versus analogous physicochemical processes in solids

1..Destruction of crystal lattice	
Mechano-Fusion: Deryagin et al., 1986	Mechano-Chemistry: Yaroslavskii, 1989
2. Cooperative mass transfer	
Electrochemical fusion in Pd: Fleischmann, Pons, 1989	Conjugated diffusion in Pd: Sokol'skii et al., 1988
3. Phase transition	
Fusion in ferroelectrics: Daryagin et al., 1992	Fast cryochemical reactions: Lishnevskii, 1978
4. Surface dynamics	
Light water fusion on Ni: Mills, 1991 Bush, Eagleton, 1992	Heterogeneous catalysis:
5. Detonation of Solids	
Deto-fusion <div style="border: 1px solid black; padding: 2px; display: inline-block;">Free position</div>	Chemical detonation: Yenicolopyan et al., 1991

polycrystals in the case of fusion [4], and a set of inorganic crystalline salts and their mixtures, polymers etc. in the case of chemistry [7]. The type of "trigger" action may be different, such as: shock wave impact to samples, bullet blast, mechanical grinding, pressure plus mechanical action, etc. The result is similar in all cases: nuclear or chemical reaction rates at small or large magnitudes as compared to background rates at the same temperatures without mechanical action. We especially point out that the specified action itself cannot lead to sufficient heating of the reaction materials, and the temperature changes under mechanical action are negligible from the point of view both nuclear fusion and chemical reaction activation. The matter is concerned with not heating of the reaction medium, i.e. enhancing chaotic motion in solid, but with unidirectional action on it.

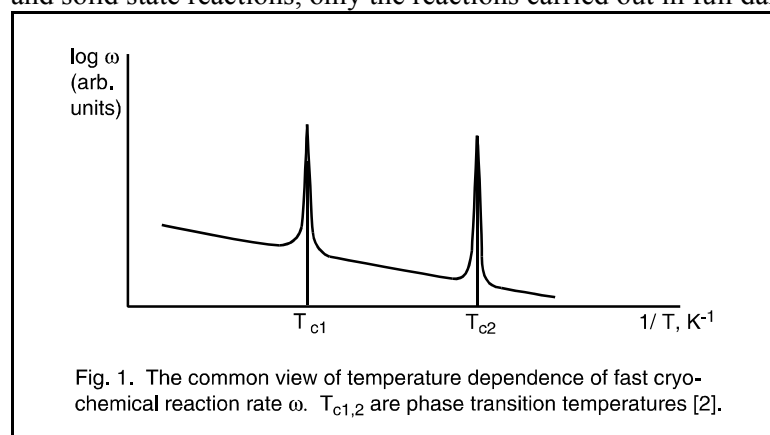
The second mode concerns the most famous CF version - the Fleischmann-Pons effect [1] and may also include such CF as the following: Ti loading by deuterium gas experiments by De Ninno et al., [8] and Kaliev-Baraboshkin tungsten bronzes - deuterium gas loading experiments [9]. The physicochemical analog is surprising but could be compared with the phenomenon of the high mobility of impurities in palladium and palladium alloys under conjugate transfer of hydrogen isotopes [10]. The acceleration of such a process, using significant activation energy, exceeds expectations by ten orders of magnitude more.

The next comparison concerns the nuclear and chemical anomalies under phase transition in solids. This phenomenon in the nuclear fusion field has been discovered by Deryagin and collaborators in 1992 [11]. We suppose that the same phenomenon is concerned, to some extent, in some other versions of CF, e.g., in above mentioned Ti-loading by deuterium gas with thermal cycling [8] and in Samgin-Baraboshkin's 1993 experiment on electrochemical deuteration of the strontium cerate hydrogen-ion conductor using thermal cycling [12].

THE SUPERFAST CRYOCHEMICAL REACTIONS IN SOLIDS - THE CLOSEST CHEMICAL ANALOG OF COLD FUSION

It is worth mentioning that the physicochemical analogy to CF is the most exciting one. It was studied by one of us (V.A.L.) during 1968-1978 in Minsk [2]. Fast exothermic cryochemical reactions may proceed in some electronic, protonic, and other donor-acceptor molecular systems having strong cooperative interactions. We especially note that most of the chemical reactions of the same components, in a gas phase, do not proceed at significant rates in ambient and moderate temperatures due to the relatively high activation energies of valence-saturated molecular reactions. Temperature dependencies of the noted reaction rates are significantly non-Arrhenius's ones, and the rates themselves are high and even explosion-like down to liquid nitrogen temperature - 77°K.

Usually the reaction mixtures for noted process - gas compositions having stoichiometric donor-to-accepter ratio fixed at 77°K are non-equilibrium processes for their structures and compositions. When treated by slow precipitation (freezing) at 77°K, the reaction activity of these mixtures proceeds rapidly and entirely at the temperatures some (3° to 20°K) below the phase transition points (including intermediate complexes and eutectics) such as melting points or structure transitions. Acceleration of the cryochemical reactions under phase transitions in solids appears to be up to 30 or even 60 orders of magnitude higher than expected by Arrhenius's rates for the same components in a gas phase or at high or enhanced temperatures as extrapolated down to the temperature of relevant phase transition (see Fig. 1). In all cases, both gas phase and solid state reactions, only the reactions carried out in full darkness are taken into account.



It is especially noted that the features (mentioned above) are not mainly produced by the quantum phenomena because the upper temperature of quantum tunneling T of particles through potential barrier E for low-temperature chemical reactions is given by the following equation derived by Goldanskii [7]:

$$T_t = \frac{h}{k\pi\sqrt{2}d} \cdot \sqrt{\frac{E}{m}} \quad (1)$$

(where h is the Plank's constant, k is the Boltzmann constant, d is the hopping length, m is the mass of the particle). The resulting temperature is 50°K for protons and correspondingly lower for particles having larger masses whereas the reported reactions proceed at more temperatures. Moreover, quantum tunneling, in this case, must exhibit a constant reaction rate below T as compared with its rate as temperatures are decreased. The observed enormous increasing value of the reaction at fixed temperature points is not expected.

It is also noted that at relatively low temperatures in solid state materials even small changes of entropy due to formation of complexes or cooperative effects in clusters sharply exhibit macro-effects of superfast cryochemical processes without the introduction of foreign matter, such as a catalyzer, although thermal energies of the molecules at the same temperatures are far lower than the quantum zero vibration energy level or Van der Waals intermolecular interaction energy.

One more analogy - compare the light water-nickel CF system by Mills, Bush-Eagleton and their followers with the surface dynamics of hydrogen and various heterogeneous catalysts. This effect is proposed and considered in detail by Glück [13].

THE SYNERGETIC ACTIVATION MODEL - A COMMON BASIS FOR COLD FUSION AND FAST CHEMICAL REACTIONS IN SOLIDS

It's easily seen that there are clear similarities in the horizontal rows of Table 1. Now let's consider similarities in the vertical columns that aren't so evident. There seem to be similar or common points between different types of CF as is observed between different kinds of chemical reactions and/or transport phenomena in solids. But it's not so.

The concept connecting different cells in the right column of the table is, in our opinion, the common nature of cooperative processes which proceed in accordance with synergetic activation (SA) model. This model dramatically distinguishes unidirectional cooperative action from thermal, chaotic actions. The main points of the SA model are as follows:

1. SA model is more gently sloped than is the exponential distribution of atoms or molecules by energy - namely quasi-power one:

$$P'_n \approx (E_n / E_0)^{-\lambda} \quad (2)$$

(where P is the probability of obtaining the energy packet E by the atom, E is the average energy per atom, e.g. the thermal one, $\lambda > 1$ and its value depends on the structure of excited energy levels of the system). This combination makes overcoming potential barriers by the system easier. Thus, this effect is possible in highly non-equilibrium, self-organizing systems. The results is a sequel to nondirect but multi-stage excitation of atoms (molecules etc.) up to higher excitation levels in some kinds of dissipative structures (see, for example, [14]).

2. Such distribution is realized in spatiotemporal limits of shock or detonation wave (SW and DW correspondingly) fronts that are therefore considered as dynamic, dissipative structures.

3. These shock waves may be introduced into solids from outside but a self-generation of SW (DW) and self-focusing of the same waves can then promote accumulation of energy in focal zones (such as are possible under mechanical action upon crystals with the resulting destruction of the lattice, phase transition implementation in the same or intense heat and mass transfer (e.g. intense hydrogen or deuterium transport) in perfect crystalline solids or on their surfaces in vicinity of phase separation region. As for the self-generation of shock waves, a phase transition and flawless crystal patterns are the conventional conditions to produce shock waves - owing to nonlinear acoustics.

The synergetic activation model is suitable for the understanding of a wide range of processes in highly non-equilibrium systems. The model is able to predict some important criteria for the implementation of high-excitation phenomena in such systems concerning both the possibility of shock wave-type nonlinear wave formation under appropriate conditions (such as phase transition, cooperative mass transfer etc.) and ensuring easy propagation of the waves in solids (such as low enough extended defects content in a crystal lattice).

Therefore, we suppose that significant and enormous acceleration of different physicochemical processes may be caused not by quantum phenomena but cooperative, synergetic processes.

We suppose also that the left column i.e. CF area may also be described within the framework of the synergetic activation model. Moreover, certain criteria of reproducible CF implementation proposed by the SA model are in accordance with published experimental data, as we've stated recently. It is unfortunate, but quite natural, that most of published papers do not record and publish data allowing one to ascertain the real crystal structure of the samples used in CF experiments. However, the minor part of the papers concerning relevant data, exhibit certain positive correlations with the main SA criterion - lattice perfectness - and the distinct correlation of the type "necessary, but not sufficient" with the second one - highly non-equilibrium state of the system under action, as we've reported recently.

So we have to claim once more that CF phenomena are caused mainly not by quantum but by synergetic phenomena. In addition to distinct criteria of CF reproducibility, the SA model is able to predict some new CF types, as is shown below:

PREDICTION OF ONE MORE COLD FUSION PROCESS TYPE

Turning back to the right column of Table 1 - physicochemical analogies of CF types - we must add one more cell. This cell is to be occupied by chemical reactions of detonation of solids. Similar to other members of this group, these exothermic processes initiated by some type of shocking action to some solids. These reactions are characterized by their superhigh rates at ambient and moderate temperatures in strange contradiction with low rates of the usual combustion of the same crystal substances when ignited. The differences between volume rates may consist up to 20 orders of magnitude. Similar to other mentioned processes, the detonation of solids and the dependency on temperature do not obey the Arrhenius's law. This fact allowed Yenikolopyan, et al., [15] to propose that chemical detonation is implemented in non-kinetic but so-called "dynamic" regime and its rate is not dependent on temperature. The latter report may not be correct, however some structural aspects of the model fit experimental data and are acceptable. Worthy of mention is that the chemical detonation of solids may be best described by SA model. Subsequent application of the SA model to detonation of solids [16] allowed us to derive the analytical expression of detonation rate v , dependencies on temperature T , activation energy E , and heat release DE of the reaction:

$$v_{dw} = A \cdot \frac{(kT)^\lambda}{E_n^{\lambda-1/2}} \cdot \sqrt{1 + \frac{\Delta E}{E_n}} \quad (3)$$

This equation is in satisfactory agreement with experimental data. As one can see, the corresponding cell on the CF side of the table is empty. Now we can predict that it must be filled by corresponding kind of CF phenomenon. What kind of a process might it be?

We are convinced that the chemical detonation of solids must be accompanied by nuclear fusion with a probability that differs from zero. Moreover, deto-fusion must be more intense than other CF types because the average energy per atom (molecule) in the detonation wave front is higher than typical thermal energies or energies of phase transitions (E in the formula 2).

It may be said that similar to heavy water and light water fusion, the predicted deto-fusion is possible in both deuterium-containing solids and in their protium equivalents. The important point to be stressed is

that the deto-fusion rates/intensities in deuterated solid substances are expected to be similar to CF rates but the reaction products are expected to be similar to "hot" fusion reactions due to destruction of crystal lattices. It is suggested that it will be impossible to stabilize the He reactions in such a reaction. One more important point is a prime criterion of SA model: the specimen used for the reaction must be perfect crystal with low (down to 10 per square centimeter) content of extended defects.

If one understands the above mentioned parameters for the predicted deto-fusion, the discovery of the effect appears to be quite easy. We have shown the deto-fusion cell as empty in Table 1 and challenge any of our interested colleagues to find the predicted effect to fill this cell.

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ACKNOWLEDGEMENTS

One of us (V.A. F.) acknowledges Belarus Fundamental Researches Foundation for financial support within Grant No F54-144/1.

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