Facts in the Cold Fusion Phenomenon (CFP)

The cold fusion phenomenon (CFP) has been discovered in 1989 and developed successively in these 25 years despite the difficulties to understand the facts revealed by experimental data such as qualitative reproducibility and nuclear reactions in near-room temperature environment. So, there are dispute concerning what are the facts in the CFP; some denies them for the lack of reasonable explanations and other accept them believing in the techniques applied to the measurement.

Our point of view to this problem is of course the latter. We have given a consistent explanation of the whole data obtained by reliable experiments in our papers and books. The most extensive presentations of our point of view have been given in our two books [Kozima 1998, 2006] and the recent up-to-date ones have been given in our several papers [Kozima 2015a, 2015b].

In this paper, we give the facts included in the outline of our point of view on this problem according to our explanations given in these books and papers.

1. The Field where occur the events of the Cold Fusion Phenomenon {Kozima 1998 (Secs. 6 – 10), 2006 (Chapter 2, Facts of the CFP)}

Table 1. System and Obtained Evidence of CFP. Mother solids, agents, experimental methods, direct and indirect evidence, cumulative and dissipative observables of the cold fusion phenomenon. Q and NT express excess heat and the nuclear transmutation, respectively. Direct evidence of nuclear reactions in CFP are Energy (ε) and position (***r***) dependencies of reaction products, decrease of decay constants of radiative nuclides, decrease of fission threshold energy of compound nuclei. [Kozima 2006 (Table 2.1 supplemented by recent papers)]

Mother solids	Pd, Ti, Ni, KCl + LiCl, $ReBa_2Cu_3O_7$, Na_xWO_3, KD_2PO_4, TGS, $SrCe_aY_bNB_cO_d$, XLPE, C (graphite)
Agents	*n*, *d*, *p*, ${}^{6}_{3}Li$, ${}^{10}_{3}B$, ${}^{39}_{19}K$, ${}^{85}_{37}Rb$, ${}^{87}_{37}Rb$、(ion beam)
Experimental methods	Electrolysis, Gas discharge, gas contact, (ion beam irradiation)
Direct Evidences	Gamma ray spectrum γ (ε), neutron energy spectrum *n*(ε), Space distribution of NT products NT(***r***), decrease of decay constants, lowering of fission threshold energy

Indirect Evidences	Excess energy Q, number of neutrons N_n, amount of tritium atom N_t, helium-4 atom N_{He4}, NT (NT_D, NT_F, NT_A), X-ray spectrum X(ε)
Cumulative Observables	NT($\boldsymbol{r}$), amount of tritium atom N_t, helium-4 N_{He4},
Dissipative Observables	Excess energy Q, neutron energy spectrum n(ε), number of neutrons $N_{n,}$ Gamma ray spectrum γ (ε), X-ray spectrum X(ε),

2. Experimental Data Sets in Deuterium and Protium Systems

Table 2.1 Pd/D(H)/Li System. Neutron density n_n and relations between the numbers N_x of event X obtained by theoretical analysis of experimental data on the TNCF model ($N_Q \equiv Q$ (MeV)/5 (MeV)) [Kozima 2006, Table 2.2]. Typical value of the surface vs. volume ratio S/V (cm^{-1}) of the sample is tabulated, also. As we see here, there are several data sets of the CFP in Pd/H/Li(S) systems even if the combination Pd/D/Li is overwhelmingly preferable for the phenomenon. [Kozima 1998 (Table 11.2)]

Authors	System	S/V cm^{-1}	Measured Quantities	n_n cm^{-3}	Other Results (Remarks)
Fleischmann et al.[1)]	Pd/D/Li	6 ~40	Q, t, n $N_t/N_n \sim 4\times10^7$ $N_Q/N_t \sim 0.25$	$\sim10^9$	(Q=10W/cm^3) $N_t/N_n \sim 10^6$ $N_Q/N_t = 1.0$
Morrey et al.[1−4)]	Pd/D/Li	20	Q, ^{4}He ^{4}He in $\ell \leq 25\mu$m	4.8×10^8	$N_Q/N_{He} \sim 5.4$ (If 3% ^{4}He in Pd)
Roulette[1''')]	Pd/D/Li	63	Q	$\sim10^{12}$	
Storms[4)]	Pd/D/Li	9	$t(1.8\times10^2$ Bq/mℓ)	2.2×10^7	(τ=250h)
Storms[4')]	Pd/D/Li	22	Q (Q_{max}=7W)	5.5×10^{10}	(τ=120h)
Takahashi et al.[5')]	Pd/D/Li	2.7	t, n $N_t/N_n \sim 6.7\times10^4$	3×10^5	$N_t/N_n \sim$ 5.3×10^5
Miles et al.[18')]	Pd/D/Li	5	Q, ^{4}He ($N_Q/N_{He}=1\sim10$)	$\sim10^{10}$	$N_Q/N_{He} \sim 5$
Okamoto et al.[12')]	Pd/D/Li	23	Q, NT$_D$ $\ell_0 \sim 1\ \mu$m	$\sim10^{10}$	$N_Q/N_{NT} \sim 1.4$ (^{27}Al→^{28}Si)
Oya[12−5)]	Pd/D/Li	41	Q, γ spectrum	3.0×10^9	(with ^{252}Cf)
Arata. et al.[14)]	Pd/D/Li	7.5 $\times10^4$	Q, ^{4}He ($10^{20}\sim10^{21}$ cm^{-3}) $N_Q/N_{He} \sim 6$	$\sim10^{12}$	(Assume t channeling in Pd wall)
McKubre[3)]	Pd/D/Li	125	Q (& Formula)	$\sim10^{10}$	Qualit.explan.
Passell[3''')]	Pd/D/Li	400	NT$_D$	1.1×10^9	$N_{NT}/N_Q=2$
Cravens[24'')]	Pd/H/Li	4000	Q (Q_{out}/Q_{in}=3.8)	8.5×10^9	(If PdD exists)
Bockris[43)]	Pd/D/Li	5.3	t, ^{4}He; $N_t/N_{He} \sim 240$	3.2×10^6	$N_t/N_{He} \sim 8$
Lipson[15−4)]	Pd/D/Na	200	γ (E_γ=6.25MeV)	4×10^5	If effic. =1%
Will[45)]	Pd/D_2SO_4	21	$t(1.8\times10^5$/cm^{2}s)	3.5×10^7	(If $\ell_0 \sim 10\mu$m)
Cellucci et al.[51''')]	Pd/D/Li	40	Q, ^{4}He $N_Q/N_{He}=1\sim5$	2.2×10^9	(IfQ=5W) $N_Q/N_{He}=1$
Celani[32''')]	Pd/D/Li	400	Q (Q_{max}=7 W)	1.0×10^{12}	(If200%output)
Ota[53)]	Pd/D/Li	10	Q (113%)	3.5×10^{10}	(τ=220 h)
Gozzi[51'')]	Pd/D/Li	14	Q, t, ^{4}He	$\sim10^{11}$	($\tau \sim 10^3$h)
Bush[27')]	Ag/PdD/Li	2000	Q (Q_{max}=6W)	1.1×10^9	(τ=54d,Film)
Mizuno [26−4)]	Pd/D/Li (If Cr in Pd)	3.4	Q, NT$_D$ $\ell \leq 2\ \mu$m)	2.6×10^8	τ=30d,Pd 1cm$\phi\times$10cm
Iwamura[17)]	PdD$_x$	20	n (400/s),t	3.9×10^8	$4.4\times10^6 t$/s
Itoh[17')]	PdD$_x$	13.3	n (22/m),t	8.7×10^7	$7.3\times10^{10} t$/s
Itoh[17'')]	PdD$_x$	13.3	n (2.1×10^3/s)	3.9×10^8	
Iwamura [17''')]	PdD$_x$	20	Q (4 W) NT$_F$(Ti, Cr etc.)	3.3×10^{10}	(NT$_F$? unexplained)
Miley[65)]	Pd/H/Li	150	NT$_F$(Ni,Zn,$\cdots\cdots$)	4.5×10^{12}	
Dash[59)]	Pd/D,H_2SO_4	57	Q, NT$_D$	$\sim10^{12}$	Pt→Au
Kozima[203)]	Pd/D,H/Li	200	n (2.5×10^{-4}/s)	2.5×10^2	Effic. =0.44%

Table 2.2. Ni/H/K System and others. Neutron density n_n and relations between the numbers N_x of event X obtained theoretical analysis of experimental data on TNCF model ($N_Q \equiv Q$ (MeV)/5 (MeV)) [Kozima 2006, Table 2.3]. Typical value of the surface vs. volume ratio S/V (cm^{-1}) of the sample is tabulated, also. As we see here, there are several data sets of the CFP in Ni/D/K systems even if the combination Ni/H/K is overwhelmingly preferable for the phenomenon. [Kozima 1998 (Table 11.3)]

Authors	System	S/V cm^{-1}	Measured Quantities	n_n cm^{-3}	Other Results (Remarks)
Jones[2)]	Ti/D/Li	8.1	n (2.45 MeV)	3.1×10^{11}	
Mills[25)]	Ni/H/K	160	Q (0.13 W)	3.4×10^{10}	
Bush[27′)]	Ni/H/K Ni/H/Na	~160 ~160	NT_D(Ca) NT_D(Mg)	5.3×10^{10} 5.3×10^{11}	$N_Q/N_{NT}\sim3.5$ ($^{40}K_T=0$)
Bush[27″)]	Ni/H/Rb	$\sim10^4$	NT_D(Sr)	1.6×10^7	$N_Q/N_{NT}\sim3$
Savva-timova[34″)]	Pd/D_2	100	NT_D(Ag)	9×10^{10}	
Alekseev[44′)]	Mo/D_2	4.1	t ($\sim10^7$/s)	1.8×10^7	(If MoD)
Romoda-nov[44‴)]	TiC/D	4.1	t ($\sim10^6$/s)	$\sim10^6$	(D/Ti~ 0.5assumed)
Reifensch-weiler[38′)]	$TiT_{0.0035}$	7×10^5	β decay reduction	1.1×10^9	(T=0~450°C)
Dufour[7)]	Pd,SS/D_2 Pd,SS/H_2	48	Q, t, n	9.2×10^{11} 4.0×10^9	(D(H)/Pd~1 is assumed)
Claytor[9)]	Pd/D_2	400	t (12.5 nCi/h)	1.6×10^{13}	(If D/Pd~0.5)
Srinivasan[16)]	Ti/D_2	1500	t ($t/d\sim10^{-5}$)	1.9×10^8	(Aged plate)
De Ninno[6′)]	Ti/D_2	440	n , t	1.2×10^6	(D/Ti=1,1w)
Focardi[23)]	Ni/H_2	8.2	Q	3.0×10^{12}	(If$N_p=10^{21}$)
Oriani[52)]	$SrCeO_3/D_2$	22	$Q\sim$ 0.7W	4.0×10^{10}	V=0.31cm^3
Notoya[35″)]	Ni/D,H/K	3.4 $\times10^4$	Q (0.9 W), t	2.4×10^{13}	(If 1/2 t is in liquid)
Notoya[35−4)]	Ni/D,H/K	same	NT_D(Ca)	1.4×10^9	(Sintered Ni)
Yamada[54)]	Pd/D_2	185	n , NT_D(C)	2.0×10^{12}	
Cuevas[55)]	$TiD_{1.5}$	134	n (102 n /s)	5.4×10^{11}	
Niedra[56)]	Ni/H/K	80	Q (11.4 W)	1.4×10^9	5km×0.5mmϕ
Ohmori[22″)]	Au/H/K	200	Q, NT_F(Fe)	$\sim10^{11}$	(Au plate)
Li[57)]	Pd/D_2	185	Q	1.6 $\times10^{12}$	(Pd wire)
Qiao[57′)]	Pd/H_2	185	NT_F(Zn)	3.8 $\times10^{10}$	(40%NTin 1y)
Bressani[58′)]	Ti/D_2	$\leq10^3$?	n (ε)	10^5-10^6	(Ti shaving)
Miley[65′)]	Ni/H/Li	50	NT_D(Fe,Cr,$\cdots$)	1.7 $\times10^{12}$	

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