C12.* Analysis of Experimental Data Sets on the Biotransmutation by Vysotskii et al. [Kozima 2016d]

The nuclear transmutations in biological systems (biotransmutations) have been investigated for more than two centuries as reviewed in several books by Komaki [Komaki 1993] and Kush [Kushi 1994] and we have analyzed them tentatively [Kozima 1996a] by using our TNCF model developed for the cold fusion phenomenon (CFP) in transition metal hydrides/deuterides. Recently, the investigation of the biotransmutations made a great progress in the direction to determine the microscopic origin of the nuclear reactions in the biological system where is apparently no mechanism to accelerate charged particles up to enough energies to cause fusion reactions of nucleons. Vysotskii et al. [Vysotskii 1996, 2000, 2009a, 2013, 2015b] have shown not only the biotransmutation but also the decay-time shortening of radioactive nuclides in systems including microbial cultures: There are data sets showing (1) production of $^{57}_{26}$Fe from $^{55}_{25}$Mn and also (2) acceleration of the decay of radioactive nucleus $^{137}_{55}$Cs, $^{140}_{56}$Ba and $^{140}_{57}$La in several bacterial cultures. In this Appendix, we give analysis of the decay-time shortening from the paper [Kozima 2016d] where have shown consistent explanation of the whole data obtained by Vysotskii et al.

Explanation of Decay-Time Shortening in Biological System

The sophisticated experiments performed by Vysotskii et al. on the nuclear processes in biological systems revealed existence of the decay-time shortening observed already in inorganic CF systems as discussed recently in our paper [Kozima 2014c]. There are two examples of the decay-time shortening in biological system; one for $^{37}_{55}$Cs in electrolytic liquid, MCT + electrolyte (KCl, NaCl, or CaCO3), and another for $^{140}_{56}$Ba and $^{140}_{57}$La in electrolytic liquid (water + metabolically active microorganisms). “MCT” means the microbial catalyst-transmutator, a special kind of granules. Explanation of MCT used in the experiment is given in [Kozima 2016d (Appendix 2)].

Decay time shortening of $^{137}_{55}$Cs

The observed acceleration of the decay process of $^{137}_{55}$Cs isotope is shown in Fig. C12-1.

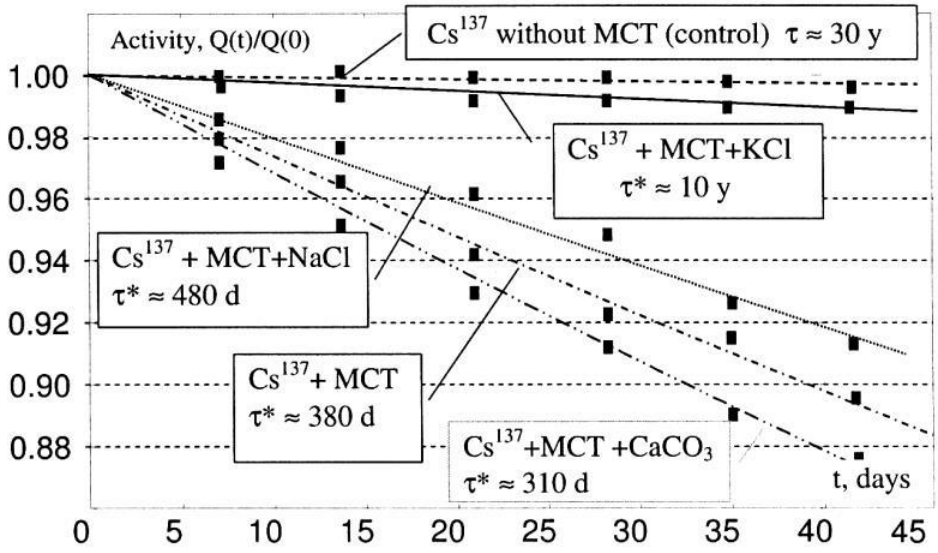

Fig. C12-1 Accelerated deactivation (accelerated decay) of $^{137}_{55}$Cs isotope in "biological cells" with presence of different chemical elements [Vysotskii 2009a (Fig. 3.23), 2013 (Fig. 10)]. "MCT" in the explanation of this figure means the microbial catalyst-transmutator, a special kind of granules. (Cf. [Kozima 2016d (Appendix 2)].

Decay time shortening of $^{140}_{56}$Ba, $^{140}_{57}$La and $^{60}_{27}$Co

Another data of the decay-time shortening in the biological system is obtained in $^{140}_{56}$Ba, $^{140}_{57}$La and $^{60}_{27}$Co in pure reactor water with presence of metabolically active microorganisms as shown in Fig. C12-2.

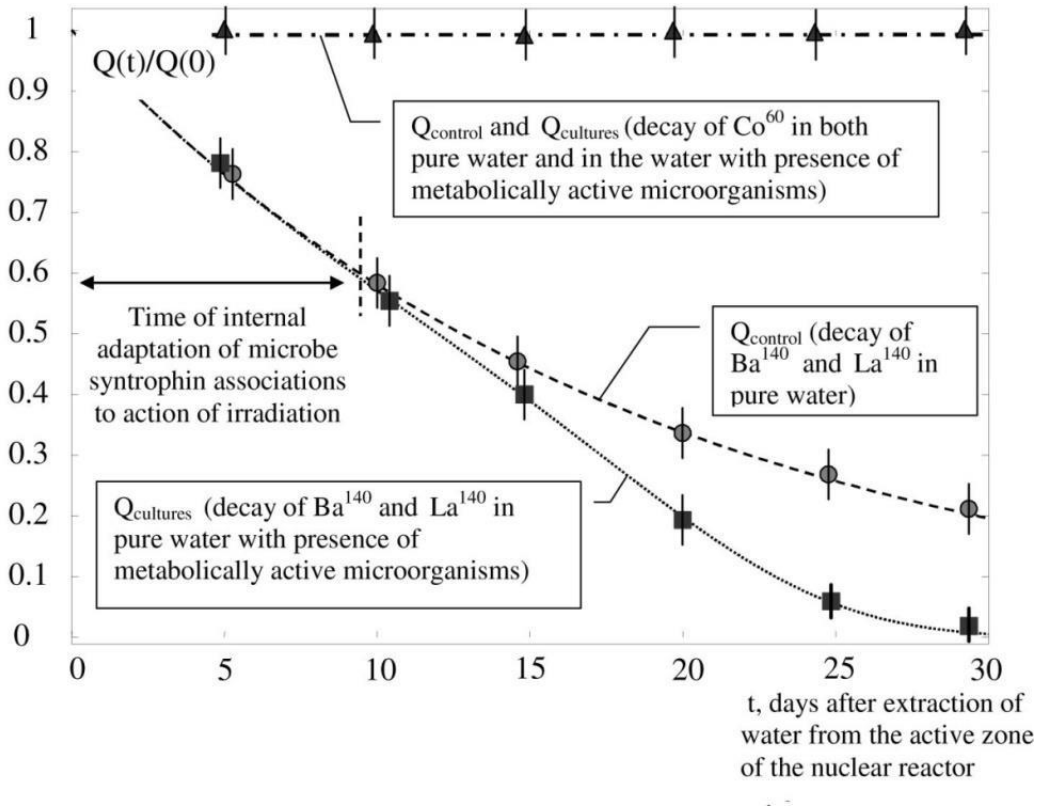

Fig. C12-2 Change of activity Q(t) of the same reactor $^{140}_{56}$Ba, $^{140}_{57}$La and $^{60}_{27}$Co isotopes in the experiment on transmutation (activity Q_{cultures} in pure reactor water with presence of metabolically active microorganisms) and in the control one (activity Q_{control} in the same pure reactor water without microorganisms) [Vysotskii 2009a(Fig. 3.21), 2013 (Fig. 8)]

On the other hand, the behavior of the decay time shortening in transition-metal hydrides had been noticed before and discussed in our paper already [Kozima 2014c].

The decay time shortening of radioactive isotope $^{137}_{55}$Cs which decays in free space according to the following reaction;

$^{137}_{55}\text{Cs} \rightarrow {}^{137}_{56}\text{Ba} + e^{-} + \nu_e$, ($\tau$= 30.07 y) (C12a.1)

Assuming the existence of the trapped neutron in the TNCF model, we can apply the equation of neutron absorption followed by a beta decay to this case;

$^{137}_{55}\text{Cs} + n \rightarrow {}^{138}_{55}\text{Cs}^{*}$, ($\sigma$= 0.113 b) (C12a.2)

$^{138}_{55}\text{Cs}^{*} \rightarrow {}^{138}_{56}\text{Ba} + e^{-} + \underline{\nu}_e$. ($\tau$= 33.41 m) (C12a.3)

The difference of the effect of MCT (microbial catalyst-transmutator) + electrolyte(KCl, NaCl, or CaCO3)on the decay-time shortening may express (1) difference of the density of the trapped neutrons n nor (2) difference of the number of $^{137}_{55}$Cs nuclei on the MCT

surface in the system due to the effect of electrolytic liquids (MCT + electrolytes) on the MCT.

The measured decay times τ^* = 380 d (MCT), 10 y (MCT + KCl), 480 d (MCT + NaCl), and 310 d (MCT + CaCO3) compared to the natural decay time 30.1 y of $^{137}_{55}$Cs in free state show the effect of the electrolytes on MCT where $^{137}_{55}$Cs nuclei are adsorbed and their decay characteristics are drastically influenced by the density of the trapped neutron in samples from our point of view. Thus, the electrolyte seems to have large effect on the adsorption characteristics of $^{137}_{55}$Cs by MCT.

This fact reminds us the effect of K and Li on the CFP of Ni and Pd discussed by us for long [Kozima 2000 (Sec. 4), 2006 (Sec. 2.2.1.2)].

"*It is should be emphasized here that there are preference for combination of a cathode metal (Pd, Ni, Ti, --), an electrolyte (Li, Na, K, or Rb) and a solvent (D_2O or H_2O) to induce CFP*." [Kozima 2000 (p. 45)].

C12a $^{137}_{55}$Cs

Now, let us investigate the characteristics of the decay-time shortening of $^{137}_{55}$Cs in these systems. The temporal evolution of the number of a radioactive nuclide with a decay constant τ is described by following equations;

$N(t) = N(0) \exp (-t/\tau)$ (C12a.4)

$dN/dt = -(N(0)/ \tau) \exp (-t/\tau)$ (C12a.5)

On the other hand, decrease of the number of a nucleus ^A_ZX due to absorption of thermal neutrons described by Eq. (3.2a.6) and the relation (3.2a.7) assumed in our model[Kozima 1998 (Sec. 11.1), 2006 (Sec. 3.2)];

$^A_Z\text{X} + n = {}^A_Z\text{X}^* = {}^{A+1}_Z\text{X}$ + phonons. (C12a.6)

$P = \delta N_X/N_X = 0.35\, n_n v_n\, \sigma_n X$, (C12a.7)

where n_n is the density of the trapped neutron, v_n is the thermal velocity of the assumed trapped neutron, N_X is the number of the nucleus ^A_ZX, and σ_{nX} is the absorption cross section of thermal neutrons by the nucleus X by the reaction (C12a.6) (= 0.113 b for $^{137}_{55}$Cs) assumed to be the same as the thermal neutron absorption cross section in free space. v_n is taken to be 2.2 × 105 cm/s according to our premises of the TNCF model. If a $^{137}_{55}$Cs nucleus is adsorbed by the MCT granules to be reacted by the trapped neutron, the reaction (C12a.6) is written as,

$^{137}_{55}\text{Cs} + n = {}^{138}_{55}\text{Cs}^* = {}^{138}_{55}\text{Cs}$ + phonons. (C12a.8)

The reaction occurs with a probability P in a unit time interval for a nucleus $^{137}_{55}$Cs as expressed in Eq. (C12a.7):

$P = \delta N_{Cs}/N_{Cs} = 0.35\, n_n v_n\, \sigma_{nCs}$. (C12a.9)

Let us determine the density n_n of the TNCF model assuming that the observed decay-time shortenings of $^{137}_{55}$Cs in electrolytic liquids depicted in Fig. C12.1 are the results of the neutron absorption described by Eq. (C12a.8).

For an example of calculation, we take up the case of $^{137}_{55}$Cs in an electrolytic liquid with MCT + CaCO3, where observed the decay time $\tau^* = 310$ d. Using Eq. (C12a.5), we obtain the relative number of decayed nucleus in a unit time (1 day for instance) as

$\delta N/N = -(1/\tau^*) \exp(-t/\tau^*)$

$= -1/(310 \times 8.64 \times 104) = -1/2.68 \times 107$

$= 3.73 \times 10^{-8}$. (C12a.10)

In this calculation, we notice that the exponential factor $\exp(-t/\tau^*) \approx 1$ and does not essentially contribute in the final result.

On the other hand, the equation (C12a.9) gives n_n through the relative number of transmuted $^{137}_{55}$Cs nuclei $\delta N/N$ as;

$n_n = (\delta N/N)/(0.35 \times 2.2 \times 10^5 \times 0.113 \times 10^{-24}) \times 1(s)$

$= (\delta N/N)/(0.35 \times 2.2 \times 0.113 \times 10^{-19})$

$= 1.15 \times 10^{-19}(\delta N/N)$ (C12a.11)

Using the value of $\delta N/N$ given in Eq. (C12 3.2a.10), we obtain the value of n_n in this case as

$n_n = 3.73 \times 10^{-8}/8.70 \times 10^{-19} = 4.29 \times 10^{11}\text{cm}^{-3}$ (C12a.12)

If the number of $^{137}_{55}$Cs adsorbed by MCT granules and that not adsorbed are in the ratio x: $(1-x)$, the calculation should be generalized to take into this fact. In the short time (e.g. 1 day) we are interested in, the number N_0 of $^{137}_{55}$Cs nuclei not adsorbed and therefore not influenced by the trapped neutron keeps its number $(1-x)N_0$ almost the same as before (for the very long decay time of $\tau_0 = 30.1$ y):

$\delta N/N|_1 = 0$. (C12a.13)

On the other hand, the nuclei adsorbed by MCT granules will suffer the action of the trapped neutron and its number xN_0 changes according to the equation (C12a.9):

$\delta N/N|_2 = 0.35\, n_n v_n \sigma_{nM}$, (C12a.14)

Therefore, we have the change δN_0 of the number N_0 of $^{137}_{55}$Cs nuclei after the time interval t (= 1 day) given by $\delta N|_1$ due to the decay process (C12a.5) with $\tau = 30.1$ y and by $\delta N|_2$ due to the neutron trapping (C12a.9). Using the relations (C12a.13) and (C12a.14), we obtain finally the expression for $\delta N_0/N_0$ as given in Eq. (C12a.16):

$\delta N_0 = \delta N|_1 + \delta N|_2 = \delta(1-x)N0|_1 + \delta\, xN0|_2$ (C12a.15)

$\delta N_0/N_0 = x(\delta N_0|_2/N_0) = x(0.35\, n_n v_n \sigma_{nM})$ (C12a.16)

Substituting the values $v_n = 2.2 \times 10^5$ cm/s and $\sigma_{nM} = 0.113$ b, we obtain following equation:

$\delta N_0/N_0 = x\, n_n(0.35 \times 2.2 \times 10^5 \times 0.113 \times 10^{-24})$

$= 8.7 \times 10^{-21} x\, n_n$ (C12a.17)

Therefore, the value n_n in this case is expressed as

$n_n = 1.15 \times 10^{19} (\delta N/N)\, x^{-1}$ (cm^{-3}). (C12a.18)

If x= 1, i.e. all the $^{137}_{55}$Cs nuclei are adsorbed by MCT granules and influenced by the trapped neutron by Eq. (C12a.8), $\delta N/N = 3.73 \times 10^{-8}$ (C12a.10) gives the same value given in (C12a.12);

$n_n = 1.15 \times 10^{19} (\delta N/N)\, x^{-1}$

$= 4.29 \times 10^{11}$ (cm^{-3}). (C12a.19)

This value is compared with the values 10^7–10^{12} cm^{-3} obtained in inorganic CF materials given in our previous books [kozima1998 (Tables 11.2 and 11.3), 2006 (Tables 2.2 and 2.3)].

As the Eq. (C12a.5) (or Eq. (C12a.10)) shows that the decrease of the number of radioactive nuclei is proportional to the decay time τ^* inversely and it is also proportional to x and n_n as shown by Eq. (C12a.16) (where x is the ratio of adsorbed nuclei). The differences of τ^* observed in different electrolytic liquids are explained as follows:

If the density of trapped neutrons n_n is not influenced by the kind of electrolyte in the liquid, the difference of τ^* depend only on the value of x which may depend on the electrolyte. The values of τ^* = 310 d, 380 d, 480 d, 10 y in the liquid with $CaCO_3$, non, NaCl, KCl, respectively, show that the ratios x in these electrolytic liquids are given by 1, 0.8, 0.6, 8.5×10^{-3}, respectively taking the case of $CaCO_3$ as x = 1.

This result may show the aqueous solution of MCT granules is very effective to adsorb $^{137}_{55}$Cs nucleus (and change the value of x) and addition of $CaCO_3$ works positively but that of NaCl and KCl negatively to the adsorption, if our interpretation by the TNCF model of the decay-time shortening in the electrolytic liquids is right.

C12b $^{140}_{56}$Ba and $^{140}_{57}$La

Similarly, we can analyze the cases of $^{140}_{56}$Ba and $^{140}_{57}$La shown in Fig. C12-2. The decays of these nuclides are described by the following formulae:

$^{140}_{56}\mathrm{Ba} \rightarrow {}^{140}_{57}\mathrm{La} + e^- + \underline{\nu_e}$ (τ = 12.752 d) (C12b.1)

$^{140}_{57}\mathrm{La} \rightarrow {}^{140}_{58}\mathrm{Ce} + e^- + \underline{\nu}_e$ (τ = 1.6781 d) (C12b.2)

The decay-time shortenings of these nuclides are explained by the absorption of a neutron by $^{140}_{56}$Ba and $^{140}_{57}$La followed by the beta-decay of the intermediate nuclei as shown below:

$^{140}_{56}\mathrm{Ba} + n \rightarrow {}^{141}_{56}\mathrm{Ba}^*$, ($\sigma$ = 1.63 b) (C12b.3)

$^{141}_{56}Ba^{*} \rightarrow {}^{141}_{57}La + e^{-} + \underline{\nu}_e$ (τ = 18.27 m) (C12b.4)

and

$^{140}_{57}La + n \rightarrow {}^{141}_{56}La^{*}$, ($\sigma$ = 2.73 b) (C12b.5)

$^{141}_{56}La^{*} \rightarrow {}^{141}_{58}Ce + e^{-} + \underline{\nu}_e$ (τ = 3.92 h) (C12b.6)

On the other hand, the decay of $^{60}_{27}Co$ is not influenced measurably by the existence and absorption of the trapped neutrons as shown by following equations:

$^{60}_{27}Co \rightarrow {}^{60}_{58}Ni + e^{-} + \underline{\nu}_e$ (τ = 10.47 m) (C12b.7)

$^{60}_{27}Co + n \rightarrow {}^{61}_{27}Co^{*}$, ($\sigma$ = 2.02b) (C12b.8)

$^{61}_{27}Co^{*} \rightarrow {}^{61}_{58}Ni + e^{-} + \underline{\nu}_e$ (τ= 1.65 h) (C12b.9)

Thus, the experimental data for $^{140}_{56}Ba$, $^{140}_{57}La$ and $^{60}_{27}Co$ shown in Fig. C12-2 is consistently explained by the TNCF model.