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Explanation of Cold Nuclear Fusion and Biotransmutations

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Abstract

Low energy nuclear reactions are possible in condensed matter because of image forces. They result from induced charges at the surface of metals or very polarizable media. The height and width of the Coulomb barrier in free space can thus be reduced. Nuclear fusion requires also the formation of a compound nucleus in one of its excited states, but two deuterons yield an α particle that has 2 excited states. They are respectively accessible at high or low energies. Since the reduction of the Coulomb barrier depends on the local curvature of the interface, cold fusion becomes autocatalytic, but heat production is controllable. Even microbes, plants and animals can produce transmutations. They are also due to image forces. This solves a basic problem in nuclear physics and there are possible applications: facilitated synthesis of superheavy elements and development of a new type of energy sources. They are moderate, but safe.

Keywords

Cold Fusion, Nuclear Reactions, Biological Transmutations, Coulomb Barrier, Image Force, Superheavy Elements, New Energy Source

1. Introduction

The tremendous energy output of the Sun and other stars results from fusion of light nuclei that are freely moving at high velocities. It is usually impossible that they touch one another because of their strong mutual repulsion *in free space*. Contact is then only possible in a very hot plasma, but as soon as two nuclei touch one another, much stronger nuclear forces take over. The nuclei can then remain intact and separate again. It is also possible that all neutrons and protons constitute a new entity. Since the resulting nucleus is not in its ground state, it has to get rid of excess energy. Fusion of two deuterons $d = (p, n)$ yields an

$\alpha = (2p, 2n)$ particle, so that

$$d + d \rightarrow (2p, n) + n(2.45\ \text{MeV}) \rightarrow 3.27\ \text{MeV}$$

$$d + d \rightarrow (p, 2n) + p(3.02\ \text{MeV}) \rightarrow 4.03\ \text{MeV}$$

$$d + d \rightarrow (2p, 2n) + \gamma(23.7\ \text{MeV}) \rightarrow 23.8\ \text{MeV}$$

Since protons and neutrons are strongly bound in *α* particle, their formation liberates a great amount of energy. However, fusion of light nucleons in free space requires high relative velocities. Thermonuclear bombs have thus to be ignited by means of an exploding fission bomb. Fusion reactors require complicated magnetohydrodynamic confinement of a high energy plasma or its creation by means of powerful laser beams. Only "hot fusion" seemed to be possible, but the chemists Pons and Fleischman announced in 1989 at a press conference [1] that they had produced fusion of deuterons at about normal temperature. They knew that the lattice of palladium metals can accommodate a high density of deuterons and thought therefore that these deuterons might there have a chance to touch one another. Since these fusion processes would liberate energy, they verified if that is true. They used an electrolytic cell and performed precise measurements of the energy input and output. They stated that production of excess energy was observed "for hundreds of hours… night and day". Since the possibility of cold fusion (CF) was believed to be absurd, their announcement provoked fierce opposition [2]. A famous science journalist spread even the message that studying cold fusion is "bad science" [3].

The real problem was that CF could not be explained by conventional theories. Prudence and skepticism are necessary in science, of course, but they should be exerted in both directions when there are opposite opinions. In the present case, the belief that CF is impossible was strengthened by the fact that duplications of the critical experiment did *not always* confirm the production of excess heat. This could be due to still unknown factors. They would require more experimental and theoretical studies, but it was "decided" that further checking is not necessary. It had already been discovered that *proton-deuteron fusion* can occur at normal temperature in bubble chambers, but these events could be explained [4]. They result from the catalytic nuclear reaction

$$p + d + \mu = (2p, n) + \mu$$

This means that the electron in HD^+ molecular ions can be replaced by a negative muon. The vibrating nuclei can then touch one another and get fused, while the muon remains available. This process was already called "cold fusion" and arose the interest of Jones, who thought that pressure-induced CF of deuterons might be possible in condensed matter. Results of his research were published [5], together with the official announcement that CF had been realized in electrolytic cells [6].

Since this possibility was vehemently refuted, some physicists wanted to find out themselves if this phenomenon is real or not. How they proceeded and what they found can be seen in the remarkable book of Tadahiko Mizuno of the Hokkaido University in Japan [7]. He constructed already in October 1989 a closed cell to examine the effects of deuteron loading of palladium. Excess heat production was confirmed, but neutron emission was sporadic. It was then established with the liquid scintillator of Akimoto that when neutrons were emitted, they had the same energy (2.45 MeV) as in hot fusion. Even tritium (p, 2n) was detected in February 1991. Mizuno concluded: "after that, it was no longer possible to deny cold fusion".

Other remarkable discoveries concerning CF in electrolytic cells were made during the 1990th. The phenomenon is real, but the underlying mechanism remained mysterious. Moreover, it had already been discovered that CF of nuclei can occur in living beings (at normal temperature). This fact had been overlooked or was also thought to be impossible, but the reality of these "biotransmutations" was clearly recognized by Louis Kervran in the 1950th. He published several books. One of them [8] provides an overview, but a historical introduction [9] is also useful, since biotransmutations had already been discovered much earlier. That microbes are able to perform transmutations was definitely established by measurements, based on Mössbauer and time of flight mass spectroscopy [10]. Vysotskii and his team did even prove that microbes can convert radioactive elements into stable ones.

More and more evidence of CF in electrolytic cells and living beings has been accumulated, but it is still believed that when a phenomenon cannot be explained by known theories, it has to result from errors or illusions. The past evolution of Science proves that this is not necessarily true. In 2007, Edmund Storms wrote a comprehensive book [11] on experimental results of CF research that contained 1369 references. Progress was obvious, but a convincing theory was still lacking. Storms tried thus in another book [12] to pave the way from observations to explanations. It is true that "observations need to be made part of any theory". They could even be helpful to localize basic problems, but that is not sufficient to solve them. Einstein told us that "a theory can be proved by experiment, but no path leads from experiment to the birth of a theory." Since previous ideas and concepts have to be replaced by new ones, that is not obvious.

The present article is based on becoming aware of 3 fundamental problems. 1) Could the Coulomb barrier be lowered in condensed matter? 2) Does the quantum-mechanical transparency of the residual potential barrier allow to reach an adequate excited state? 3) It is possible to understand why biological transmutations are possible? These questions determine the structure of this article. The final discussion includes the need to solve a more fundamental problem concerning science policies.

2. Reduction of the Coulomb Barrier by Image Forces

2.1. Nuclear Fusion Is Facilitated on Flat Interfaces

Relatively light nuclei are spherical and homogeneously charged. They create thus an electric field like a point-charge, situated at its center. The radial electric field is then Z/r^2, when Z is the charge (in units $e = 1$) and when this force is expressed in natural units (so that $4\pi\varepsilon_o = 1$). When the centers of two nuclei of charge Z and radius a are separated by a distance x, their interaction energy is thus

$$V(x) = \frac{Z^2}{x} \quad \text{where} \quad x \geq 2a \tag{1}$$

This expression defines the Coulomb barrier in free space. It is very heigh when a is small, but the barrier can be modified in condensed matter. It is well known that Coulomb forces are reduced in a homogeneous polarizable medium, since any point-charge produces there a distribution of orientable dipoles. The potential $V(x)$ is then divided by the dielectric constant ε of this medium. Other effects are also possible. Indeed, when a positive point-charge Z is situated near the surface of a metal, it attracts electrons and produces a distribution of negative surface charges. A very polarizable dielectric medium would also produce surface charges. For a flat surface, their effect is equivalent to those of a single point charge, Z, symmetrically situated on the other side of the interface. When the charge Z is situated in a medium of dielectric constant ε_1 near another medium of dielectric constant ε_2 the image charge is

$$Z' = \frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + \varepsilon_2} Z$$

Thus, $Z' = -Z$ when $\varepsilon_2 \gg \varepsilon_1$. It is possible to generalize this result by considering frequency and wavelength dependent dielectric constants [13]. This accounts for the excitation of surface plasmons, but for our purpose, it is sufficient to use electrostatics. Any bare nucleus is thus attracted by the surface of a metal or very polarizable medium. Even when a charged particle collides with a solid, it can there be trapped by sharing energy with the denser medium. This leads to *adhesion*. Oblique incidence of 2 identical nuclei on a flat metal surface can thus allow them to move on this surface. They can meet one another because of their initial motion, but as shown in **Figure 1(a)**, the magnitude of the repulsive force $\boldsymbol{F}$ is reduced by the projection of the attracting force exerted by the image of the other charge. This yields

$$F' = Z^2 \left(\frac{1}{x^2} - \frac{x}{d^3} \right)$$

The Coulomb barrier (1) is thus defined by

$$U(x) = Z^2 \left(\frac{1}{x} - \frac{1}{d} \right) \quad \text{where} \quad d^2 = x^2 + (2a)^2 \quad \text{and} \quad x \geq 2a \tag{2}$$

Figure 1(b) shows that the height $U(2a)$ of the Coulomb barrier is lowered from 1 to 0.293. A reduction by 70% is quite remarkable, but the width of the potential barrier is even more strongly reduced. Wave-mechanical tunneling through the residual potential barrier is thus enormously improved. Moreover, the surface of a palladium electrode it not necessarily flat at small scales.

2.2. Image Forces for Locally Spherical Interfaces

A positive point-charge induces also surface charges when it is close to an interface that is locally spherical. The distribution of surface charges is not the same as for flat surfaces, but also equivalent to a single point-charge. To determine the effect of the radius of curvature *R*, we consider two point-charges q_1 and q_2, respectively situated at a distance $r_1 < R$ and $r_2 > R$ from the center of curvature O. As shown in **Figure 2(a)**, both charges produce a Coulomb potential at any point *P* of the interface. Since it has to be an equipotential surface and since only the spatial variations of potentials are physically relevant, we set

$$V = \frac{q_1}{s_1} + \frac{q_2}{s_2} = 0 \quad \text{where} \quad s_i^2 = R^2 + r_i^2 - 2Rr_i \cos\theta$$

$i = 1$ or 2 and θ is the angle between OP and the symmetry axis. For $\theta = 0$, $s_1 = R - r_1$ and $s_2 = r_2 - R$, but other values of θ require that $q_1^2/s_1^2 = q_2^2/s_2^2$. It follows that

$$\frac{-q_1}{q_2} = \frac{R - r_1}{r_2 - R} \quad \text{and} \quad r_1 r_2 = R^2 \tag{2}$$

since $\left(R^2 + r_1^2 - 2Rr_1\cos\theta\right)\left(r_2 - R\right)^2 = \left(R^2 + r_2^2 - 2Rr_2\cos\theta\right)\left(R - r_1\right)^2$

These relations are also valid for closed spherical surfaces, but often stated without complete proof. **Figure 2(b)** represents the particular case where a single nucleus of charge *Z* and radius *a* adheres to the concave side of an interface. Thus, $q_1 = Z$ and $r_1 = R - a$. The image charge $q_2 = -Z'$ is situated on the

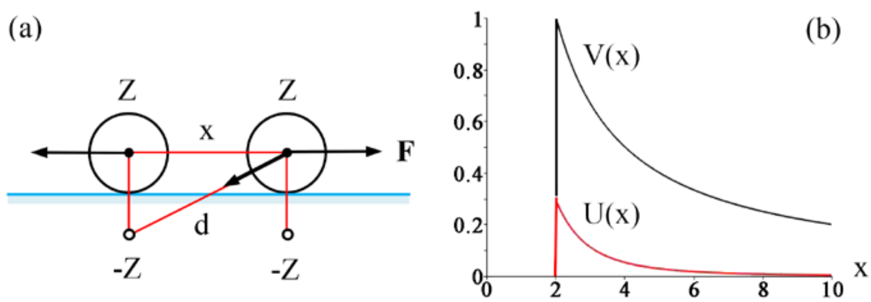

Figure 1. (a) When two identical nuclei are adsorbed on a flat metal surface, their mutual repulsion is reduced by image forces. (b) The Coulomb potential $V(x)$ in free-space is replaced by U(x). The units are $a = 1$ and $Z^2 = 2$.

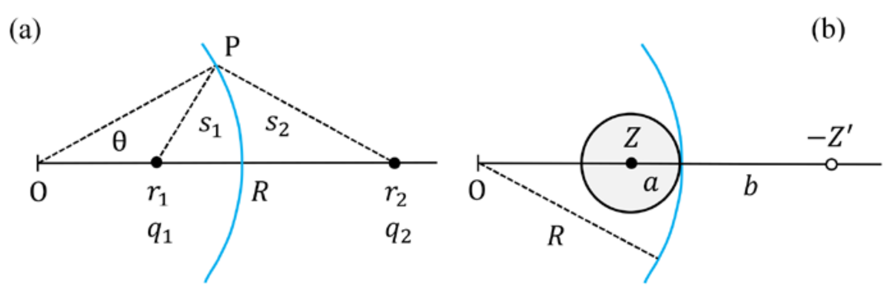

Figure 2. (a) The charge q_1 near a concave interface creates an image charge q_2. (b) For a nucleus of charge *Z* and radius *a* touching a concave metal surface, the image charge is situated at a distance $b > a$ from the interface and $Z' > Z$.

same axis, but at the distance b from the surface, so that $r_2 = R + b$. It follows then from (2) that

$$\frac{Z'}{Z} = \frac{b}{a} \quad \text{where} \quad b = \frac{Ra}{R-a} \tag{3}$$

For a flat surface ($R = \infty$), we get $b = a$ and the image charge is $-Z$, as expected. When R decreases, the image charge is situated at a greater distance, but Z' is also increased. The magnitude F'' of the repulsive force depends thus on the ratio b/a and on the distance $\delta = a + b$. Actually,

$$F'' = \frac{ZZ'}{\delta^2} = \frac{Z^2}{(2a)^2} \frac{4R(R-a)}{(2R-a)^2}$$

This force is reduced when the radius R decreases, but adhesion subsists. It is thus worthwhile to consider the mutual repulsion of two identical nuclei, when they are situated inside a pit of a metal surface or a very polarizable medium. Figure 3(a) shows such a configuration. The distance D between one charge Z and the image of the other charge depend on the separation x of the centers of the nuclei, since

$$D^2 = (x + \delta \sin\theta)^2 + (\delta \cos\theta)^2 \quad \text{where} \quad \sin\theta = \frac{x}{2(R-a)}$$

The potential energy of these nuclei will thus be reduced to

$$U(x,R) = Z^2 \left(\frac{1}{x} - \frac{b}{aD}\right) \quad \text{where} \quad D^2 = \left[1 + \frac{\delta}{R-a}\right] x^2 + \delta^2 \tag{4}$$

We can now calculate the height $H(R) = U(2a, R)$ of the Coulomb barrier when $Z^2 = 2$ and $a = 1$. This allows for comparison with the normalized height $H = 1$ in free space and the reduced height $H = 0.293$ for a flat interface, according to Figure 1(b). Surprisingly, the height of the Coulomb barrier is more reduced by image force effects when the nuclei are situated in a locally spherical pit of small radius R. Figure 3(b) compares $H(R)$ for 3 different cases. It can be verified by means of $U(x,R)$ that the width of the potential

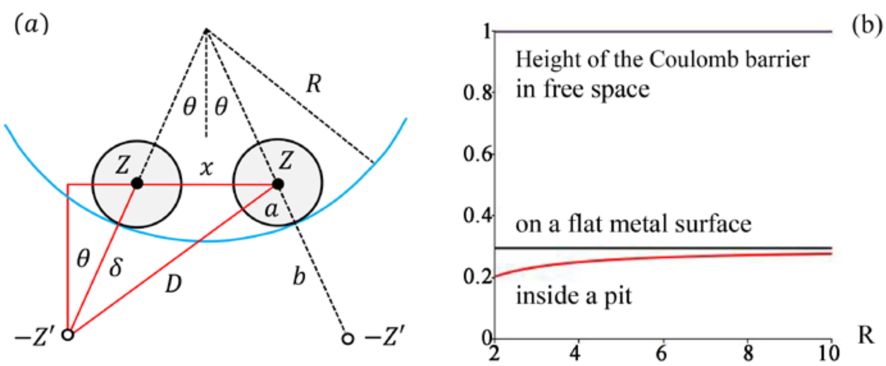

Figure 3. (a) Parametrization of the spatial configuration for two identical nuclei, adhering to a concave spherical interface. (b) The height $H(R)$ of the Coulomb barrier is more reduced by image force effects when the nuclei touch one another inside a dip of radius R than on a flat surface. The radius of the nuclei $a = 1$ and $Z^2 = 2$.

barrier is also reduced inside a pit.

2.3. The Discovery of Craters and Dendrites

The phenomenon of CF was considered too rapidly as being simply due to errors or illusions. When Pons and Fleischman mentioned at their press conference that "this experiment has to be approached with some caution" the audience burst into laughter [1]. However, a scientist was killed and his three collaborators were injured in 1992 at Menlo Park [14] by the explosion of an electrolytic cell that they used for studying the CF phenomenon. The cause was unclear, but eventually attributed to a chemical reaction. Mizuno was preoccupied by security and the need of prudence when one begins to explore an unknown domain. He constructed thus a sturdy cell, but observed "an anomalous heat bust" and high pressure in May 1991.

He began then to search a method for controlling heat production and found that it is sufficient to keep the temperature of the electrolytic cell slightly below 100˚C, where water begins to boil. The temperature dropped after terminating electrolysis, but it did spontaneously rise again for a cell that had persistently produced excess heat. Pons and Fleischman, continuing their research in France, had also discovered this "life-after-death" phenomenon. Successful low energy fusion of deuterons did thus become *autocatalytic*, but the reason was unknown.

Mizuno and Ohmori wanted to see if CF of deuterons does produce (p, 2n) and (2p, n) nuclei that remain on the surface of palladium electrodes. Using energy dispersive X-ray spectroscopy (EDX) to detect these nuclei, they made an amazing discovery. CF did not only produce $_1H^3$ and $_2He^3$ nuclei, but "all kinds of elements come out." It appeared also that CF is not only possible for palladium electrodes, containing deuterons. Cheaper metals can also be used and the deuterons can be provided from outside the metal. CF of deuterons does not require compression inside a crystal lattice. It is not a volume effect, as initially assumed, but a *surface effect.* Why deuterons can be fused at metal surfaces remained obscure.

Mizuno and Ohmori examined in 1995 the surface of a gold cathode that Ohmori had used. Scanning electron microscopy (SEM) revealed at low magnification, that "the surface was sprinkled with white spots". CF did thus occur at separated hot spots that leave a trace on the surface. Observing one of these spots at higher magnification, they discovered an ensemble of *craters.* Their size was of the order of 10 μm and they constituted groups. Since big craters had a deep central hole, they resembled lily-like flowers. The cover page of Mizuno's book [7] displays an image of such a group of craters. Figure 32 of this book shows a spectacular image of three big craters and several smaller ones. Another article [15] presented more images, but how and why these craters were formed remained also an unsolved mystery.

The article of 2006 mentioned that boiling water creates a vapor layer between the palladium electrode and liquid water. Having developed the theory of image force effects (sections 2.1 and 2.2), we realized that this information did provide the key for explaining CF. It is sufficient, indeed, to accept that Pd electrodes, loaded with deuterons, allowed that some deuterons left the metal by diffusion. The vapor layer contained thus deuterons, which could be adsorbed on the metal surface by image forces and be fused inside small pits. They are then progressively deepened, since CF liberates energy in the form of kinetic energy of the resulting particles. They eject atoms, like exploding bombs, artillery shells or meteors eject matter from the ground. CF at the bottom of pits makes them progressively narrower and will eventually lead to *autocatalytic fusion.* We understand also why there are groups of craters. The hot metal is more malleable and facilitates thus the formation of new craters.

Why did initial attempts to reproduce the Pons-Fleischman experiment not always confirm their results? Ironically, when Pd electrodes were carefully prepared to be very smooth, they did not provide the dips that are necessary to initiate CF. Edmund Storms insisted on the need of a Nuclear Active Environment (NAE) since "reaction products are always found within small regions of the sample". Storms were very interested by a discovery that Dash *et al.* made in 1994. It appeared, indeed, that successful fusion of deuterons can be accompanied by creating hair-like structures on the surface of the electrode. Clear SEM images were only published somewhat later [16]. They proved that "fibers" had grown on the surface of thin palladium foils, though "the mechanism which produced them is not known".

We can now also attribute this peculiar phenomenon to image force effects. Indeed, when the metal surface is in direct contact with the electrolytic solution, two deuterons that are situated inside a local bump of the metal surface will attract the negative sides of water molecules. The bumps will then become dendrites that penetrate more and more in the liquid, since CF is favored at the narrow tip. The filaments grow by extrusion. They yield whiskers that are characterized by separate bulges, since the metal is hot. It tends thus to constitute spherical surfaces by surface tension. This is known for water condensed on thin filaments of spider webs. **Figure 4** summarizes in a schematic way what is essential to explain both types of observed surface structures.

The Indian physicist Iyengar found already in 1989 that CF of deuterons does produce tritium at small spots on the surface of deuterated titanium electrodes

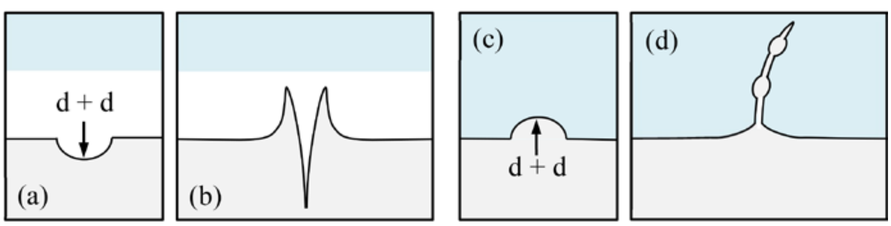

Figure 4. (a) Cold fusion by image forces is favored in a dip, when the metal is not in direct contact with water. (b) This process yields craters. (c) Direct contact with water facilitates CF inside bumps. (d) Hot material is then extruded and creates dendrites with bulges.

[17]. This was established by autoradiography of emitted beta rays. Since it was still believed that CF results from compression of deuterons inside a metal, Iyengar assumed that tritium had migrated to lattice defects at the surface. We mention also that hot spots are easily visible at the bottom of kettles, just before water is boiling. Indeed, bubbles of water vapor are then formed at places where 100˚C has already been reached. At this temperature, the bubbles can resist the pressure of liquid water and rise to the surface in separated columns.

Although the warning of Pons and Fleischman did seem to be ludicrous, a violent explosion occurred on January 24, 2005 in Mizuno's laboratory. The cell was shattered by a "sharp increase of inner pressure". The heat output was even about 800 times higher than the energy input. The outburst produced a bright white flash and the debris have been documented [18]. Even this powerful demonstration that energy is released by CF processes did not modify the lethargy or stubbornness of those scientific journals that had denied the possibility of CF. Fortunately, it is possible to harness this energy source, by keeping the temperature close to 100˚C, but no prominent science journal did report these facts. They were thus bypassed by specialized international conferences and alternative publications.

3. Fusion by Tunnelling and Nuclear Resonance

3.1. Forming a Compound Nucleus

Rutherford discovered the existence of atomic nuclei in 1911, by analyzing and explaining the angular distribution of elastically scattered α particles. They have only a short range, but Rutherford reported in 1919 that α particles behave differently in nitrogen [19] since

$$ {}_2\mathrm{He}^4 + {}_7\mathrm{N}^{14} \rightarrow {}_8\mathrm{O}^{17} + {}_1\mathrm{H}^1 $$

This was the first example of a nuclear reaction. The word "transmutation" was avoided for fear of being associated with alchemists [20]. At the beginning of the 1930$^{\text{th}}$ it was discovered that

$$ {}_2\mathrm{He}^4 + {}_4\mathrm{Be}^9 \rightarrow {}_6\mathrm{C}^{12} + \mathrm{n}^1 \quad \text{and} \quad {}_2\mathrm{He}^4 + {}_{13}\mathrm{A}^{27} \rightarrow {}_{15}\mathrm{P}^{30} + \mathrm{n}^1 $$

Processes of this type were called "artificial radioactivity", but they are genuine nuclear reactions. They do redistribute the same nucleons in a different way. The total number of protons (lower indexes) and the total number of nucleons (upper indexes) remain identical. Neutron emission suggested that neutron capture is also possible and led to the discovery of nuclear fission processes like

$$ \mathrm{n} + {}_{92}\mathrm{U}^{235} \rightarrow {}_{56}\mathrm{Ba}^{144} + {}_{36}\mathrm{Kr}^{89} + 3\mathrm{n} $$

They allowed for explosive chain reactions, which had tremendous consequences. From the standpoint of pure science, it is important that most incident neutrons are elastically scattered and that neutron capture can only occur at some particular energies. Niels Bohr explained this fact in early 1936 by attributing it to the "surprisingly great tendency even for a fast neutron … to attach itself to the nucleus" [21]. The energy of the incident neutron is then "rapidly divided among all the nuclear particles". This process implies the "formation of a compound system of remarkable stability". Nuclear reactions require therefore that the energy of the incident particle is adequate to yield an exited state for all nucleons inside the compound nucleus. Breit and Wigner [22] developed a detailed theory of these nuclear resonance processes.

3.2. Elastic Scattering in Nuclear Physics

Freely moving deuterons can only be fused at high energies, because of the Coulomb barrier, but its height and width can be reduced by image force effects. However, CF requires also that the residual potential barrier does not prevent contact of the colliding particles. This problem has to be treated by wave-mechanics. It is thus convenient to assume that one particle is at rest and that the incident particle has a well-defined energy $E = \hbar\omega$. Its wave function is then $\psi(\boldsymbol{r},t) = \varphi(\boldsymbol{r})e^{-i\omega t}$. If the incident particle had also a well-defined momentum in free space, it could be deviated in any direction by elastic scattering. The plane wave would thus be transformed in a radially outgoing wave of the same frequency. When the interaction is determined by a spherically symmetric potential $V(r)$, the dominant scattered wave is spherically symmetric and is determined by

$$\varphi(r) = \frac{u(r)}{r} \quad \text{where} \quad u''(r) + V(r)u(r) = Eu(r) \quad \text{and} \quad u(0) = 0$$

Since this is a one-dimensional equation, we replace $u(r)$ by $\phi(x)$ and $V(r)$ by $U(x)$. To concentrate on essential effects, we can adopt the simplified model of Figure 5(a). The rectangular potential well (of depth W and width a) specifies the effect of the target nucleus, while the rectangular potential barrier (of height V and thickness $d = b - a$) represents the reduced Coulomb barrier, since it is low and thin. The incident particle has an energy E, which is not modified for elastic scattering. However, the wave function $\phi(x)$ has to account for partial

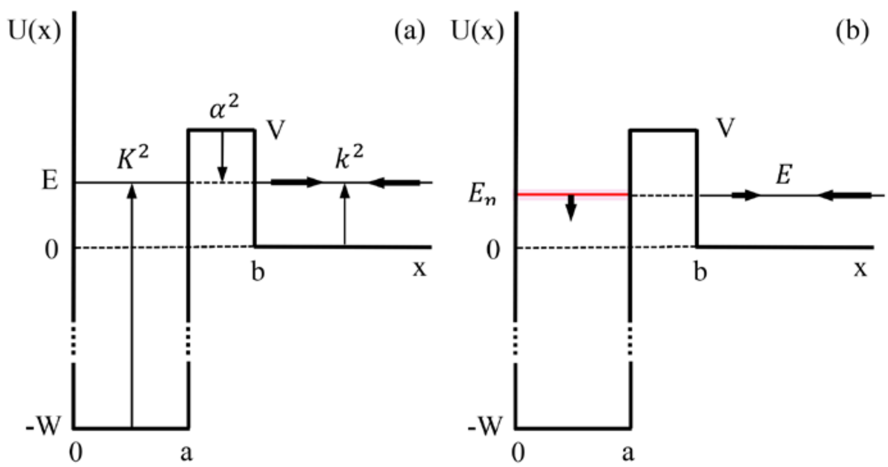

Figure 5. (a) Elastic scattering means that the incident particle is backscattered. (b) Nuclear fusion requires that the incident particle can pass through or over the potential barrier. It is also necessary that $E = E_n$ for a possible excited state of the compound nucleus.

reflection at both sides of the potential barrier. Moreover, the transmitted part is totally reflected at $x = 0$, since $\phi(0) = 0$. The parameters k and K determine the wavelength and kinetic energies of the incident particle. Arrows of equal length indicate that the probability flux is equal for the incident and reflected wave when it is merely scattered.

Figure 5(b) represents the same potential, but applies to the case where the energy E of the incident particle is very close to the energy E_n of a possible excited state of the compound nucleus. The wave function can then be partially reflected by the potential discontinuities, but inside the target nucleus, the incident particle gets fused with all other nucleons. They create a new egalitarian community. Since it is in an excited state, it has a finite lifetime τ_n and its energy is not sharply defined ($\Delta E_n \approx \hbar/\tau_n$). The arrows show that the incident particle is only partially reflected. Elastic scattering (**Figure 5(a)**) requires that the wave function satisfies the Schrödinger equation for stationary states:

$$\phi''(x) + U(x)\phi(x) = E\phi(x)$$

Choosing adequate units ($\hbar = 1$ and $2m = 1$), the solution has three parts:

$$\begin{aligned} \phi_1(x) &= A\sin Kx && \text{for } 0 < x < a \text{ when } K^2 = E + W \\ \phi_2(x) &= Be^{-\alpha x} + Ce^{\alpha x} && \text{for } a < x < b \text{ when } \alpha^2 = V - E \\ \phi_3(x) &= Fe^{-ikx} + Ge^{ikx} && \text{for } x > v \text{ when } k^2 = E \end{aligned} \tag{5}$$

Since the function $\phi(x)$ and its first derivative have to be continuous at $x = a$, we get

$$2\alpha Ce^{\alpha a} = M_+ A \quad \text{and} \quad 2\alpha Be^{-\alpha a} = -M_- A \quad \text{where} \quad M_\pm = K\cos Ka \pm \alpha \sin Ka \tag{6}$$

Continuity at $x = b$ yields two algebraic equations for Fe^{-ikb} and Ge^{ikb}. Thus,

$$F = -\frac{(\alpha - ik)M_+e^{\alpha d} + (\alpha + ik)M_-e^{-\alpha d}}{4i\alpha k}Ae^{ikb} \quad \text{and}$$

$$G = \frac{(\alpha + ik)M_+e^{\alpha d} + (\alpha - ik)M_-e^{-\alpha d}}{4i\alpha k}Ae^{-ikb}$$

When we set $F = 1$, we get

$$A = \frac{-4i\alpha ke^{-ikb}}{(\alpha - ik)M_+e^{\alpha d} + (\alpha + ik)M_-e^{-\alpha d}} \quad \text{and}$$

$$G = -\frac{(\alpha + ik)M_+e^{\alpha d} + (\alpha - ik)M_-e^{-\alpha d}}{(\alpha - ik)M_+e^{\alpha d} + (\alpha + ik)M_-e^{-\alpha d}}e^{-2ikb}$$

Olkhovski *et al.* [23] solved the same equation in 2008 for spherically symmetric waves and defined the transmission $T(E)$ of the potential barrier, by comparing probability fluxes. We have then to consider only the part $(A/2)e^{-iKx}$ of $\phi_1(x)$. We can even define a probability of reflection $R(E)$ so that

$$T(E) = \frac{K}{4k}|A|^2 \quad \text{and} \quad R(E) = |G|^2 = 1 \tag{7}$$

The calculated transmission reveals interesting features of the energy dependence for 3 different types of processes. Figure 6(a) provides results when $W = 100$ and $a = 1$. Even when there is no potential barrier (black curve for $V = 0$), the transmission can only progressively increase, because of the reflection at $x = a$. However, there is a maximum that results from interference inside the compound nucleus. A small and thin barrier (red curve for $V = 2$ and $d = 1$) does only slightly reduce the transmission at low energies and shifts the maximum to somewhat higher energies.

When the potential barrier is higher and thicker (blue curve for $V = 6$ and $d = 3$), it excludes transmission at low energies ($E < V$), but the incident particle can pass *over* the potential barrier. This leads to peaks that modulate the transmission $T(E)$, because of interference of waves above the potential barrier. This effect is important since CF of deuterons in electrolytic cells depends on a possible coincidence of these peaks with energies E_n of exited states of the compound nucleus. Figure 6(b) compares the probability of fusion $P(E)$ for two excited states, if they were situated at the indicated energies for a small residual potential barrier. The Coulomb barrier is not rectangular, of course, but we see what is most important.

3.3. Nuclear Resonance Absorption and 2 Excited States of α Particles

Usually, the incident nucleus is elastically scattered, but it can create a compound nucleus as shown in Figure 5(b). This leads to "nuclear resonance absorption". This terminology has historical roots, since Lorentz interpreted atomic spectra by assuming that atoms contain electrons that are distributed inside a positively charged homogeneous medium. If every electron were there elastically bound to a particular place, the electric field of EM waves would set them in forced oscillations. According to classical mechanics, the displacement $x(t)$ of such an electron would be determined by

$$\ddot{x} - \omega_n^2 x - \gamma_n \dot{x} = X\mathrm{e}^{-i\omega t} \quad \text{or} \quad x(t) = \frac{X\mathrm{e}^{-i\omega t}}{\omega^2 - \omega_n^2 + i\omega\gamma_n}$$

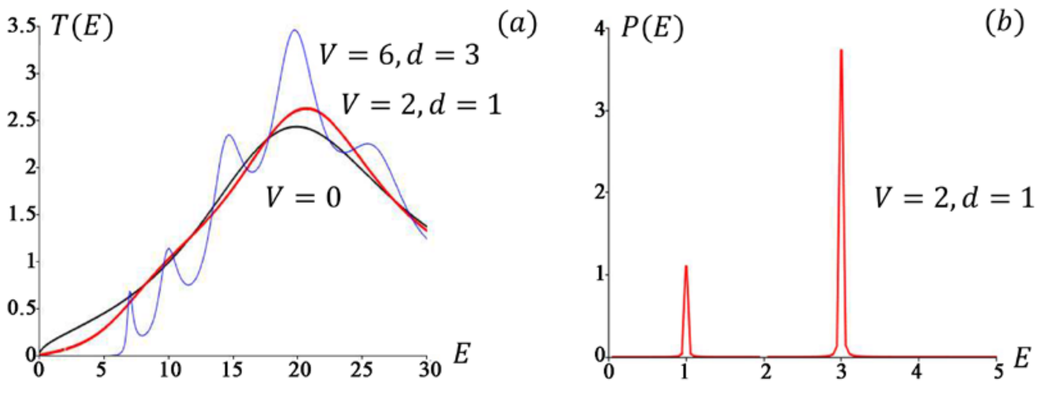

Figure 6. (a) Energy dependence of the transmission T through and over a potential barrier of height V and thickness d for elastic scattering. (b) Nuclear resonance absorption.

The oscillations are attenuated by viscous friction and the imaginary part of $x(t)$ determines absorption at the resonance frequency ω_n. The sharpness of the resonance depends on the value of γ_n. Drude adopted the same model for nearly free electrons in metals. Bohr's semi-classical approximation revealed that these resonances result from transitions between possible energy states, but this did only yield a correspondence principle until wave mechanics allowed to calculate transition probabilities. Nuclear fusion does also yield excited states and "resonance absorption". Fusion of two deuterons depends then on the existence of excited states of α particles in the domain of accessible energies. Are such states really possible?

It has been suggested that the first excited state of $_2He^4$ nuclei could be situated somewhere between 21 and 27 MeV and that it would be a breathing mode [24]. We propose a simpler approach, since the binding energy of nucleons in a nucleus is increased when more of them touch one another to allow for gluon exchanges. It follows that the ground state of α particles requires that the centers of 4 nucleons constitute a regular tetrahedron. However, two deuterons can also be bound by touching one another at fewer points. This allows for planar or linear configurations, defining excited states of alpha particles. They are schematically represented in **Figure 7** with their decay modes.

Hot fusion of two deuterons is possible at *high* energies, near the top of the huge Coulomb potential in free space. It populates the excited state α^{**}, but not the state α^*. The opposite is true for CF, since the available energy E is not sufficient to reach the state α^{**}. This state can decay by emitting gamma rays, but transition to the lower exited α^* is favored. It can also be populated by CF. In both cases, this does preferentially lead to dissociation where 3 nucleons remain bound to one another. Since all orientations of the resulting triangle are equally probable, the (2p, n) or (p, 2n) nuclei are spherical. The separations between possible energy states are not at scale in **Figure 7**, but we understand why neutrons of the same energy (2.45 MeV) are emitted as well for cold as for hot fusion. Only the probabilities are different. Since CF yields fewer neutrons, it produces a safer energy source.

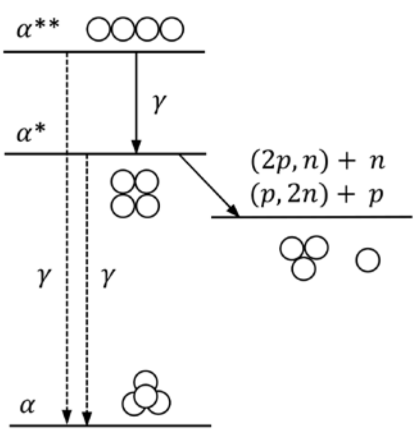

Figure 7. Proposed model for the ground state and two excited states of α particles.

3.4. Generation of Many Nuclei by Cold Fusion

In 1996, Mizuno discovered a remarkable phenomenon. He writes in his book [7]: "I investigated the palladium and discovered a fabulous array of unexpected elements in large amounts: silicon, calcium, titanium, chromium, iron, manganese, cobalt, nickel, copper, zinc, platinum, lead, and more". This was established by EDX (energy dispersive x-ray spectroscopy) and duly communicated [25].

Figure 26 and 29 of Mizuno's book [7] show two examples of spectra, where "many peaks vigorously spring up". Miley and Patterson discovered also in 1996 the existence of "palladium isotope anomalies". Figure 51 of Storm's book [12] presents these results in terms of the atomic number of new elements. The logarithm of their density displays two peaks at $Z \approx 12$ (Mg, Si) and $Z \approx 30$ (Cu, Zn). There are two secondary peaks at about $Z \approx 48$ (Pd, Ag, Cd) and $Z \approx 82$ (Pt, Au). This pairing suggests fission processes. We try to make sense of these findings, since deuterons might not only fuse with one another, but also with palladium nuclei. They are present in great quantities at the surface of the electrodes. The following fusion and fission processes could then liberate α particles and neutrons:

$$\begin{aligned} \mathrm{d} + {}_{46}\mathrm{Pd}^{112} &\to {}_{26}\mathrm{Fe}^{54} + {}_{17}\mathrm{Cl}^{37} + 2\alpha + 18\mathrm{n} \\ &\to {}_{27}\mathrm{Co}^{59} + {}_{16}\mathrm{S}^{32} + 2\alpha + 18\mathrm{n} \\ &\to {}_{29}\mathrm{Cu}^{63} + {}_{14}\mathrm{Si}^{28} + 2\alpha + 18\mathrm{n} \\ &\to {}_{30}\mathrm{Zn}^{64} + {}_{12}\mathrm{Mg}^{24} + 2\alpha + \mathrm{d} + 21\mathrm{n} \\ &\to {}_{34}\mathrm{Se}^{80} + {}_{13}\mathrm{Al}^{27} + 6\mathrm{n} \\ &\to {}_{38}\mathrm{Sr}^{88} + {}_{8}\mathrm{O}^{16} + 1\mathrm{d} + 8\mathrm{n} \end{aligned}$$

Other isotopes are possible, of course, but the most stable ones are energetically preferred. When CF has already produced fission products on the surface of palladium metals, it is even possible to fuse deuterons with two nuclei. These type of processes could yield for instance

$$\begin{aligned} \mathrm{d} + {}_{46}\mathrm{Pd}^{112} + {}_{30}\mathrm{Zn}^{64} &\to {}_{47}\mathrm{Ag}^{107} + {}_{29}\mathrm{Cu}^{63} + \mathrm{p} + 7\mathrm{n} \\ &\to {}_{48}\mathrm{Cd}^{112} + {}_{24}\mathrm{Cr}^{52} + 2\alpha + \mathrm{p} + 9\mathrm{n} \\ &\to {}_{50}\mathrm{Sn}^{120} + {}_{23}\mathrm{V}^{50} + 2\alpha + 3\mathrm{n} \end{aligned}$$

3.5. Synthesis of Superheavy Elements by Cold Fusion

All transuranium elements (beyond ${}_{92}$U) are produced by nuclear reactions. This concerns neptunium (${}_{93}$Np), plutonium (${}_{94}$Pu), americium (${}_{95}$Am), curium (${}_{96}$Cm), berkelium (${}_{97}$Bk), californium (${}_{98}$Cf), einsteinium (${}_{99}$Es), fermium (${}_{100}$Fm), mendelevium (${}_{101}$Md), nobelium (${}_{102}$No), lawrencium (${}_{103}$Lr), rutherfordium (${}_{104}$Rf), dubnium (${}_{105}$Db), seaborgium (${}_{106}$Sg), bohrium (${}_{107}$Bh), hassium (${}_{108}$Hs), meitnerium (${}_{109}$Tt), darmstadtium (${}_{110}$Ds), roentgenium (${}_{111}$Rg), copernicium (${}_{112}$Cn), Nihonium (113Nh), flerovium (${}_{114}$ Fl), moscovium (${}_{115}$Mc), livermorium (${}_{116}$Lv), tennessine (${}_{117}$Ts) and oganesson (${}_{118}$Og).

So-called "superheavy elements" begin with the atomic number 104. Since the height of the Coulomb barrier is proportional to the product Z_1Z_2 of atomic numbers, it is useful to reduce these values by using ions. Powerful ion accelerators are thus needed, but the excitation energy of the compound nuclei should be as small as possible to get fission products that survive long enough for identification. This requires careful selection of the target and projectile nuclei, since elongated ones reduce the mutual repulsion of their charge centers. This method was pioneered in 1976 at Dubna, Russia. It was also called "cold fusion" and applied in the 1980th at the Institute for Heavy-Ion Research in Darmstadt [26]. For instance,

$$_{82}Pb^{208} + {}_{28}Ni^{62} \rightarrow {}_{110}Ds^{269} + n$$

$_{113}$Nh was obtained at Riken, Japan and $_{116}$Lv at Dubna. Production of superheavy elements is merely a matter of scientific curiosity. Since the nuclear shell model predicts that closed shells yield stronger bonds, there exists an "island of stability" for 114 protons and 184 neutrons. It would be interesting to find out if element $_{114}X^{289}$ does really exist. Its production could be facilitated by image force effects. One heavy element should then constitute the metal that intercepts moderately accelerated heavy ions at grazing incidence. Is his possible or not?

4. The Mechanisms of Biological Transmutations

4.1. Discovery of $N_2^* \rightarrow$ CO Transmutations

We will consider three examples of biotransmutations, since they raise concrete problems that have to be solved. The first one concerns *carbon-monoxide intoxications* of welders. They can be fatal and did thus preoccupy already industrial medicine since the 1930th. The mechanism was very puzzling. Indeed, careful measurements had established that there was no CO in the air that the welders had inhaled. Louis Kervran solved this problem in 1955 by considering nuclear reactions. His method of verifying the reality of unorthodox processes consisted in searching similar exceptions to standard rules.

He remembered that cast-iron stoves were commonly used in schools at the beginning of the 20th century. They could be heated to become glowing red, but windows had then to be regularly opened to prevent health problems. Why was that necessary? Kervran thought that N_2 molecules of normal atmospheric air are set in vibration when they touch very hot iron or are exposed to its infrared radiation. He assumed therefore that when children or welders inhale excited N_2 molecules they can be transformed inside their body into CO molecules by the nuclear reaction

$$_7N^{14} + {}_7N^{14} \rightarrow {}_6C^{12} + {}_8O^{16} \quad (8)$$

This implied a transmutation that he did not exclude for the following reason. Workers in the Sahara were able to operate without discomfort on drilling platforms in hot air. A military doctor and his assistants measured any physiological intake and output of these workers during 6 month. It appeared then that they had ingested more sea salt by sucking tablets and that their sweet contained more potassium than usual. The engineer Kervran, specialized in health problems, was officially asked to investigate. He proposed that

$$_{11}Na^{23} + {}_{8}O^{16} \rightarrow {}_{19}K^{39} \quad (9)$$

This could have a cooling effect, since already know facts in nuclear physics implied that this reaction would be endothermic. How the proposed transmutation could be achieved in human beings was unknown, but the reaction (9) seemed to be the only possible explanation. In regard to the transmutation of excited nitrogen molecules ($N_2^* \rightarrow CO$), Kervran suggested that it might be due to an "unidentified enzyme" [[8], p.18]. That was plausible for living systems, but we want to know what is really happening. We have then to start with the electronic structure of neutral nitrogen atoms. Since the nucleus contains 7 protons, it is surrounded by 7 electrons in $[1s^2]2s^22p^3$ states. This yields an N^{+5} ion core and 5 peripheral electrons. N_2 molecules contain thus two N^{+5} ion cores, embedded in a cloud of 10 electrons. Their spatial distribution is such that they form 3 pairs between the ions and 2 external pairs, in conformity with the usual representation (:N≡N:).

These concepts can be justified by the model of **Figure 8(a)**. The upper part shows (in red) the positions of the centers of the N^{+5} ion cores and (in gray) the average positions of electrons. The positive and negative charges are indicated (in units $e = 1$) and also their separations. The lower part of this figure represents the ion cores. They behave like hard spheres, since their electron clouds cannot be superposed because of Pauli's exclusion principle. Quantum-mechanical effects are not suppressed, but simplified.

Figure 8(b) represents the resulting potential energy of the molecule in terms of x. To preserve the same proportions for different values of x, we set $x' = px$, where the value of p is adjusted to situate the minimum of $V(x)$ at $x = 1$. This value is defined by the radius of the ion cores. They can only touch one another, but are slightly compressible, as indicated by the rapid increase of $V(x)$ when $x < 1$. We indicate also the energy levels for the ground state and the first excited

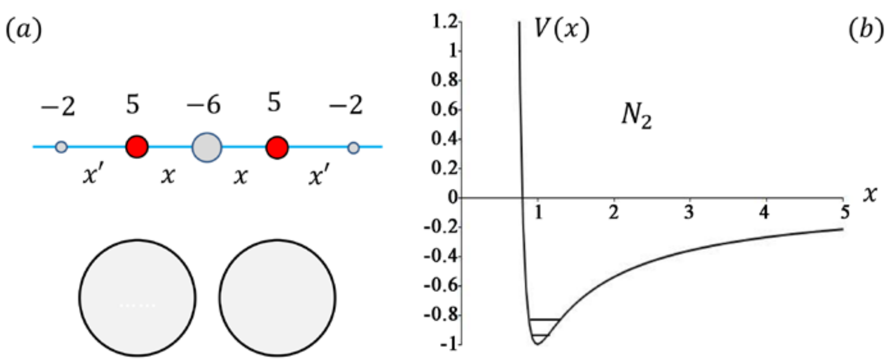

Figure 8. (a) The essential parameters that determine the structure of N_2 molecules. The lower part represents the ion cores, when they do not yet touch one another. (b) The resulting potential energy.

state. This model is sufficient to see that the nitrogen nuclei cannot be fused, even when they are vibrating. The presumed transmutation should thus be impossible, but we considered only isolated N_2 in atmospheric air or free space. What happens when they are inhaled? To answer this question, we begin with examining the role of inhaled O_2 molecules.

They are transferred from the lung to fluid blood, where they are attached to hemoglobin inside red blood cells. These cells transport the precious oxygen molecules to any place where they are needed. A chemical reaction yields there energy and CO_2 molecules. They are carried to the lung, ejected by expiration and replaced by fresh O_2 molecules. This marvelous mechanism is blocked when CO molecules are inhaled, since they are more strongly attached to hemoglobin than O_2 molecules. They cause thus asphyxiation, but how is it possible that exited N_2 molecules can become CO molecules?

4.2. Explanation of Biotransmutations by Image Forces

We begin with recalling that inhaled air fills numerous alveoli in our lung. These pockets are in close contact with capillaries where blood is flowing. Oxygen molecules have thus to pass through the membranes of alveoli and capillaries. They are constituted of phospholipid membranes, forming the so-called "air-blood barrier". Their internal structure is flexible and allows the passage of O_2 molecules by diffusion. This process is simply regulated by density gradients, since collisions between any type of molecules will distribute them evenly in space. Inhaled O_2 molecules are thus migrating from the alveoli towards the blood. This happens also inside membranes blood cells and those of the tissues where oxygen molecules are needed. When the density of CO_2 molecules is there increased, they move towards the blood and are transported to the alveoli, where they are replaced by O_2 molecules.

N_2 molecules are also present, of course, but they are not consumed. There are thus no density gradients and no diffusion of normal nitrogen molecules inside membranes. However, *vibrating* nitrogen molecules are different. Inhalation of N_2^* molecules leads thus to their diffusion from the alveoli to fluid blood. Moreover, phospholipid membranes have a very low dielectric constant ($\varepsilon \approx 1.5$), while liquid blood has a high dielectric constant ($\varepsilon \approx 79$). At the instant where N_2^* molecules touch the membrane-blood interface, their peripheral electrons are attracted by their image charges. There remain then two N^{+5} ion cores that touch one another and are attracted by their image charges. This situation is represented in **Figure 9(a)**. The 10 peripheral electrons are also attracted by their image charges, but electrons are elementary particles and thus merely points. With their images charges, they will constitute an infinitely thin dipole layer, but outside this layer, they act like neutral entities. This happens even for the electrons of the ion cores. They are moving and strongly attracted by their images. **Figure 9(b)** shows that there remain only two bare nuclei of charge +7. They repel one another, but are attracted by the image of their companion.

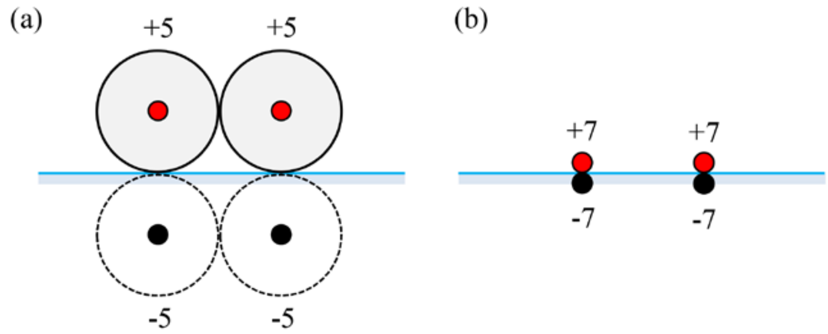

Figure 9. (a) Two ion cores of N_2 molecules at the membrane-blood barrier. The 10 peripheral electrons adhere to the interface and are neutralized by their image charges. (b) Even the electrons of the ion cores are inactivated and the mutual repulsion of the bare nuclei is then reduced by image force effects.

The size of the nuclei and their images has been increased in this figure for didactic purposes, but they are adsorbed. Their mutual repulsion is reduced by image forces and they can move towards one another. Being still inside the membrane, they attract the negative parts of water molecules on the side of the blood. This creates a pit in the polarizable medium, facilitating CF as in **Figure 4(c)**. The nuclear reaction (8) becomes possible. The transmutation requires only that a single proton is transferred from one nitrogen nucleus to the other one. This is favored by the fact that C and O nuclei are of type (3α) and (4α). This does not mean that they are constituted of α particles, but that all nuclei are more strongly bound, because of magic numbers for the nuclear shell model. After passing through the interface, the transmuted nuclei recapture their share of electrons and constitute normal CO molecules. They are captured by hemoglobin and can cause asphyxiation. The process depicted in **Figure 9** accounts for all types of biotransmutation, since, all living systems contain interfaces between phospholipid membranes and strongly polarizable fluids.

4.3. Egg Shells Need Si → Ca Transmutations

The French chemist *Vauquelin* noted already in 1799 that the calcium metabolism of poultry is abnormal. He quantified this effect by feeding some hens only with oat, which contains a known quantity of calcium. All droppings and the eggs they laid during a given number of days were carefully analyzed. The result was that the output of calcium phosphate was 2 times greater than its intake. The amount of calcium carbonate was even 5.7 times greater. The hens were thus able to produce themselves the element calcium.

The British chemist and physiologist *William Prout* wanted to know if the amount of calcium remains constant inside eggs during incubation, since calcium is also needed for building the skeleton of chicken embryos. He presented his results in 1822 at the Royal Society [27]. Surprisingly, the amount of calcium was progressively increasing during hatching. This fact contradicted Lavoisier's law of 1789. Prout knew it very well, since he had justified the atomic hypothesis, by establishing in 1815 and 1816 that the weight of different gases per unit volume is a an integer multiple of the specific weight of hydrogen. Since chemical reactions can only combine atoms in different ways, the total amount of any given element should be constant in any closed system. Nevertheless, Prout had to conclude from his measurements that inside eggs, calcium is "derived from some unknown source." He added that there are strong reasons to reject the hypothesis that calcium can be derived from the eggshell. "The only alternative left me to assert that it is formed by *transmutation* from other matter." Chemical reactions could not produce calcium by transforming another element, but Prout declared: "I think I can venture to assert, after the most patient and attentive investigation, that it does not preexist in the recent egg."

The atomic theory of matter was shaken, but who cares? Kervran did, by considering that even low energy nuclear reactions are possible in biological systems. He was self-critical and when he found in the 1950th that the formation of eggshells and the bones of chicken embryos inside eggs implied apparently impossible transmutations, he wanted to be sure. In his youth, he had seen with astonishment that hens were fascinated by small pieces of *mica*. They picked them up, but mica is an aluminosilicate and most often $KAl_2(AlSi_3O_{10})(OH,F)_2$. Mica contains no Ca atoms at all, but it seemed that hens did instinctively know that mica provides calcium. Kervran performed thus an experiment. It began with enclosing small chickens and raising them without ever seeing mica. Chalky sand ($CaCO_3$) was at their disposition, even when they were adult and laying eggs. They could thus directly extract Ca atoms from their food. However, when these hens were suddenly deprived of Ca, the eggshells became soft. As soon as pieces of mica were spread on the ground, they swallowed them with obvious avidity. Already the following day, the eggshells were normal again [28]. Kervran though that this could result from the following transmutations:

$$ {}_{19}K^{39} + {}_{1}H^{1} \rightarrow {}_{20}Ca^{40} \quad \text{or} \quad {}_{14}Si^{28} + {}_{6}C^{12} \rightarrow {}_{20}Ca^{40} \tag{10} $$

The second nuclear reaction was more probable, since mica contained more Si atoms and C atoms could easily be derived from normal food. The author of the present study learned in primary school that hens have a special digestive system. They have no teeth, but good eyesight and use their hard beaks to pick up not only grains, some vegetables and insects, but also little stones. These stones remain in their muscular gizzard, apparently to crush food. Such *gastroliths* (stomach stones) have been the object of many scientific studies. All birds use this peculiar system, even hummingbirds, though they feed on nectar. Colibris are specially adapted to reach the energy-rich sugary fluid. They add some insects to equilibrate their diet, but why do they swallow grit? The reason was said to be is unclear [29], since nectar does not have to be crushed. However, it was observed that grit is mainly used by female hummingbirds during the breeding season. "This result suggests that ingested grit could have played a role as a supplement of some micronutrients, such as calcium needed for eggshell production". Could stones provide Ca?

We know that birds are evolutionary descendants of dinosaurs. They did also ingest stones, accumulated in their gizzard. Moreover, they were laying hard shelled eggs, requiring calcium. Dinosaurs did even need it for their own gigantic growth. The case of enormous birds that could not fly and lived in New Zeeland is particularly interesting in this regard. When Moari settled there in the 13^{th} century, these birds were easy and nourishing pray. They were even totally exterminated and their past existence was unknown until the British anatomist Owen discovered an enormous bone in 1838. He identified it as belonging to a bird and that was confirmed by later diggings. The greatest *moa* were about 3.5 m tall and weighed half a ton, like buffaloes. Robert Bakker reported in his remarkable book [30] that moa were herbivorous, since mummified specimen proved that "their meals consisted entirely of shredded leaves." Some fossils were bearing eggs, but the type of stones in their gizzard could only be found at a distance of about 15 km. These stones had thus to be constituted of some particular type of matter.

It is not customary to consider *dinosaurs* in physics journals, but this is necessary to find out if dinosaurs were already able to produce calcium by transmutations. Since this is not obvious, we recall that about 200 million years ago (MYA), the supercontinent Pangea was breaking up because of continental drift. This led to outgassing CO_2 and a warmer climate. Life on land became possible, but required adaptations. Amphibians lay eggs in water, but female sea turtles go to sandy beaches to lay and hide soft-shelled eggs. This allowed already somewhat better protection. Reptiles and land turtles are living on dry land, but their eggs have only leathery shells. The first eggs of dinosaurs, discovered in South-Argentina and Mongolia, were still soft-shelled. Those of early Jurassic dinosaurs were hard, but very thin. Progressively, they became thicker. This is usually attributed to biomineralization of calcium carbonate ($CaCO_3$), but this source of calcium was quite rare. Dinosaurs had thus to produce Ca atoms themselves.

It is instructive in this regard to consider the case of *Brontosaurus* (thunder lizard) of the late Jurassic epoch, about 150 MYA. These dinosaurs weighted up to 35 tons and reached from head to tail a length of 22 - 27 m. However, their long neck enabled them to reach leaves on very high trees. Since blood had then to be pumped to their brain, their head was tiny in proportion to their body, but that was less important than the fact that they had no competitors for their food. Their teeth showed wear, but were only used to strip leaves from huge trees, since they had pebbles in their gizzard. Vegetarian dinosaurs fed on conifers, palm-like cycad trees and ferns. Since flowering plants did not yet exist, we have to ask if the unparalleled gigantism of dinosaurs could be related to their food. This question led to a comprehensive review of already acquired knowledge [31]. It resulted from a cooperation of 16 authors and contains 365 references.

Available plants were Araucaria, Equisetum, Ginkgo and Cycads. They are shown in an easily accessible article [32] and contain silicon (Si). It is the second most abundant element in soils, predominantly in the form of H_4SiO_4. Moreover, silicon is readily absorbed by plants and essential for their growth [33]. The silicon content of plants is widely variable, but *equisetum arvense* is particularly rich in silica (SiO_2). It is the major constituent of sand (over 90%) and particularly hard [34]. However, mummified stomach contents and fossilized coprolits (droppings) of huge sauropods proved that equisetum (horsetail) was a privileged food. It was the dominant plant at that time and produced very high trees. They were up to 30 m tall, but brachiosaurus could easily reach this food with his long neck. Since enormous plant growth and anatomical adaptations of dinosaurs resulted from evolutionary processes, there had to be a reason.

To find it, we begin with mechanical considerations. Galileo wrote already [35] that "it is impossible to build two similar structures of the same material, but of different size and have them proportionately strong." To make that clear, he considered a cube of mass M and volume L^3. This cube would collapse if its weight W could not be supported by its basis. Whether this is possible or not depends on the mass density ρ of the constituting material and the maximal stress σ (force per unit surface) that can be supported by its basis. We get thus the following relations:

$$M = \rho L^3 \quad \text{and} \quad W = gM \le \sigma L^2 \quad \text{or} \quad M \le \frac{\sigma}{\rho g} L^{2/3}$$

The maximal mass M is related to a characteristic length L, but it is not simply proportional to it. It is even known today that for any solid material and any type of stress (compression, bending and torsion), there is always a "scaling law" for average values. Its general form is $M = kL^n$. Only the constants k and n are modified [36]. It is therefore possible to estimate body masses of extinct species of animals by means of the size of their bones. Excellent agreement was even found for a large group of quadruped dinosaurs when L is the sum of humerus and femur circumferences [37]. In that case, $n = 2.749$ and $\log(k) = -1.104$. To double the average mass M it is thus only necessary to increase L by a factor $2^{1/n} \approx 1.3$ instead of $2^{3/2} \approx 2.8$ for a homogeneous cube. Bones are very resistant, indeed.

They are mainly constituted of agglomerated $Ca_{10}(PO_4)_6(OH)_2$ molecules. Analysis of the long bones of dinosaurs revealed that they had a fibro-lamellar structure [38] and that the matrix of collagen fibers was well supplied with blood vessels. This combination allowed for rapid growth. When the young emerged from eggs, they were small, of course, but reached their enormous adult size after merely 6 years. This required great amounts of calcium, resulting from Si → Ca transmutations. Could the huge size of dinosaurs be a byproduct of the need of Ca for constituting hard eggshells? Actually, the extension of life from water to land was associated with several vital adaptations. The whole lung-hart system was modified [39], but better protection of offspring was of primary importance for the survival of the species. It was very successful during millenaries and preserved by birds, but why are birds still swallowing stones?

Oliver Wings tested the hypothesis that gastroliths are needed to grind food by performing experiments with a tumbler [40]. It might simulate a gastric mill, but "no polish had formed on the surface of the stones". Eventually, it was concluded [41] that "sauropod dinosaurs lacked a gastric mill". The function of gastroliths remained thus mysterious, but it was mentioned that approximately 90% of the gastroliths in German ostriches were pieces of siliceous rocks, mainly in the form of silica. Edith Carlisle did prove that the element silicon (Si) is essential for animal nutrition [42]. Fig. 1 of this article shows a photograph of two chickens that had been raised on a silicon enriched and a silicon poor diet. The difference is spectacular. It is also known in medicine that silicon is efficient against osteoporosis [43], though the "mechanisms are not clear" [44].

Silicon is even important for present-day plants, but "despite this empirical knowledge, the essentiality of Si still remains enigmatic" [45]. It was mentioned at least that silicic acid moves across membranes. This is important, since it is related to the explanation of biotransmutations by image force effects (section 3.2). It is also reasonable to think that dinosaurs did swallow stones that contain Si to acquire Ca. The formation of Ca is favored by the fact that ${}_{20}Ca^{40}$ nuclei have the structure of (10*a*), but how could the Si → Ca transmutation be realized by means of gastroliths? Si atoms had to be detached somehow from the silicon-rich stones. Did that merely occur by abrasion or were there local pits that could be associated with image forces? In this regard, it is advisable to examine the surface of gastrolith by scanning electron microscopy (SEM) and to explain the resulting facts. Moreover, the digestive system includes membranes, where the transmutations can occur. Further investigations are thus necessary, but some clarifications could already be harvested. It is not irrelevant, of course, to become aware of the fact that even the evolution of life on Earth was related to biotransmutations.

4.4. Microbes Can Transmute Radioactive Nuclei into Stable Ones

In the 1990th, Vladimir Vysotskii and his team discovered that growing biological cultures of microbes are able to synthesize *iron isotopes*. This was established by combining Mössbauer spectroscopy with time of flight mass spectroscopy. The results were published in articles and a book [10]. More recent developments are included in a review article, concerning condensed matter and nuclear physics [46]. Since microbes need Fe for their growth, they produce it themselves when this element is not available in their environment. It was found that

$$d + {}_{25}Mn^{55} \rightarrow {}_{26}Fe^{57}$$

Manganese has only one stable isotope and when $MnSO_4$ was dissolved in heavy water, it did yield this particular isotope. Many other transmutations are also possible by means of microbes. For instance,

$${}_{11}Na^{23} + {}_{15}P^{31} \rightarrow {}_{26}Fe^{54} \quad \text{and} \quad {}_{55}Cs^{137} + p \rightarrow {}_{56}Ba^{138}$$

The first nuclear reaction yields another iron isotope. The second one indicates that radioactive nuclei can be converted into stable ones. These transmutations are privileged, since stable isotopes are those where nucleons are strongly bound. Yum and his Korean colleagues found that deactivation of radioactive waste is even possible by combining only 10 different strains of microorganisms [47].

Vysotskii and his collaborators tried to solve the fundamental problem: why are microbes able to perform transmutations? Since these authors were absolutely sure that microbes had this capacity, there had to be an explanation. Their proposition underlines the difficulty to discover it. They assumed that living systems have special properties. Since they are "dynamic", they might be able to *suppress* the Coulomb barrier during short time intervals ([10], p. 101 and 110). They tried to justify this idea by considering Schrödinger's time dependent equation and a wave-packet. QM implies that during a short time interval Δt, the energy of a system can only be determined with an uncertainty: $\Delta E \approx h/\Delta t$, but that is not sufficient to suppress the Coulomb barrier. We could only say that the energy E of the incident particle could be high enough to pass over the immense Coulomb barrier in free space or through its tip by tunneling, but the probability would be extremely low. Moreover, the explanation of biotransmutations has to be compatible with the explanation of CF of deuterons and other transmutations in electrolytic cells.

This is achieved by reducing the height and thickness of the Coulomb potential barrier by image force effects (section 2.2) and that is confirmed by experimental observations (section 2.3). Moreover, there are two possible excited states of α particles (section 3.3), accounting as well for cold as for hot fusion of deuterons. Even biotransmutations can be attributed to image force effects (section 4.2). The brave attempt to explain biotransmutations confirms the difficulty of this problem, even when it is absolutely sure that biotransmutations are possible. This decisive progress resulted from an Ukrainian-Russian cooperation. A comprehensive review was presented in 2013 by Vysotskii and Kornilova in a standard science journal [48]. They mentioned also that "microorganisms accumulated metals by depositing them on the surface of a cell or inside it" ([10], p. 123) and added that this process "is directly related to the phenomenon of transmutation" (p. 125). They were not far from considering adsorption and image forces.

So-called "bacterial sorption" of heavy metals was already demonstrated in 1989 by electron microscopy [49]. Four types of bacteria were found to remove Ag^{+}, Cd^{2+}, Cu^{2+} and La^{3+} ions from solutions. Decontamination is at present an active field of research, but we mention only some typical studies [50] [51] [52]. It is also noteworthy that Kervran predicted already in the 1970^{th} that microorganisms could even "transmute radioactive wastes into stable nuclides" ([8], p. 110).

5. Discussion and Conclusions

More than 3 decades ago, we learned through newspapers about the claim that nuclear fusion processes were possible in electrolytic cells. This was unexpected and even declared to be impossible. Three years later, we read the book of the nuclear physicist Huizenga [2], who was radically opposed to the concept of CF. We were not convinced by his assertions, since the reported fusion of deuterons occurred in condensed matter and not in a gas-like plasma. The mechanism could thus be different. Moreover, we should not simply proclaim that when experimental results do not agree with known theories, they have to be fake. Surprises are possible and deserve special attention, since they could be signs of limited validity of former theories. This happened already in the past. Reality is not defined by ideas, principles or "laws", but by observations and measurements, even when they are not immediately understood.

We were busy with other problems at the frontiers of physics, but verified from time to time that the reality of CF was confirmed by more detailed experimental investigations. Pons and Fleischman were not specialized in nuclear physics, but chemists are also able to perform careful measurements with state of the art instruments. Those that they had used were shown after their press conference [1]. We saw no objective reason to presume that they were charlatans. A constantly increasing number of experimental physicists discovered even very remarkable facts concerning CF.

It is therefore unavoidable to ask *why* the prominent scientific journals that had "decided" that CF cannot be real did only respond to progress in this field by strictly banning any publication of results that did support the reality of the cold fusion phenomenon. If they were unaware of these results and their importance, they would not merit their reputation. Their silence had thus to be deliberated. They did not want that the scientific community was informed about new results in his domain. It is common dictatorial practice to limit access to factual information, but that is contrary to scientific ethics. Could it be that these journals feared to recognize an error on their part, since that would reduce confidence in their judgments? This confidence had top priority for them, since their customary way to block free access to their publications proves that they are more interested in making money than to serve the scientific community.

The honorable and essential task of scientific journals is to stimulate scientific research, by providing objective information about its results. It is thus also astonishing that no other science journals dared to call attention on the continuing conflict between facts and ideology. This problem merits special attention of all scientists and scientific institutions. What is at stake is whether or not Science is governed by free and autonomous search of knowledge and wider understanding of reality.

In the present case, the basic problem was to find out if the huge Coulomb barrier, preventing cold fusion of nuclei in free space, could be reduced in condensed matter. Is it unthinkable that their mutual repulsion could there be modified by additional electric fields? This question pointed towards image forces, but we were surprised when we found that they depend quite strongly on the local curvature of the interface. Empirical data, accessible by means of alternative publications, revealed that CF can produce astonishing surface effects. They could be explained. Why biotransmutations are possible was more deeply hidden, but they could also be attributed to image forces. It appeared even that it is useful to look beyond the customary limits of compartmented science. Indeed, asphyxiation of welders, egg shells and the gigantism of dinosaurs are also related to nuclear transmutations ...

However, the essential point is that we have to become aware of a much more fundamental problem: *it is very difficult to modify deeply rooted ideas.* This appeared already in a dramatic way, when Aristotle's concepts of motions, absolute rest and the structure of the Universe began to be questioned. Cusanus did this in l440, Copernicus in 1543 and Giordano Bruno in 1584. He presented at European universities the idea that stars are not attached to a sphere that is steadily rotating around an axis, passing through the center of the Earth. This point is not the center of the Universe and Stars are other Suns that are distributed in unlimited space. They could thus also be surrounded by planets. Accused of heresy and being obstinate in defending his ideas, he was condemned to public burning and died on stake in 1600. Kepler presented in his book *Astronomia nova* of 1609 a mathematical analysis of observations, justifying the heliocentric model. Galilei made observations that confirmed this concept, but was accused of heresy in 1633. He retracted. That was better than futile confrontation with rigid convictions of powerful authorities, since Galilei could continue scientific research. Under house arrest, he wrote his "discourses", published in the Netherlands. This book contained already justifications of Newton's principle of inertia and the concept of relative motions.

CF research was also confronted with autocratic decisions, but they could be bypassed. That was not at all motivated by resignation, but a kind of protest. Unfortunately, the History of human societies is full of examples were the "right of the strongest" has been applied in a reckless way. This temptation has not yet been overcome. Dictatorship is even based on lies and legalized murder, but such regimes do not last forever. Progress of humanity and especially scientific research require liberty of thought, combined with objective verifications. This may seem obvious, but there are obstacles. Max Planck wrote in his autobiography [53]: "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it." This statement has been called "Planck's principle". It concerned discussions with Boltzmann, but Planck estimated still in 1945 that it had to be included in his scientific testament.

To realize that current science policies need revision, we should not merely focus attention on the CF phenomenon. There are other signs of misfunctioning. It is obvious, for instance, that physics has been deeply modified by Planck's discovery of a universal constant (h). Einstein realized that Maxwell's theory of EM waves implies the existence of another universal constant (c). This led to the development of quantum mechanics and the theory of relativity. It became even clear that the profound meaning of these theories was that *nature can impose restrictions on possible results of measurements.* Classical physics applied to a domain where these restrictions could be ignored, but they do exist and are of tremendous importance to understand other facts. Nevertheless, we continue to believe that space and time are continuous and similar to matter.

Actually, space and time are only defined by possible results of distance and duration measurements. This implies that there could exist a finite limit for the smallest measurable distance. The value (a) of this "quantum of length" is unknown. It could thus be extremely small, but when it is finite it has to be a universal constant. This requirement is sufficient to construct a theory that generalizes relativistic quantum mechanics and to verify that this type of space-time quantization (STQ) is logically consistent. This took time, but once we had established that there are no internal contradictions, we applied this theory to elementary particle physics. The "standard model" results from analyzing experimental results. The basic fact is that elementary particles can be distinguished from one another by means 4 quantum numbers. The reason remained hidden in the conceptual framework of relativistic quantum mechanics. However, STQ accounts for new degrees of freedom [54], since any (arbitrarily chosen) space-time axis in any (arbitrarily chosen) inertial reference frame allows for two imbricated lattices. They explain the existence of the mysterious quantum numbers and their properties.

Though the standard model is a brilliant semi-phenomenological theory, it leads to many unsolved problems [55]. One of them concerns dark matter. We might presume that it is constituted of elementary particle that are called WIMPS (weakly interacting massive particles), but that it only a name. STQ tells us more, even in regard to puzzling "anomalies" with respect to predictions of the standard model. The nature of the single entity that produced the Big Bang becomes also more understandable. Nevertheless, we met sometimes fierce opposition from controllers who tried to prevent that these ideas get known and can be subjected to experimental tests.

The amazing phenomenon of "water memory" is also instructive. Its reality had been experimentally established, but was "declared" to be impossible [56]. Any structuring of liquid water seemed to be excluded, indeed, because of the thermal agitation of water molecules. Moreover, the initially dissolved medically active molecules had been completely eliminated by successive dilutions. The editor in chief of the journal Nature was thus convinced that the unexpected experimental results were due to errors or wishful thinking. He found a way to win the battle by destroying his assumed opponent. Nevertheless, the facts were confirmed, even in a much more detailed manner. We were intrigued by the continued lack of a rational explanation. Since it is well-known that water molecules are electrical dipoles, we wondered if they could be assembled like magnetic dipoles in ferromagnetic materials. This turned out to be true, but only inside very small spheres. These "nanopearls" are stronger electrical dipoles than single water molecules and can thus constitute chains. Reality can be more complex than commonly believed.

Minute pearls of crystallized water are formed by the electric field of small charged parts of the medically active molecules. Every ferroelectric crystallite generates a new one. They are attached to one another, but since their generators are oscillating at a frequency that is characteristic of the type of active molecules, they produce a standing wave when the chain has reached a specific length. Even when the chains are detached, their oscillations are sustained by impacts of water molecules. The initially dissolved active molecules are progressively eliminated by repeated dilutions (to reduce possible danger). They are followed by vigorous succussions (to insure homogeneity). A fraction of the chains is then broken, but they are reconstituted by the oscillating electric field of the subsisting chains. The total number of identical chains is thus progressively increased. They produce a sufficiently strong electric field to activate the specific receptors of the initially dissolved medically active molecules.

The reality of this mechanism has been confirmed by detailed experiments, but the editor of the famous journal, who claimed (in an devastating way) that the measurements of Dr. Benveniste and his team were fake, did not inform about new results on water memory. The journal did never present excuses. Is that correct? An important byproduct of this research was the discovery that medically active molecules and their substitutes activate their specific receptors by means of an oscillating electric field and resonance effects. This might have been discovered earlier, if further research had not been blocked by the reckless, arrogant and erroneous attitude of this science journal.

The treatment of the work and discoveries of Royal Raymond Rife is another scientific scandal, involving dominant science journals and medical institutions [57]. Rife constructed at about 1920 an optical "super-microscope". It allowed him to detect ultrasmall entities and to prove that they cause cancer. He found even that these entities could be selectively destroyed by an electric field that oscillates at a specific frequency. These results were dictatorially declared to be impossible, without appropriate studies. The efficiency of this cancer treatment has been medically confirmed, but the "cancer cure that worked" was prohibited. Rife himself was viciously attacked and eventually eliminated.

We ask therefore: is it normal that prominent scientific journals can condemn honest and creative scientists, because of preconceptions and insufficient studies? Why do scientific institutions allow and cover up such methods? Should blocking of research and deliberate concealing of experimentally confirmed facts be tolerated, without recourse? We hope that the elucidation of CF phenomena and biotransmutations will contribute to progress in this regard.

Declarations

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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