Does a Mössbauer effect really exist?

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Part 3

Abstract – The Mössbauer effect, based on the variation in resonant absorption of gamma radiation, is described here as an extreme result of a kicked quantum oscillator. The Mössbauer effect shows what happens around the atom whose nucleus have emitted or absorbed a gamma quantum. A "strange" momentum compensation happens for the quanta momentum recoil. All seems to obey a conservation principle in the natural fluctuations of the zero point phonons. But all this is just *mysteriously* encoded in the Schrödinger time dependent equation, as we have seen in Part **2** from an analytic solution for a particular hypothetic case. The conclusion is that the **Mössbauer effect really does not exists,** being only a particular case of quantum mechanics. All is just encoded in the Schrödinger time dependent equation, as we have seen from an analytic and numeric solution for an hypothetic case in **Part. 1, 2**.

1 - Introduction

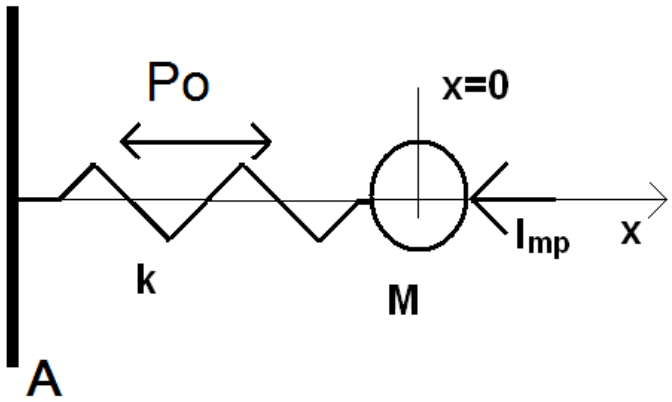

Fig. 1 This is the physical model to which is applied the Schrödinger time dependent equation (see Part.2). The analytical solution[1] is shown after a numerical treatment [2]. The mass M (one atom) is linked to the rigid structure **A** with an elastic constraint **k**. The $\mathbf{I_{mp}}$ is the impulse of the gamma quantum. The energy of mass M can be only at the levels: **n** = 0,1, 2, … The starting point is at n = 0 (T=0K), Everything is initially at a temperature of 0K, so there are no thermal phonons, at the beginning: n = 0. [2]. P_γ (I_{mp}) is the impulse of the gamma quantum received by mass M. The ratio **Ɛ** is given by: $\mathbf{Ɛ = E_c/\hbar\omega_c}$. (see in [2], eq.(18)). The results are summarized in Figs. 4a, 4b.

In the Mössbauer effect bonds and states of the atoms that are far from the atom where the effect occurs, are not revealed. The hypothesis is that the Mössbauer effect is possible thanks to the ***intervention of the energy and momentum of zero point phonons***, that are present in all the atoms of the lattice. Probably the same intervention can happen from thermal phonons (**n**) where there is a probability that a transitions **n**↔ **n** occurs (Fig.2). Most important are the high energy phonons, with short wavelength. No phonon is created so that the energy of the lattice is conserved with a "loan" that is returned during the time interval, allowed by the uncertainty principle. An atomic nucleus is hit by a gamma quantum (the same goes for a neutron or other particles). This atom, if it were not bound in a lattice, would recoil. But instead, normally, if the atom is bound in a lattice, it would have to transfer energy and momentum to the lattice, starting from the closest atoms. This transfer occurs by creating phonons, the quanta of vibration that spread moving at sound velocity. Nothing happens in the supposed Mössbauer effect. It is not true that it involves the other atoms of the lattice because the phenomenon occurs even if the hit atom is enclosed in a nanoparticle, that does not have enough mass to hide the recoil. The atom hosts all the (N-1)3 zero-point phonons of the lattice with N atoms.
In order the lattice remains rigid, in the struck atom must be neutralized the impulse received. This can be obtained using a zero point phonon that is parked around him. But these zero point phonons could never be used. True, but for the uncertainty principle it can be done within the time interval allowed. Then everything goes back to the way it was before, in the meantime the so-called Mössbauer effect has occurred. The Mössbauer effect shows what happens near and around the atom whose nucleus have absorbed a gamma quantum. For the same atom happens a momentum compensation to neutralize the pulse received. All to obey a conservation principle in the fluctuations of the zero point phonons. But all this is just mysteriously encoded in the Schrödinger time dependent equation, as we shall see from its analytic and numeric solution for an hypothetic case (Fig. 1).

In **Part 1** we have noted the existence of two important experimental results that make current theories about Mössbauer effect unacceptable, all regarding the in-stantaneous collaboration of all the atoms of a lattice:
1) no Mössbauer spectrum does a shift appear due to the recoil, however small is the mass of the nanoparticle that houses the atoms absorbing gamma photons, impulse conservation would not be respected.

2) reducing the mass of the nanoparticles the absorption of the gamma photons is attenuated (the Mossbauer diagram area is reduced) even if, as we have said (Part 1), there is no shift by recoil even if the mass of the particle would not be able to hide the recoil.
In **Part 2** we first examine the negative consequences caused by the belief that there is a sudden (and impossible) collaboration between the atoms of a lattice.
The new theory - We will then illustrate the present theory that involves the intervention of energy and momentum of the zero point phonons of the atom that emits or absorbs a gamma photons in the Mössbauer effect. The appearance of the narrow line of irradiation and the same for absorption, (about 10^5 less than R) would not have been conceivable and undetectable without the chance discovery of Mössbauer.
We have found that a harmonic oscillator has a quantic “stiffness”, unknown and impossible in classical mechanics. But the Mössbauer effect does not only make use of a "quantum rigidity" to occur, for nanoparticles, it apparently must also violate the conservation of the impulse, which is impossible in both classical and quantum mechanics. The old question is: *how the impulse received by the nucleus, when a gamma photon is emitted or absorbed, is neutralized?*
In the current Mossbauer theory, the impulse would be transmitted to the entire mass of the lattice and then "diluted" until it was not measurable.
The proof of the impossibility of explaining the Mössbauer effect with actual theory, is given by the examination of the gamma absorption spectra of the nanoparticles with an insufficient mass to justify the absence of recoil. To verify the condition of insufficient mass, the Mössbauer spectra relating to nanoparticles were examined. It must be remembered that the spectrum of the lattice oscillations of a nanoparticle is not comparable to a continuous spectrum as in a large solid (bulk).
The belief, founded on the collaboration of all the atoms of the lattice, goes back to Mössbauer himself. This is an erroneous belief that, until now, no one was able to correct. As seen from this misconception, the Mössbauer effect remained a mystery of physics for sixty years. Since the Mössbauer effect tells in great detail the state of the atom whose nucleus has absorbed a quantum of gamma radiation, it would have been obvious to assume that the cause of the apparent rigidity of that nucleus where to be found in the same atom to which that nucleus belongs. But what we find in an atom, inserted in a lattice, to give this “quantum rigidity”?
In **Part 3** We illustrate the present theory that says that the Mössbauer effect does not exists. Thanks to the intervention of energy and momentum of the zero point phonons of the atom that emits or absorbs a gamma photons in the Mössbauer effect. The appearance of the narrow line of irradiation and the same for absorption,

(about 10^5 less than the energy gap of recoil R) would not have been conceivable and undetectable without the Mössbauer discover.

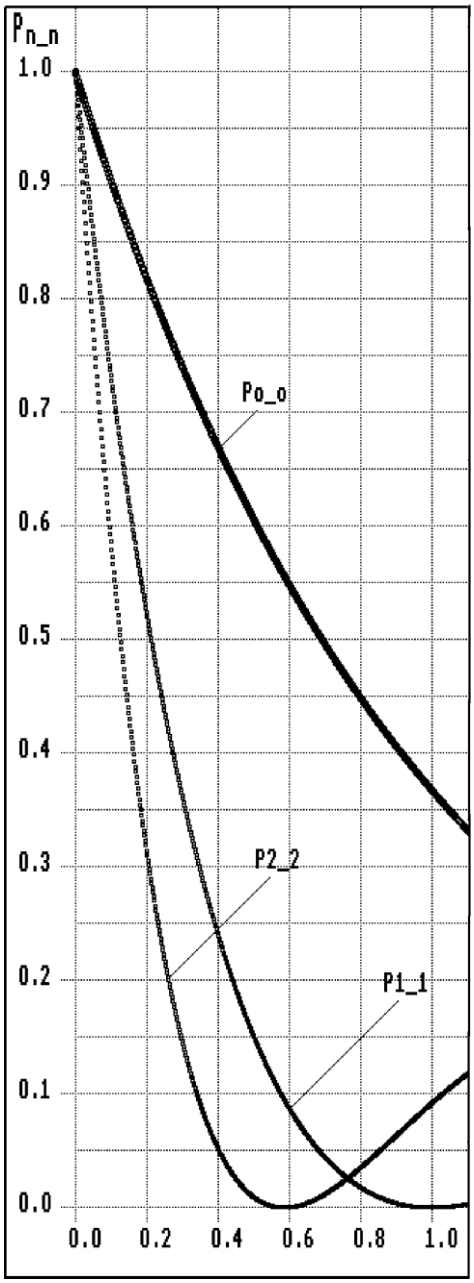

Fig. 2. Probability of no transaction for levels: 0,1, 2, versus the energy ratio $\boldsymbol{\varepsilon = E_c/\hbar\omega_c}$. (see eq.(18) [2]). Where the *classic* energy $E_c = k\cdot x_c^2/2 + M\cdot(dx_c/dt)^2/2$, the frequency ω_c is equal to $(k/M)^{0.5}$

$\varepsilon(t) = \frac{1}{\eta\,\omega_c}\left(\frac{k\,x_c^{\,2}}{2} + \frac{M\,\dot{x}_c^{\,2}}{2}\right)$ represents the total energy reached by the *classical oscillator* at the time *t*, divided by the quantum energy $\eta\,\omega_c$.

We have found [2, 3] that a harmonic oscillator has a quantum “stiffness”, unknown and impossible in classical mechanics. But the Mössbauer effect does not only make use of a "quantum rigidity" to occur, for nanoparticles, it apparently must also

violate the impulse conservation, which is impossible in both classical and quantum mechanics.

The question is: ***when a gamma photon is emitted or absorbed how the impulse received by the nucleus is neutralized ?***

Following the current theory: the gamma impulse would be transmitted to the entire mass of the lattice and then "diluted" until it was not measurable.

The proof of the impossibility of explaining the Mössbauer effect, with this theory, is given by the examination of the gamma absorption spectra of the nanoparticles with an insufficient mass to justify the absence of recoil (see **Part. 1**, also Fig. 2).

It must be remembered that the spectrum of the lattice oscillations of a nanoparticle (Fig.4) is not comparable to a continuous spectrum as in a large solid bulk.

The belief, founded on the collaboration of all the atoms of the lattice, goes back to Mössbauer himself. This is an erroneous belief that, until now, no one was able to correct. As seen from this misconception, the Mössbauer effect remained a mystery of physics for sixty years. Since the Mössbauer effect tells in great detail the state of the atom (and around it) whose nucleus has absorbed a quantum of gamma radiation, it would have been obvious to assume that the cause of the apparent rigidity of that nucleus where to be found in the same atom to which that nucleus belongs. But what we find in an atom, inserted in a lattice, to give this “quantum rigidity”? Exists other similar phenomena?

1 - Zero point phonons in nanoparticles

We resume the study of nanoparticles:

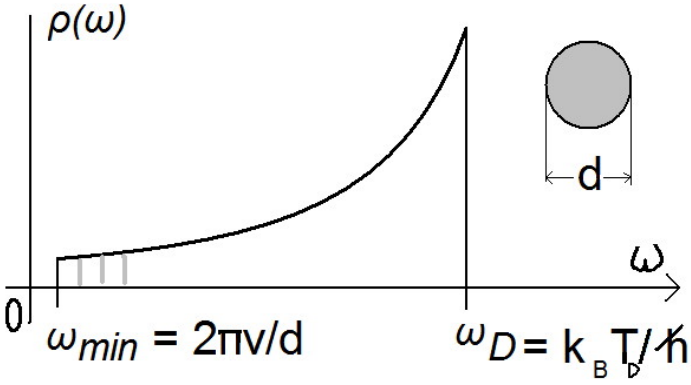

Fig. 3 - A nanoparticle of diameter **d**, in which the speed of sound is **v**, has no oscillation frequencies lower than ω_{min}. T_D is the Debye temperature. K_B is the Boltzmann constant. Obviously this spectrum of possible frequencies is also the spectrum of the real zero point oscillations present in all the atoms of the nanoparticle.

It is well known that in bulk solids the vibrational density of states (DOS) forms a continuous band, and at low energies is well described by the Debye law.

However, in small crystals the finite size leads to a discretization of the phonon spectrum. This is strongly manifested at low frequencies where the separation between modes may become larger than their width, and no modes exist below the lowest vibrational frequency (Fig.4).
We shall refer to the frequency $\boldsymbol{\omega_{min}}$ of the lowest vibrational mode as the acoustic 'gap'. The density of frequency $\varrho(\boldsymbol{\omega})$ in discrete form is given by:

$\varrho(\boldsymbol{\omega})=\sum_{n=1} 3N\boldsymbol{\omega^2}/(\omega_D{}^3-\omega^3{}_{min})$, where $\varrho(\boldsymbol{\omega})$ is the density of states versus the frequency $\boldsymbol{\omega}$. A spherical nanoparticle of diameter **d** cannot support internal vibrations at frequencies less than about $\boldsymbol{2\pi v/d}$, where v is a characteristic bulk sound velocity (Fig. 3). Any property of the nanoparticle that depends on the vibrational spectrum, will be very different at low energies than in bulk crystals. This will be especially true for nanoparticles only weakly coupled to their surroundings. The phonon emission rate at frequencies less than that of the lowest internal vibrational mode, i.e., in the acoustic 'gap' ($\boldsymbol{0 - \omega_{min}}$) is zero. **In small crystals** the finite size leads to a discretization of the phonon spectrum (Fig. 3). This is strongly manifested at low frequencies where the separation between modes may become larger than their width, and no modes exist below the lowest vibrational frequency $\boldsymbol{\omega_{min}}$. The discrete DOS is expected to change dramatically many physical processes involving low frequency phonons, but are not changed the properties at high frequencies that are supposed to be the possible cause of Mössbauer effect. The hypothesis is made that an impulse does not create phonons, mainly thanks to the intervention of the momentum of the zero point high frequency phonons, that exists equally in bulk and in nanoparticles. If we reduce the mass of the crystal, thus reducing the number N of the atoms it contains, we will have fewer frequencies ((N-1) zero-point frequencies for each atom) of the crystal. The consequence is a reduction in the probability of elastic emission/absorption, which however will also occur with a lattice composed of a single atom, linked to a large mass (physical model of Fig. 3) and therefore with a single oscillation frequency (only for collinear pulse).

2 – The new theory

Failure to understand the true nature of the Mössbauer effect was the cause of over sixty years of senseless research on the attempt to reveal low-energy neutrinos that arise with the decay of Tritium, as we shall see in a later section.
*In small crystals the finite size leads to a discretization of the phonon spectrum (Fig. **3**). This is strongly manifested at low frequencies where the separation be-*

tween modes may become larger than their width, and no modes exist below the lowest vibrational frequency ω_{min}. The discrete DOS is expected to change many physical processes involving low frequency phonons, but the properties due to the high frequency phonons, as the interactions with a sudden pulse, are not changed (i. e. the interaction with gamma quantum mechanical pulse).

It is well known that the vibrational density of states (DOS) forms a continuous band in bulk solids, and at low energies is well described by the Debye law.

So all the zero point phonons for all possible frequencies of the entire lattice are present simultaneously in all atoms of the lattice. In the time interval allowed by the uncertainty principle, these zero point phonons can oscillate in order to cancel an external pulse located in an atom of the lattice.

The mass M oscillates with only one frequency. By solving [2, 3] the time dependent Schrödinger equation for the mass M, we will find that it has the Mössbauer effect that therefore already seems to be contained in the heart of Quantum Mechanics. Our model (Fig.**1**) consists of a single atom prompted by a mechanical pulse $\mathbf{I_{mp}= F x Dt}$, equal to the pulse $\mathbf{P_\gamma}$ of a radiated or absorbed gamma quantum. It turns out that the result has a strong analogy with the Mössbauer effect (results of numerical calculations are represented in Figs. 4a, 4b). A mass M is connected with a hypothetical large rigid mass **A,** to which is linked by an elastic bond, a potential V(x), which does not depend on time. The mass M, equal to the mass of a ^{57}**Fe** atom, will have only one oscillation frequency (which corresponds approximately to the maximum frequency in a solid composed of N atoms of Fe).

$\mathbf{P_\gamma} = 0.775 \cdot 10^{-18}$ [g·cm/s] = $\mathbf{I_{mp}}$. (gamma quantum pulse)

But in the quantic world there exists another momentum $\mathbf{P_0}$ that cannot be eliminated. It is originated by atoms zero point motion: the phonon zero point momentum (we are interested in the zero point phonons with higher energy). This momentum $\mathbf{P_0}$ can be comparable with the ***recoil momentum***: $\mathbf{P_R} = E_R / c_s$ [where $E_R = E_\gamma/(2Mc^2)$, E_R is the recoil energy, E_γ is the gamma quantum energy, M is the atom mass, c is the light velocity, c_s is the sound velocity in the lattice] ***but until now the momentum P_0 is considered not at disposal to perform anything***.

3 – Exact analytical solutions of the Schrödinger equation [2, 3].

The details of the analytical solution were carried out by Prof. Adriano Orefice [2].

From [2] (with the same number for equations):

$$\psi_m(x,t) = N_m \exp\left\{\frac{i}{\eta}[M\dot{x}_c\, x - \int_0^t \delta(t)\,dt - W_m t]\right\} H_m[\alpha(x-x_c)]\ \exp[-\frac{\alpha^2}{2}(x-x_c)^2] \quad (14)$$

From [7] the probability **f** that Mössbauer effect occurs is:

f ≈ $\exp[-3E_R/(2k_B\cdot\theta)(1+2\cdot(\pi\mathbf{T}/\theta)^2/3)]$. Where **θ** is the Debye temperature.

For T=0 becomes: f ≈ $\exp[-3\mathbf{E_R}/(2k_B\cdot\theta)]$ = **Mf,** that is reported in Fig. 6a, 6b.

In the Debye model and at zero degree Kelvin temperature, the recoil free fraction is given by: $DW_{T=0K} \approx \exp[-E_R \times 3/2]$. This is indicated in Fig.4a, 4b as **Wf**

4 - Zero point phonons: energy and momentum

This model (Fig. 1) shows a "stiffness" slightly higher than that predicted by the Debye-Waller theory applied to a solid (bulk), for which **f** = DW = **0.929**, (at zero K) while from the calculation with the model of Fig. 1 with a single atom we have: DW = **0.95**. This model is not physically feasible but reveals that a single atom, with a single oscillation frequency, bound by a potential V(x), which does not depend on time, has the Mössbauer effect. In reality, every atom that emits or absorbs a gamma quantum in a lattice is bound to a potential that is also a function of time: V(r, t). The propagation of the anchoring of the potential would obviously proceed with "acoustic" speed in such long times that the time dependence of the potential V is irrelevant.
Another problem arises when the solid, which should anchor the atom that absorbs the gamma quantum, is a nanoparticle, which should recoil, with an effect strong enough to be detected in the same Mössbauer spectrum. (see **Part 1**)
In the model adopted in our calculation (Fig. 1), the atom (with mass M), hit by a pulse $\mathbf{I_{mp}}$, is bound to a very large mass **A**, which with the Mössbauer effect not only does not absorb energy in vibrational levels (phonons created are the same envisaged by the Debye-Waller formula) but neither seems to recoil if in place of mass **A** we have the mass of a nanoparticle. Seems that the entire nanoparticle does not receive translational energy.
The whole nanoparticle does not even seem to recoil as a whole.

In Fig. **1** we see a single atom, elastically bonded to a large mass A. We can ascertain that at 0 K, after applied the gamma pulse, the results are shown in the figures **4a, 4b**. Before apply the gamma pulse we have probability **1** for n=0, the other (n= 1, 2, 3) probabilities are zero). After the pulse is applied for n=0 the probability shall be less than 1. This value represents the Mössbaur effect (Mf) for the single atom.

The "rigidity", already present in the solutions of the Schrödinger equation, is seen to arise even leading to the disappearance of the recoil. [8]
The analysis, carried out on the single atom model, leads to the result that the Mössbauer effect occurs also with a single atom which is the seat of a single zero point phonon. So the Mössbauer effect is already described by the time dependent Schrödinger equation. The conclusion is: ***the Mössbauer effect derives exclusively from the phonons "parked" in the same atom of the lattice in which the effect occurs***.
The highest probability of not creating phonons is P_{0_0} (Fig. 2). Even for phonons with n> 0 (Pn_n >0), for low energy transfer (**ε**), there is a non-zero probability that a transition occurs that does not create thermal phonons. The recoil time of the entire nanoparticle can be covered by the Heisenberg uncertainty time.

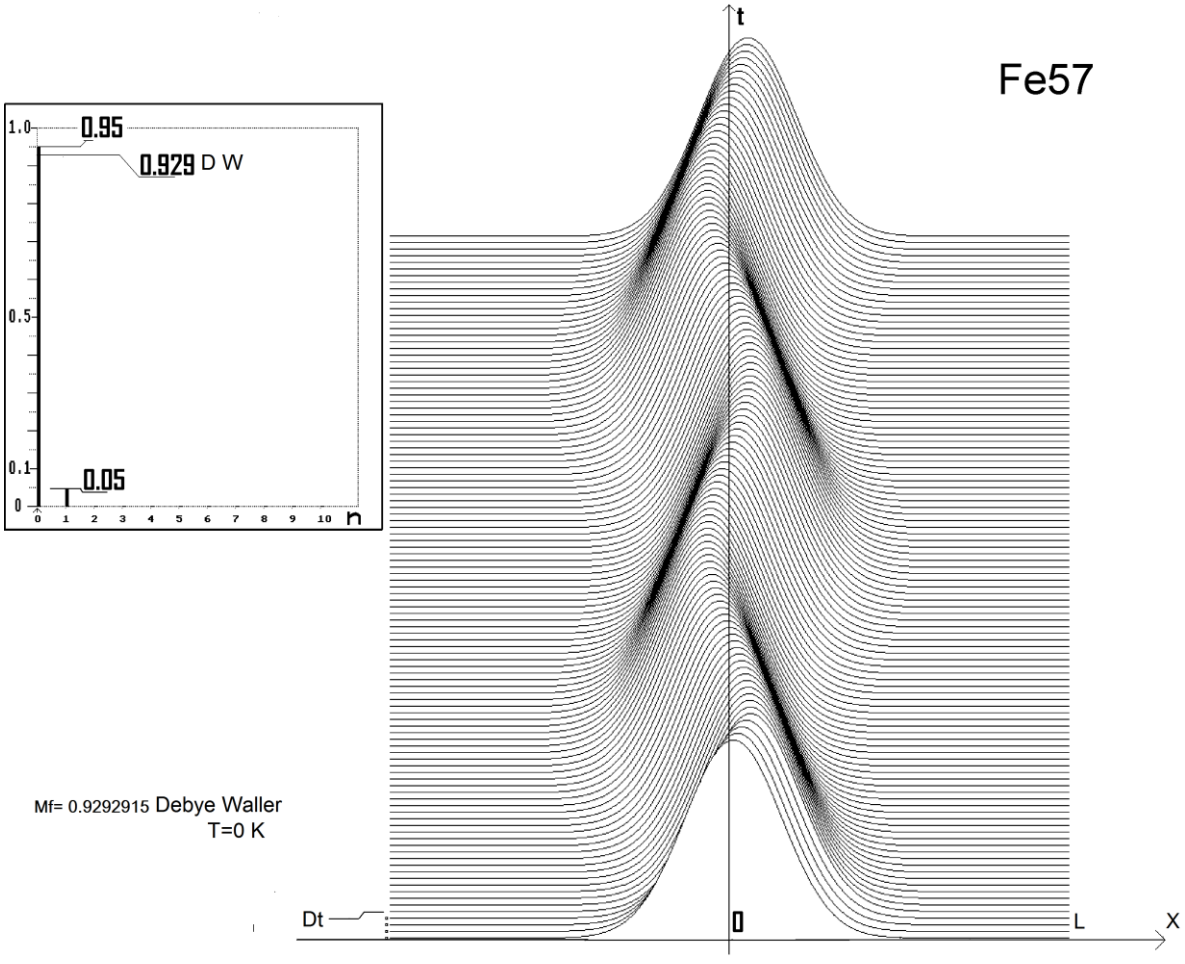

Fig.**4a**; For ^{57}Fe probability density ψ_m during and after the pulse: $\mathbf{l_{mpg}} = E_g/c$ is represented in the space with dimension: L = 2,0x5.2917x10^{-9}[cm]. In the insect are represented the probabilities (between 0 and 1) that after the pulse **lg**, **n** have the vales 0,1,…10.

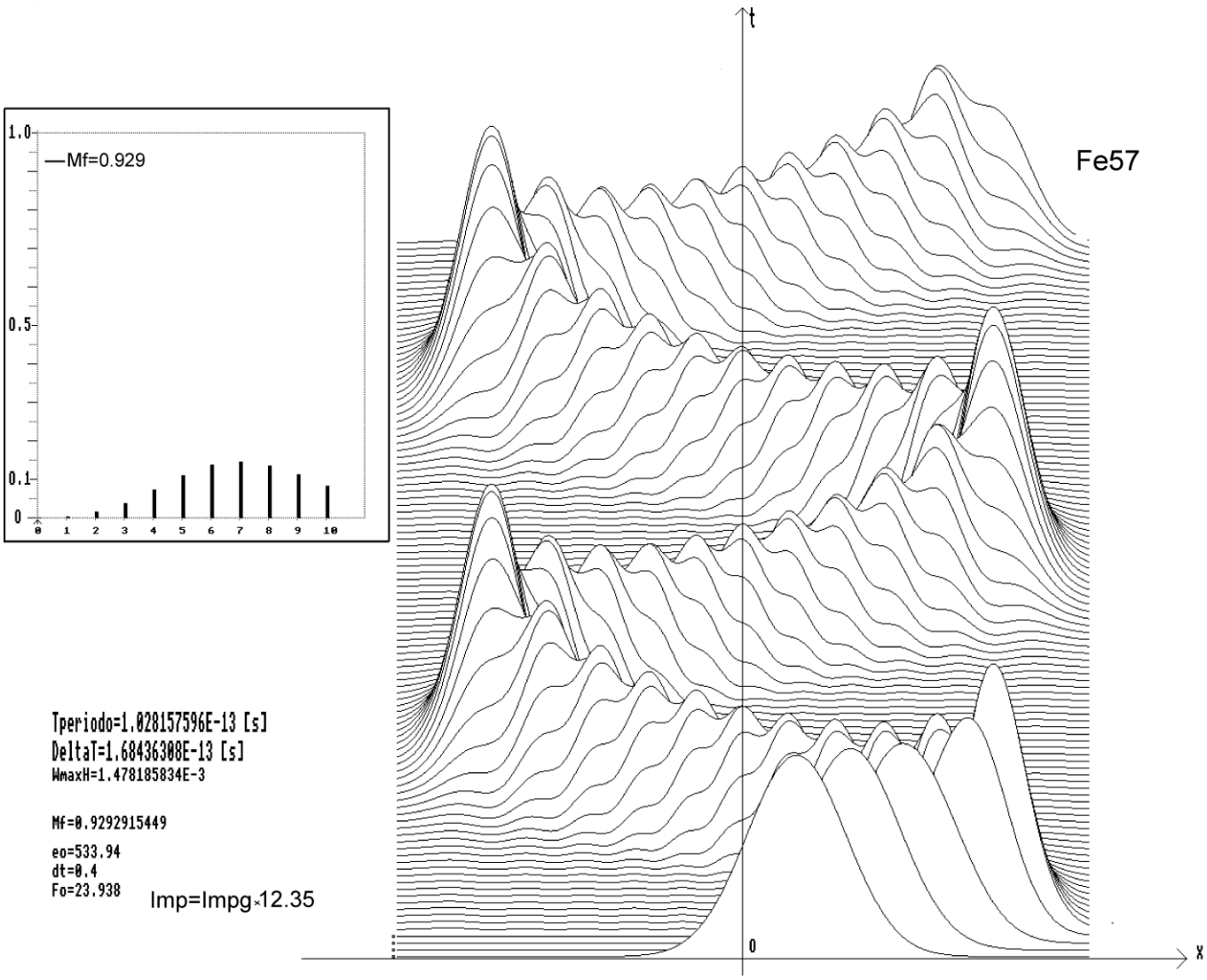

Fig. **4b**. This is the result if the impulse have a very high value, as: Imp=**12.35** x Impg. The probability of n_0 is the Mössbauer effect if the oscillator before the gamma quanta impact was at 0 K, with $n_0 = 1$ (and $n_{>0} = 0$). If the gamma pulse is very high, as for example: 12.35 times the "natural" gamma pulse) after the impact $n_0 \approx 0$, so that no Mössbauer effect exists.

The existence of the Mössbauer effect, even in nanoparticles with a mass lower than that necessary to mask the recoil (see Part 1 and Part 2), as already mentioned, removes any validity from any theory based on the "solidarity" of the whole lattice around the atom that undergoes a "mechanical impulse", either by emission or absorption of a gamma quantum.

5 - Zero point momentum and energy for a single oscillator

All oscillators, in the quantum description, have a zero point energy. In very fast transient phenomena, zero point energy can occur in the time intervals covered by the uncertainty principle. For a single oscillator j, and the direction i, the energy is:

$$E_{j,i} = \hbar\omega_i[½ + (e^{\hbar\omega/kT}-1)^{-1}]. \qquad (29)$$

The total mode of oscillation is 3N. **n** (n>0) is the average number of (thermal) phonons present. **n** depends on the temperature, while the angular frequency ω is the frequency typical of the single classical oscillator and applies: $\omega = (k/m)^{1/2}$. For a single, isolated oscillator, we have only one angular frequency ω. The number **n** of phonons is a function of temperature T (from [2]) be present in the oscillator for the frequency ω is given by:

$$\mathbf{n}(\omega,\mathbf{T}) = 1/(e^{(\hbar\omega/K\mathbf{T})}-1) \qquad (30),$$

where K is the Boltzmann constant. For T→0: n→0

The density of states is: $\rho(\omega) = B\,(\omega^2 / \omega^3_D)$,

$E_{j,T=0} = \omega_j \cdot \hbar \cdot (½)$ is the *residual* energy of quantum oscillator for T=0.

This quantum model applies to any oscillation in the atomic field. In particular, for a lattice many (3N) different oscillations are possible, with different frequencies, from the lowest ones that involve the far atoms, up to the highest ones involving 2 contiguous atoms. The total vibration energy of the i-th atom will be given by the sum of all 3N possible frequencies:

$$E_i = \sum_{j=1}^{j=3N} \omega_j \cdot \hbar \cdot (n_j(\omega_j,T) + ½) \qquad (31)$$

The total vibrational energy E_t of the lattice is given by the sum of the energies of the N atoms, where all the zero-point 3N oscillations (zero-point phonons) are present:

$E_{0,i} = \sum_{(j=2,\ldots N)} [\omega_j \cdot \hbar \cdot (½)]$ energy of N - 1 zero-point phonons

$$E_t = \sum_{(i=1,\ldots N-1)} E_{0,\,I} \qquad (32)$$

Thus each lattice atom will accommodate all N zero point oscillations at all the lattice frequencies ω_j.

About the relevance of zero-point phonons it is interesting to read: "*Characterization of Zero-point Vibration in One-Component Crystals*"[10], that show the magnitude of zero-point vibration in one-component crystals. For the crystals whose constituent atoms share the same bonding geometry, we prove the existence of a characteristic temperature, $\mathbf{T_0}$, at which the magnitude of zero-point vibrations displacement equals to that of the excited vibrations. Within the Debye model $\mathbf{T_0}$ is found to be ~1/3 of the Debye temperature $\mathbf{T_D}$.

6 The Heisenberg uncertainty

The attempt to invoke the Heisenberg uncertainty principle to give an explanation of the Mössbauer effect has rarely been made. An attempt at explanation in this direction was tempted by H.-D. Pfannes et al. [9]. But the conclusions are unclear: «The Mössbauer effect is based on the "recoilless" absorption and emission of low energy (E_0=10÷100 keV) gamma-photons in solids. ***A simple explanation for this effect relies on the Heisenberg uncertainty relation:*** the uncertainty in momentum of bound atoms is: $\Delta p \geq \hbar/\Delta x$. Where uncertainty in momentum Dp is of the order of 10^{-23} [kg·m·s^{-1}]. The uncertainty in position is Dx (Δx = 0.1 Å) but the recoil moment of e.g. a gamma photon with energy E_0=10 [keV] is smaller ($\Delta p \geq 5\cdot10^{-24}$ [kg·m·s^{-1}]?), i.e. the recoil which eventually can excite vibrations (phonons) of the emitting atom sometimes may not be measurable.» Pfannes [9] continues, following the current theory, saying: «*The recoil is then transmitted to the crystal as a whole and since the mass of the crystal is much greater than the atomic mass it does not alter the gamma-energy ("recoilless" emission). … when the lifetime* ***t*** *of the excited Mössbauer energy level is longer (e.g.* ***t*** *= 10^{-7}s) than a period T of vibration (phonon) frequency of the emitting or absorbing atom (e.g. 10^{-13}s). The atom carries out many cycles during the lifetime of the gamma photon and the Doppler broadening of the emitted radiation averages out. As a result a sharp line with the natural linewidth $G = \hbar/t$ at the position E_0 is emitted from the source and nuclear resonance absorption with an energetic resolution $G/E_0 = 10^{-13}$, sufficient to resolve hyperfine interactions, is possible. The above mentioned conditions for recoilless emission limits the Mössbauer isotopes to those isotopes which possess low energy nuclear g-transitions (small recoil moment), long lifetimes of the excited state (hyperfine resolution), high Debye temperature (small Dx) and solid sources and absorbers.*»

From this new theory we have instead: the Heinsenberg uncertainty principle enters the physical nature of the phenomenon by providing a time interval (a "*cover*" of time) $\mathbf{\Delta t \geq 3.29\cdot10^{-14}}$ [s]) for the phenomena of emission or absorption without the creation of phonons. In the following we employ the atom ^{57}Fe.

The recoil momentum can be stopped only by the high energy phonons "parked" in the atom where the so-called Mössbauer effect occurs:

$\mathbf{E_\gamma}$ = $1.44\cdot10^{4}$ [eV] = $2.307\cdot10^{-8}$ [erg]: is the energy of gamma quantum.

From the uncertainty principle:

$\Delta p \cdot \Delta x \geq \hbar/2$; for a change of energy ΔE: $\mathbf{\Delta E \cdot \Delta t} \geq \hbar/2$;

an undetermined time interval Δt is created: $\Delta t \geq (\hbar/2)/\Delta E$

$\mathbf{\Delta E = E_R}$ - The recoil energy must be "missed". With the period T_D of an oscillation of the highest energy zero-point phonons:

$T_D = 2\pi/\omega_D = 1.14 \cdot 10^{-13}$ [s]; Debye period where ω_D is the Debye frequency: $\mathbf{\omega_D} = K_B \cdot T_D/\hbar \approx 5.5 \cdot 10^{13}$ [rad/s]; Debye frequency

$\mathbf{\Delta E = E_R} = E^2_g/(2M_{Fe} \cdot c^2) \approx 2 \cdot 10^{-3}$[eV] $= 3.204 \cdot 10^{-15}$[erg];

$\mathbf{\Delta t} \geq (\hbar/2)/E_R = 5.2727 \cdot 10^{-28}/(3.204 \cdot 10^{-15}) = \mathbf{1.6456 \cdot 10^{-13}}$[s]

The maximum energy of **zero point phonons** is given by:

$E_{\omega\text{-max}} = \hbar \cdot \omega_D/2 = 1.055 \cdot 10^{-27} \cdot 6.11 \cdot 10^{13}/2 = \mathbf{3.223 \cdot 10^{-14}}$ [erg]

$E_\gamma >> E_{\omega\text{-max}}$;

On the contrary the momentum of the high energy phonons $\mathbf{P_\omega}$ and the momentum of gamma photon Pγ, are comparable:

$c_s \approx 5.1 \cdot 10^5$ [cm/s]

$\mathbf{P_\omega = E_\omega/c_s} = 6.32 \cdot 10^{-20}$ [g·cm/s], where c_s is the sound velocity :

$\mathbf{P_\gamma} = E_\gamma/c = 7.75 \cdot 10^{-19}$ [g·cm/s], where c is the light velocity

$\mathbf{P_\omega < P_\gamma}$

Recoil momentum $\mathbf{P_R}$

$\mathbf{P_R} \approx \mathbf{E_R}/c_s = 3.204 \cdot 10^{-15}/5.1 \cdot 10^5 = 6.282 \cdot 10^{-21}$ [g·cm/s]

$\mathbf{P_\omega >> P_R}$; this confrontation is wright because $\mathbf{P_\omega}$ is the impulse of the zero point oscillations, that is greater than that of the recoil, the impulse transferred from the gamma quanta to the atom. The gamma quantum with energy Eγ was absorbed (or emitted) by the nucleus. At the moment of absorption (or emission), the

recoil movement of the same atom must be canceled. To achieve this, it is necessary to eliminate the mechanical recoil energy E_R. This can happen mainly thanks to the momentum of the zero point phonons. At the moment of absorption (or emission) of gamma quantum **Eγ**, to cancel the mechanical recoil, that spreads with the speed of sound c_s, the movement of the atom must be canceled. Therefore only the mechanical recoil energy must be eliminated thanks to the momentum of the zero-point phonons: $\mathbf{P_\omega > P_R}$.

To verify the uncertainty concerning the recoil:

$\Delta E \cdot \Delta t \geq \hbar/2$; where: $\Delta E = E_R$

$\Delta t \geq (\hbar/2)/E_R$; Time period at maximum frequency: $\mathbf{T}=1.14\cdot10^{-13}$ [s]

$\Delta t \geq 5.2727\cdot10^{-28}/\ 1.602\cdot10^{-14} = 0.329\cdot10^{-13}$[s]; $\mathbf{\Delta t<T}$

But Δt and T are comparable. We provide two clues:

a) the momentum of the gamma photon recoil can be "stopped" locally by the momentum of zero point phonons. The whole event takes place within the time interval Δt covered by the uncertainty.

b) After the gamma photon has been emitted (or absorbed), the distribution of the zero-point phonons is re-established in a time covered by the uncertainty principle.

Emission and absorption occur with the "immobilized" atoms in a short time interval, with the result that no localized creation of phonons occurs.

A gamma photon, whose energy is close to that of absorption by resonance, must have a supplement of energy equal to the recoil that the atom will undergo. A photon that has exactly the same energy as the resonant must meet a "blocked" atom so that it does not have to lose the E_R energy, which would send it out of the resonance. To realize this "block" it is necessary to cancel the recoil ***before*** it is formed. A sort of temporal inversion should be created that is possible within quantum mechanics, in the time interval allowed by the uncertainty principle. If the momentum associated with the energy E_R is not too high it can be canceled by zero-point phonons. During the time Δt a mechanical action is necessary to maintain the atom in its original position. A pulse must be available in an extremely short

time to block the recoil, but during this time, for the Heisenberg uncertainty principle, we cannot know what really is happening.
The recoil is not canceled but occurs in the indetermination time interval Δt and therefore does not appear in the energy balance of irradiation and absorption of the gamma quantum. The recoil occurs after the "elastic" phenomenon has occurred. Therefore the quantum elastic phenomena would be the result of the temporal coverage given by the uncertainty principle.

It remains to be discovered who absorbs, even temporarily, the momentum of the incoming particle or gamma quantum.
The most plausible hypothesis is that the recoil is canceled by the momentum of the zero point oscillations (zero point phonons) *for the natural tendency to maintain the initial conditions*. Thus the oscillation impressed to the atom by the recoil would be stopped by the momentum of the zero point oscillations. This causes a temporary imbalance in these oscillations, an imbalance that disappears in the interval of time allowed by the uncertainty.

7) - CONCLUSION

Until now exists *A Mysterious Consequence of Mössbauer's Effect* [11].The Mössbauer effect is a phenomenon localized in atoms whose nuclei radiate or absorb a quantum of gamma radiation. In fact, in the gamma absorption spectra, only information concerning that same single atom and nucleus appears. No evidence exists of a sudden solidarity of the atoms of the lattice. The solidarity, however, is impossible due to lack of time. But there is another reality: the zero point phonons. These phonons are present in every atom. This model has been criticized for suspicion of divergence in the number of phonons by Gründler [4], a number that would tend to infinity for a very large solid. However, as far as the Mössbauer effect is concerned, this is a false problem. Only phonons with high momentum are useful, those that concern phonons with a small wavelength and involve the atoms closest to the atom concerned. The possibility remains that the momentum of the zero point phonons can compensate and cancel the momentum of the recoil of atom hit by gamma quantum emitted or absorbed. Let's try to apply Heisenberg's uncertainty.

REFERENCES

1) E. H. Kerner,"Note on the Forced and Damped Oscillator in Quantum Mechanics", Can. J. Phys. **36** (1958) 371
2) R. Giovanelli, A. Orefice, "Quantum rigidity of microscopic bonds", Physics Letters, **A 311**, 67-76 (2003)

4) Gerold Gründler , “The zero-point energy of elementary quantum fields”, As trophysical Institute Neunhof, Nürnberg, Germany, arXiv:1711.03877v1 [phys-ics.gen-ph]

5) L. Landau, E. Lifschitz, Mécanique, Mir, Moscow, 1966, Ch. 5.

6) L.I. Schiff, Quantum Mechanics, McGraw-Hill, New York, (1949)

7) Arthur H. Muir Jr. “TABLES AND GRAPHS FOR COMPUTING DEBYE-WALLER FACTORS IN MOSSBAUER EFFECT STUDIES”, Atomic International, North American Aviation (1963)

8) R. Giovanelli, A. Orefice, “Quantum elasticity in Debye solids”, Solid State Comm., **135**, 82-86 (2005).

9) H. D. Pfannes, J. H. Dias Filho, R. Magalhães-Paniago, J. L. López, and R. Panago, “Mössbauer Spectroscopy Superparamagnetism and Ferrofluids”, Labor-atory for Hyperfine Spectroscopy and Surface Physics, Departamento de Física, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil, Braz. J. Phys. Vol. **31**, no.3 São Paulo, Sept. 2001

10) Yong Yang and Yoshiyuki Kawazoe, “Characterization of Zero-point Vibra-tion in One-Component Crystals”, EPLA, (Europhysics Letters, Vol. **98**, N. 6 (2012), https://arxiv.org/pdf/1111.4064

11) V.N.Strel’tsov, “A Mysterious Consequence of Moessbauer’s Effect”, Joint Institute for Nuclear Research, Dubna, Moscow Region 141980, RUSSIA Journal of Theoretics, Vol. 6-6, (2004)

12) R. R. Gabbasov, V. M. Cherepanov, M. A. Chuev, M. A. Polikarpov, V. Y. Panchenko, “Size effect of Mössbauer parameters in iron oxide nanoparticles”, Hyperfine Interact , 09, January 2014

Appendix

Attempt to detect neutrinos with the Mössbauer effect

When Mössbauer turned to neutrino research in the 1970s, it was still regarded as an exotic and somewhat esoteric field (see Potzel [1A]): phononless resonant capture of monoenergetic electron-decay in the ^{3}H–^{3}He system: "*An excited nucleus bound in a crystal can emit - with the probability* ***f****, called the Lamb-Mössbauer factor - a γ ray with the full energy E and the natural linewidth* ***Γ****. We mention an example of most interesting Mössbauer transition:*
^{57}Fe (E = 14.4 [keV], for linewidtth **$\Gamma = 4.3 \cdot 10^{-9}$ [cm^2] .**

The experimental linewidth Γ_{exp} *takes line-broadening effects into account. … The maximal cross section* σ_{max} *is only determined by λ and is typically in the range between* 10^{-17} *and* 10^{-19} *[cm^2] and thus is very much larger than the cross section for* ***weak interaction*** *(neutrino capture) which is:* $\Gamma \sim 10^{-44}$ *[cm^2]. The large cross section makes Mössbauer spectroscopy very interesting in many areas of physics. Mössbauer neutrinos - if they could be produced, e.g., by bound-state β-decay - would also exhibit these large resonance cross sections since Mössbauer neutrinos* ν_e *are characterized by low energies, where λ is much larger than the dimensions of a nucleus. In this limit, the specific properties of the weak interaction come into play only via the natural linewidth* ***Γ****, i.e., the lifetime of the resonant state.*
Mössbauer antineutrino experiments could be used to gain new and deep insights into several basic problems in neutrino physics." But it is only a hope ….
Failure to understand the true nature of the Mössbauer effect was the cause of over sixty years of the senseless research on the attempt to reveal low-energy neutrinos that arise with the decay of tritium.

1) Usual β - decay and bound-state

To have a bound-state the tritium and helium atoms must be embedded in a host lattice whose atoms have mass M. Tritium and helium atoms can be considered as impurity whose atoms have mass M**'**.
From [2a] Yu. Kagan, Ya. A. Iosilevskii): "*The Mössbauer effect for an impurity nucleus in a crystal I*", JETP, **15**, 182 (1961) we have: the parameters **ε** that is given from:

ε = (M – M**'**)/M; (a)

The parameter γ is the force constants that decrease when the impurity atom is introduced in the lattice. Here the force constant is assumed to be: $\gamma \approx 0$. The frequency **ω** of the "impurity" is given by:

$$\omega = \langle\omega_0^2\rangle (\varepsilon-\gamma)/(1-\varepsilon) \approx \langle\omega_0^2\rangle \varepsilon/(1-\varepsilon) \quad (b)$$

As is well known Tritium is radioactive by emission of electrons (β^-) :

$$^3_1T \rightarrow {}^3_2He + (e^- + \nu_e)$$

with a maximum energy of the electron Emax = 18.6 keV and a half-life equal to 12.32 years. The neutrino Ve with energy is also emitted----------

(3) **W. Potzel, "***Recoilless Resonant Emission and Detection of Electron Antineutrinos*", ISSN 1063_7796, Physics of Particles and Nuclei, Vol. **42**, No. 4, pp. 661–666. (2011)

The phononless resonant capture of monoenergetic electron antineutrinos (Mössbauer antineutrinos), emitted in bound-state β-decay in the **^{3}H → ^{3}He** system, are examined starting from an experimental failure. The lattice expansion and contraction, after the transformation of the nucleus, will drastically reduce the probability of phononless transitions and the various solid-state effects will cause large line broadening. But another reason can be the cause of the experimental impossibility. As an alternative, the rare-earth system **^{163}Ho-^{163}Dy** was proposed [5]. We have supposed that the apparent "quantum rigidity" arises primarily from zero point phonons "parked" in the atom in which the Mössbauer effect occurs. Therefore, to cancel the recoil due to the generation or absorption of neutrinos, it will be necessary to maximize the energy of the zero-point phonons *parked* in the helium or tritium atoms that must generate or absorb neutrinos.

The atoms of the entire lattice intervene only for having created the zero-point phonons present in all the atoms of the lattice itself.

Their mass plays no role. As we have seen with a single atom bound to a hypothetical rigid mass. The conceptual error became evident with the attempts to reveal neutrinos with the MÖssbauer effect. An experimental evidence () that disproves the current theories on the MÖssbauer effect is provided by the failure of the experimental attempts to detect neutrinos with a procedure similar to the MÖssbauer effect. The failure of the experiment to reveal neutrinos with a sort of Mössbauer effect with helium and tritium atoms embedded in a lattice of high atomic number is a proof that disproves the current theories on the Mossbauer effect.

Let's start with two elements, one heavy atomic weight: Holmium, the other very light: Beryllium.

We assume for a **neutrino** a mechanical impulse $\mathbf{P_n}$ of the order of magnitude of that of a photon with the same energy E and speed c:

P = E/c Se E = 18.6 keV : $P_n = 9.93 \cdot 10^{-19}$ [g x cm /s]

$18.6 \cdot 10^3$ [eV] x $1.602 \cdot 10^{-12}$[erg/eV] = $29.797 \cdot 10^{-9}$[erg]? Neutrino energy

L'impulso del fonone con la massima energia in un atomo di Elio in matrice di Berillio è:

[2a] Yu. Kagan, Y[a. A. Iosilevskii): "*The Mössbauer effect for an impurity nucleus in a crystal* I", JETP, **15**, 182 (1961)

R. Giovanelli, A. Orefice, "Quantum rigidity of microscopic bonds", Physics Letters, **A 311**, 67-76 (2003)

Holmium ----------

atomic weigh: **164.94**

Debye frequency for Holmium: T_{DHo}=**190** [K] Debye temperature for Holmium

$\omega_{D\text{-}Ho} = (k_B \times T_{D\text{-}Ho})/\hbar = 2.4882 \cdot 10^{13}$[rad/s]

$\hbar \cdot \omega_{D\text{-}Ho}/2$ = **$1.05445 \cdot 10^{-27}$**[erg s] x **$2.4882 \cdot 10^{13}$** [rad/s]/2=

= **$1.31184 \cdot 10^{-14}$**[erg]**;** zero point phonon energy at Debye frequency

$1.31184 \cdot 10^{-14}/2.76 \cdot 10^5$ = **$4.753 \cdot 10^{-20}$**[g·cm/s]

$2.4882 \cdot 10^{13}$ [rad/s] massima frequenza di un solido costituito da atomi di Olmio.

A proof that the current theories on the Mössbauer effect are invalid is provided by the failure of the attempt to detect neutrinos with a procedure similar to the Mössbauer effect.

Beryllium ---------- now let's try a metal that has the lowest atomic weight

atomic weight: **9.012**

$T_{D\text{-}Be}$ = **1481** [K] Beryllium Debye temperature

$\omega_{D\text{-}Be} = (8.617 \cdot 10^{-5} \times 1481)/6.58 \cdot 10^{-16}$ $= 1.93948 \cdot 10^{14}$[rad/s] Debye frequency for Beryllium

(*Debye frequency for Holmium* ..... $2.4882 \cdot 10^{13}$[rad/s]

Sound speed $c_s = 1.29 \cdot 10^6$ [cm/s]

$\hbar \cdot \omega_{D\text{-}Be}/2 = 5.2727 \cdot 10^{-28}$ [erg·s] zero point phonon maximum energy

$1.05445 \cdot 10^{-27}$ [erg·s]x$1.93948 \cdot 10^{14}$ [rad/s]/2

$(1\hbar \cdot \omega_{D\text{-}Be}/2)/c_s = 5.2727 \cdot 10^{-28}/1.29 \cdot 10^6 = \mathbf{7.9266} \cdot 10^{-20}$ Momentum

$\omega_{D\text{-}Be} = (k_B \times T_{D\text{-}Be})/\hbar = 1.93948 \cdot 10^{14}$[rad/s] Debye frequency for Beryllium

L'impulso **P** di un fotone con energia E = 18.6 [keV] e velocità **c** è:

P = E/c : **P = 9.93*10^{-19}** [g x cm /s] **~ 10^{-18}**

Sound velocity in solid Beryllium c_s=**1.29·10^6** [cm/s]

Ћ=1.0544 10^{-27} [erg s]

P = ħ x $\omega_{D\text{-}Be}/c_s = 1.05445 \cdot 1.93948 \cdot 10^{-13}/1.29 \cdot 10^6 =$

$= 1.5853 \cdot 10^{-19}$ [g·cm/s] The momentum **P** of the phonon with the highest energy in a helium atom in a beryllium matrix is:

ω_{Ho}=$2.4882 \cdot 10^{13}$ [rad/s] Holmium

ω_{Be}=$1.94 \cdot 10^{14}$ [rad/s] Beryllium

ε_{Ho}=(164.94-3.016)/164.94 = **0.9817**

ε_{Be}=(9.012-3.016)/9.012 **= 0.6653**

$^{Ho}\omega_{He} = \omega_{Ho} \cdot [\varepsilon_{Ho}/(1-\varepsilon_{Ho})]^{0.5} = \omega_{Ho} \times 0.1352 =$ **3.364x10^{12}**

Debye frequency [rad/s] for helium atom in Holmium host lattice

$^{Be}\omega_{He} = \omega_{Be}\,[\varepsilon_{Be}/(1-\varepsilon_{Be})]^{0.5} = \omega_{Be} \times 1.40987 =$ **2.73514x10^{14}**

Debye frequency [rad/s] for helium atom in Beryllium host lattice

c_s = 1.29·10^6[cm/s] Beryllium sound velocity

$P_p = \hbar\omega/2c_s =$ $5.2723 \cdot 10^{-28} \cdot 2.73514 \cdot 10^{14}/1.29 \cdot 10^6 =$

$= 1.1178 \cdot 10^{-19}$ [g·cm/s] the maximum pulse of the phonon is less than the neutrino pulse

Helium atom in Holmium matrix

$\omega = 2.4882 \cdot 10^{13} \times 0.1352 = \mathbf{3.364 \cdot 10^{12}}$[rad/s]

$\mathbf{c_s} = 2.76\ 10^{5}$[cm/s] sound velocity in solid Holmium

Phonon momemtum: $\hbar\omega/2c_s = 5.2723 \cdot 10^{-28} \cdot 3.364 \cdot 10^{12} / 2.76 \cdot 10^{5} =$

$\mathbf{6.373 \cdot 10^{-21}}$[g · cm/s]

P = E/C Se E = 18.6 keV : $P = 9.93 \cdot 10^{-19}$ [g x cm /s]

L'impulso del fonone di massima energia per un atomo di Elio in matrice di Berillio è: $1.1659 \cdot 10^{-18}$ [g cm/s]

A proof that the current theories on the Mössbauer effect are invalid is provided by the failure of the attempt to detect neutrinos with a procedure similar to the Mössbauer effect.

Matrice in metallo leggero come il Berillio

L'impulso di un fotone con energia E = 18.6 [keV] e velocità c è:

P = E/c. Se E = 18.6 [keV] : $\mathbf{P = 9.93 \cdot 10^{-19}}$ [g x cm /s] ~ $\mathbf{10^{-18}}$ **[g x cm /s]**

The "quantum rigidity" of an atom in a lattice (atom as an impurity) does not depend on the mass of the atoms of the lattice in which the atom is inserted, but mainly on the momentum of the zero-point phonons present in the atom itself and equally in all atoms of the lattice.

When the single atom has much less mass than that of the host lattice atoms, its momentum will be much lower than that of the lattice atoms, because the velocity is the same as that of the heavy atoms of the matrix. ???

From Kagan et al. [2A] we have the parameters ε and γ to obtain the frequency ω of an "impurity" atom.

Its quantum stiffness will also be lower than that of the host lattice atoms.

The difficulty of having the Mössbauer effect with light atoms such as He, inserted in a network of heavy atoms, depends on the low momentum of the phonons stationed (parked) in the light atoms. This phonons are created in the heavy atoms network. One could have a better effect by using a lattice of light atoms such as beryllium.

REFERENCES for Appendix

1A) W. Potzel, “Mössbauer antineutrinos: Recoilless resonant emission and absorption of electron antineutrinos”, ISSN 1063_7796, Physics of Particles and Nuclei vol. **42**, No. 4, pp. 661-666. (2011)

2A) Yu. Kagan, Ya. A. Iosilevskii, “The Mossbauer effect for an impurity nucleus in a crystal I”, JETP, **15**, 182 (1961)

3A) W. Potzel - Physik-Department E15, Technische Universitat Munchen, D-85748 Garching, Germany (2010), arXiv: 1012. 5000v1(2020)