Electromagnetic Method for blocking the action of Neutrons, α-particles, β-particles and γ-rays upon Atomic Nuclei.

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Here we show an electromagnetic method for blocking the action of external neutrons, α-particles, β-particles and γ-rays upon atomic nuclei. This method can be very useful for stopping nuclear fissions, as the chain reactions that occur inside a nuclear fission reactor, and also those nuclear fissions that continue occurring, and generating heat (*decay heat*) , even after the shut down of the reactor.

Key words: Quantum Gravity, Gravitational Mass, Nuclear Physics, Nuclear Chain Reactions, Decay heat.

1. Introduction

Nuclear fission is the splitting of an atomic nucleus into smaller parts (lighter nuclei). The fission process often produces free neutrons and gamma rays, and releases a very large amount of energy.

Nuclear fission chain reactions produce energy in the nuclear fission reactors of the nuclear power plants, and drive the explosion of nuclear weapons.

The chain reactions occur due to the interactions between neutrons and *fissionable* isotopes (usually — uranium-235 and plutonium-239.). When an atom undergoes nuclear fission, a few neutrons are ejected from the reaction. These neutrons will then interact with the surrounding medium, and if more fissionable fuel is present, some may be absorbed and cause more fissions. This makes possible a self-sustaining nuclear chain reaction that releases energy at a controlled rate in a nuclear reactor or at a very rapid uncontrolled rate in a nuclear weapon.

The thermal energy generated by a nuclear fission reactor come from the chain reactions produced inside the reactor. An important fact is that the nuclear reactor continues generating heat even after the stopping of the nuclear chain reactions (*decay heat* [1]). The heat is released as a result of radioactive decay produced as an effect of radiation on materials: the energy of the alpha, beta or gamma radiation is converted into the thermal movement of atoms. This heat requires the cooling of the reactor during long time. It is believed that is impossible quickly stop this phenomenon [*] [2].

Here we show an electromagnetic method for blocking the action of external neutrons, α-particles, β-particles and γ-rays upon atomic nuclei. It was developed starting from a process *patented* in July, 31 2008 (BR Patent Number: PI0805046-5) [3]. This non invasive method can be very useful for stopping nuclear fissions, as the chain reactions that occur inside a nuclear fission reactor, and also those nuclear fissions that continue occurring even after the shut down of the reactor. These nuclear reactions produce a significant decay heat, which requires the permanent cooling of the reactor, and have been the cause of some nuclear disasters, as the occurred in the Nuclear Power Plant of Fukushima [4].

2. Theory

The contemporary greatest challenge of the Theoretical Physics was to prove that, Gravity is a *quantum* phenomenon. The quantization of gravity shows that the *gravitational mass* m_g and *inertial mass* m_i are correlated by means of the following factor [5]:

$$\chi = \frac{m_g}{m_{i0}} = \left\{ 1 - 2\left[\sqrt{1 + \left(\frac{\Delta p}{m_{i0} c} \right)^2} - 1 \right] \right\} \tag{1}$$

[*] After one year offline, used fuel still emits about 10 kilowatts of decay heat energy per ton. After 10 years, it emits 1 kW of heat per ton.

where m_{i0} is the *rest* inertial mass of the particle and Δp is the variation in the particle's *kinetic momentum*; c is the speed of light.

In general, the *momentum* variation Δp is expressed by $\Delta p = F\Delta t$ where F is the applied force during a time interval Δt. Note that there is no restriction concerning the *nature* of the force F, i.e., it can be mechanical, electromagnetic, etc.

For example, we can look on the *momentum* variation Δp as due to absorption or emission of *electromagnetic energy*. In this case, by substitution of $\Delta p = \Delta E/v = \Delta E/v(c/c)(v/v) = \Delta E n_r/c$ into Eq. (1), we get

$$\chi = \frac{m_g}{m_{i0}} = \left\{1 - 2\left[\sqrt{1 + \left(\frac{\Delta E}{m_{i0}c^2} n_r\right)^2} - 1\right]\right\} \qquad (2)$$

By dividing ΔE and m_{i0} in Eq. (2) by the volume V of the particle, and remembering that, $\Delta E/V = W$, we obtain

$$\chi = \frac{m_g}{m_{i0}} = \left\{1 - 2\left[\sqrt{1 + \left(\frac{W}{\rho\, c^2} n_r\right)^2} - 1\right]\right\} \qquad (3)$$

where ρ is the matter density $\left(kg/m^3\right)$.

Another important equations obtained in the quantization theory of gravity is the new expression for the *momentum* q and *energy* of a particle with gravitational mass M_g and velocity v, which is given by [6]

$$\vec{q} = |M_g|\vec{v} \qquad (4)$$

$$E_g = |M_g|c^2 \qquad (5)$$

where $|M_g| = \left|m_g \middle/ \sqrt{1 - v^2/c^2}\right|$; m_g is given by Eq.(1), i.e., $m_g = \chi\, m_i$. Thus, we can write

$$|M_g| = \left|\frac{\chi\ m_i}{\sqrt{1 - v^2/c^2}}\right| = |\chi| M_i \qquad (6)$$

Substitution of Eq. (6) into Eq. (5) and Eq. (4) gives

$$E_g = |\chi| M_i c^2 \qquad (7)$$

$$\vec{q} = |\chi| M_i \vec{v} = \frac{\vec{v}}{c}|\chi|\frac{h}{\lambda} \qquad (8)$$

For $v = c$, the *momentum* and the energy of the particle become infinite. This means that a particle with non-null mass cannot travel with the light speed. However, in Relativistic Mechanics there are particles with *null mass* that travel with the light speed. For these particles, Eq. (8) gives

$$q = |\chi|\frac{h}{\lambda} \qquad (9)$$

Note that only for $\chi = 1$ the Eq. (9) is reduced to the well=known expressions of DeBroglie $(q = h/\lambda)$.

Since the factor χ can be strongly reduced under certain circumstances (See Eq.(1)), then according to the Eqs. (7) and (9), the *energy* and *momentum* of a particle can also be strongly *reduced*. Based on this possibility, we have developed an electromagnetic method for blocking the action of external neutrons, α-particles, β-particles and γ-rays upon atomic nuclei. In order to describe this method we start considering an *atom* subjected to a static magnetic field B_e, and an oscillating magnetic with frequency f_{Bosc} (Fig.1). If this frequency is equal to the electrons' precession frequency $f_{pr(e)}$, they absorb energy from the magnetic field B_e (*Electronic Magnetic Resonance*). The frequency $f_{pr(e)}$, is given by [6, 7]

$$f_{pr(e)} = \frac{\gamma_e}{2\pi} B_e = \frac{\mu_e^s}{2\pi L_e^s} B_e = \frac{g_e \dfrac{e}{2m_e} S_z}{2\pi(n_s\hbar)} B_e =$$

$$= \frac{g_e \dfrac{e\hbar}{2m_e} m_s}{2\pi(n_s\hbar)} B_e = \left(\frac{g_e e}{4\pi\, m_e}\right) B_e = 2.798\times10^{10} B_e \qquad (10)$$

where $g_e = 2.002322$ is the electron g-factor.

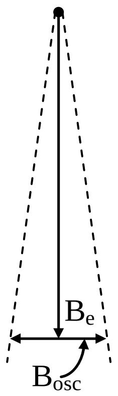

Fig.1 – In this method, an oscillating magnetic field B_{osc} , with small intensity, is applied perpendicularly to a static magnetic field B_e.

Thus, under theses conditions, the energy absorbed by one electron, is given by [8]

$$\Delta E_e = \gamma_e \hbar B_e \qquad (11)$$

The electrons are often described as moving around the nucleus as the planets move around the sun. This picture, however, is misleading. The quantum theory has shown that due to the size of the electrons, they cannot be pictured in an atom as localized in space, but rather should be viewed as smeared out over the entire orbit so that they form a cloud of charge. Thus, the region around the nucleus represents a *cloud of charges*, in which the electrons are most likely to be found. However, this cloud is sub-divided into shells. Each shell can contain only a fixed number of electrons: The closest shell to the nucleus is called the "K shell" (also called "1 shell"). Heavy atoms as Uranium, has 7 shells (K, L, M, N, O, P, Q). The K shell can hold up to *two* electrons. The *numbers of electrons* that can occupy each shell are: L = 8, M =18, N =32, O = 21, P = 9, Q = 2 [9, 10].

According to Eq. (11), the energy absorbed by each one of the shells are respectively, given by

$$\Delta E_e = N_e \gamma_e \hbar B_e \qquad (12)$$

where N_e is the number of electrons in the shell.

Dividing the Eqs. (12) by the correspondent volume of the shell, we get

$$W = \frac{N_e \gamma_e \hbar B_e}{V_s} \qquad (13)$$

Substitution of Eq. (13) into Eq. (3) gives

$$\chi = \frac{m_g}{m_{i0}} = \\ = \left\{1 - 2\left[\sqrt{1 + \left(\frac{N_e \gamma_e \hbar B_e n_r}{\rho_s\ V_s c^2}\right)^2} - 1\right]\right\} \qquad (14)$$

Substitution of $\gamma_e = g_e e / 2m_{i0e}$ (See Eq. (10)) into Eq. (13) gives

$$\chi = \left\{1 - 2\left[\sqrt{1 + \left(\frac{N_e g_e e \hbar B_e n_r}{2m_{i0e}\rho_s\ V_s c^2}\right)^2} - 1\right]\right\} \qquad (15)$$

In order to calculate ρ_s we start considering the hydrogen gas. If we remove the hydrogen nuclei what remains is an electron gas with density equal to ρ_s. Thus, we can calculate this density by multiplying the density of the Hydrogen gas by the factor $\left(m_{i0e}/m_{i0p} + m_{i0e}\right)$. However, in the case of heavy atoms this factor must be, obviously, $\left(Zm_{i0e}/Zm_{i0p} + Zm_{i0n} + Zm_{i0e} \cong m_{i0e}/2m_{i0p}\right)$. Thus, in this case, we can write that

$$\rho_s = \rho_H\left(\frac{m_{i0e}}{2m_{i0p}}\right) \cong 8.99\times10^{-2}\left(2.73\times10^{-4}\right)$$

$$= 2.45\times10^{-5}\,kg.m^{-3} \qquad (16)$$

The values of the V_s, can be easily calculated starting from the thickness, l, and the inner radii, r, of the shells. The thicknesses l, are given by

$$\begin{aligned} l_K &= K(2R_e) = 4R_e \\ l_L &= L(2R_e) = 16R_e \\ l_M &= M(2R_e) = 36R_e \\ l_N &= N(2R_e) = 64R_e \\ l_O &= O(2R_e) = 42R_e \\ l_P &= P(2R_e) = 18R_e \\ l_Q &= Q(2R_e) = 4R_e \end{aligned}$$

where R_e is the electron's radius. It can be calculated starting from the *Compton sized electron*, which gives $R_e = 3.862\times10^{-13}m$, and from the standardized result recently obtained of $R_e = 5.156\times10^{-13}m$ [11]. Based on these values, the average value is $R_e = 4.509\times10^{-13}m$.

The *inner radii* of the shells, are given by

$$r_K = r_1 = 5.3\times10^{-11} m$$
$$r_L = (r_1 + l_K) = 5.48\times10^{-11} m$$
$$r_M = (r_1 + l_K + l_L) = 6.20\times10^{-11} m$$
$$r_N = (r_1 + l_K + l_L + l_M) = 7.82\times10^{-11} m$$
$$r_O = (r_1 + l_K + l_L + l_M + l_N) = 1.07\times10^{-10} m$$
$$r_P = (r_1 + l_K + l_L + l_M + l_N + l_O) = 1.26\times10^{-10} m$$
$$r_Q = (r_1 + l_K + l_L + l_M + l_N + l_O + l_P) = 1.34\times10^{-10} m$$

Note that $(r_Q + l_Q) - r_K = 0.81\times10^{-10} m$. However, in the case of the Uranium, $r_{outer} - r_{inner} = 1.56\times10^{-10} - 0.53\times10^{-10} \cong 1.03\times10^{-10} m$. Thus, there is a difference of $1.03\times10^{-10} - 0.81\times10^{-10} = 0.22\times10^{-10} m$.This value must be added in the values of $r_L,...r_Q$, in order to obtain *the corrected values of* $r_L,...,r_Q$. The result is

$$r_K = 5.30\times10^{-11} m$$
$$r_L = 7.68\times10^{-11} m$$
$$r_M = 8.40\times10^{-11} m$$
$$r_N = 1.00\times10^{-10} m$$
$$r_O = 1.29\times10^{-10} m$$
$$r_P = 1.48\times10^{-10} m$$
$$r_Q = 1.56\times10^{-10} m$$

Finally, we obtain

$$V_K = 4\pi r_K^2 (l_K) = 6.36\times10^{-32}$$
$$V_L = 4\pi r_L^2 (l_L) = 5.35\times10^{-31}$$
$$V_M = 4\pi r_M^2 (l_M) = 1.44\times10^{-30}$$
$$V_N = 4\pi r_N^2 (l_N) = 3.63\times10^{-30}$$
$$V_O = 4\pi r_O^2 (l_O) = 3.96\times10^{-30}$$
$$V_P = 4\pi r_P^2 (l_P) = 2.23\times10^{-30}$$
$$V_Q = 4\pi r_Q^2 (l_Q) = 5.51\times10^{-31} \qquad (17)$$

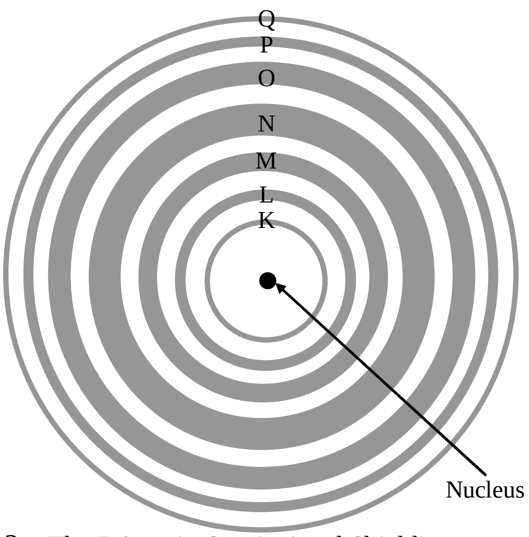

Fig.2 – The 7 Atomic Gravitational Shieldings

The mobility of the orbital electrons confers an electrical conductivity σ for each shell, i.e.,

$$\sigma_s = \rho_e \mu_e \qquad (18)$$

where ρ_e expresses the concentrations of electrons (C/m^3) and μ_e is the mobility of the electrons. The expression of ρ_e is

$$\rho_e = eN_e / V_s \qquad (19)$$

On the other hand, since by definition $\mu_e = v_d / E$ and $v_d = v_e = e/\sqrt{4\pi\varepsilon_0 \bar{r}_s m_e}$ [12] and $E = Ze/4\pi\varepsilon_0 \bar{r}_s^2$, we obtain

$$\mu_e = \frac{1}{Z}\sqrt{\frac{4\pi\varepsilon_0 \bar{r}_s^3}{m_e}} \qquad (20)$$

Substitution of Eqs. (19) and (20) into Eq. (18),gives

$$\sigma_s = \frac{eN_e}{ZV_s}\sqrt{\frac{4\pi\varepsilon_0 \bar{r}_s^3}{m_e}} \qquad (21)$$

The values of $\bar{r}_s$, in the case of the Uranium, are given by

$$\bar{r}_K = (r_1 + l_K/2) = 5.39\times10^{-11} m$$
$$\bar{r}_L = (r_L + l_L/2) = 8.04\times10^{-11} m$$
$$\bar{r}_M = (r_M + l_M/2) = 9.21\times10^{-11} m$$
$$\bar{r}_N = (r_N + l_N/2) = 1.14\times10^{-10} m$$
$$\bar{r}_O = (r_O + l_O/2) = 1.38\times10^{-10} m$$
$$\bar{r}_P = (r_P + l_P/2) = 1.52\times10^{-10} m$$
$$\bar{r}_Q = (r_Q + l_Q/2) = 1.56\times10^{-10} m$$

Therefore, according to Eq. (21), the values of the σ_s are the followings

$$\sigma_K = 6.044\times10^{20}\sqrt{\bar{r}_K^3} = 2.39\times10^5 S/m$$
$$\sigma_L = 2.874\times10^{20}\sqrt{\bar{r}_L^3} = 2.07\times10^5 S/m$$
$$\sigma_M = 2.402\times10^{20}\sqrt{\bar{r}_M^3} = 2.12\times10^5 S/m$$
$$\sigma_N = 1.694\times10^{20}\sqrt{\bar{r}_N^3} = 2.06\times10^5 S/m$$
$$\sigma_O = 1.019\times10^{20}\sqrt{\bar{r}_O^3} = 1.65\times10^5 S/m$$
$$\sigma_P = 7.757\times10^{19}\sqrt{\bar{r}_P^3} = 1.45\times10^5 S/m$$
$$\sigma_Q = 6.976\times10^{19}\sqrt{\bar{r}_Q^3} = 1.36\times10^5 S/m \qquad (22)$$

From Electrodynamics we know that the index of refraction, n_r, of a material with relative permittivity ε_r, relative magnetic permeability μ_r and electrical conductivity σ is given by [13]

$$n_r = \frac{c}{v} = \sqrt{\frac{\varepsilon_r \mu_r}{2}\left(\sqrt{1+(\sigma/\omega\varepsilon)^2}+1\right)} \qquad (23)$$

If $\sigma >> \omega\varepsilon$, $\omega = 2\pi f$, Eq. (23) reduces to

$$n_r = \sqrt{\frac{\mu_r \sigma}{4\pi\varepsilon_0 f}} \qquad (24)$$

Substitution of $f = f_{Bosc}$ given by, Eq. (10) into Eq. (24) yields

$$n_r = 0.566\sqrt{\frac{\sigma_s}{B_e}} \qquad (25)$$

Substitution of the σ_s given by Eq. (22) into Eq. (25) yields

$$\begin{aligned} n_{rK}^2 B_e^2 &= 7.65\times 10^4 B_e \\ n_{rL}^2 B_e^2 &= 6.62\times 10^4 B_e \\ n_{rM}^2 B_e^2 &= 6.78\times 10^4 B_e \\ n_{rN}^2 B_e^2 &= 6.59\times 10^4 B_e \\ n_{rO}^2 B_e^2 &= 5.28\times 10^4 B_e \\ n_{rP}^2 B_e^2 &= 4.64\times 10^4 B_e \\ n_{rQ}^2 B_e^2 &= 4.35\times 10^4 B_e \end{aligned} \qquad (26)$$

Substitution of the values of the ρ_s given by Eq. (16) into Eq. (15) gives

$$\chi = \left\{1-2\left[\sqrt{1+1.414\times 10^{-70}\left(\frac{N_e}{V_s}\right)^2 n_{rs}^2 B_e^2}-1\right]\right\} \qquad (27)$$

Now, by considering the values of N_e, V_s (Eq. 17) and $n_{rs}^2 B_e^2$ (Eq. 26), we can calculate the values of χ for each shell, i.e.,

$$\chi_K = \left\{1-2\left[\sqrt{1+0.107B_e}-1\right]\right\} \qquad (28)$$

$$\chi_L = \left\{1-2\left[\sqrt{1+2.09\times 10^{-3}B_e}-1\right]\right\} \qquad (29)$$

$$\chi_M = \left\{1-2\left[\sqrt{1+1.49\times 10^{-3}B_e}-1\right]\right\} \qquad (30)$$

$$\chi_N = \left\{1-2\left[\sqrt{1+7.24\times 10^{-4}B_e}-1\right]\right\} \qquad (31)$$

$$\chi_O = \left\{1-2\left[\sqrt{1+2.10\times 10^{-4}B_e}-1\right]\right\} \qquad (32)$$

$$\chi_P = \left\{1-2\left[\sqrt{1+1.07\times 10^{-4}B_e}-1\right]\right\} \qquad (33)$$

$$\chi_Q = \left\{1-2\left[\sqrt{1+0.81\times 10^{-4}B_e}-1\right]\right\} \qquad (34)$$

In the particular case of $B_e = 11.68T$, the Eqs. (28) … (34), yields

$$\begin{aligned} \chi_K &\cong 1.60\times 10^{-4} \\ \chi_L &\cong 0.97 \\ \chi_M &\cong 0.98 \\ \chi_N &\cong 0.99 \\ \chi_O &\cong 0.99 \\ \chi_P &\cong 0.99 \\ \chi_Q &\cong 0.99 \end{aligned} \qquad (35)$$

In a previous paper [14] it was shown that, if the *weight* of a particle in a side of a lamina is $P = m_g g$ then the weight of the same particle, in the other side of the lamina is $P' = \chi m_g g$, where $\chi = m_g / m_{i0}$ (m_g and m_{i0} are respectively, the gravitational mass and the inertial mass of the lamina). Only when $\chi = 1$, the weight is equal in both sides of the lamina. The lamina works as a Gravitational Shielding. This is the *Gravitational Shielding* effect. Since $P' = \chi P = (\chi m_g)g = m_g(\chi g)$, we can consider that $m_g' = \chi m_g$ or that $g' = \chi g$.

If we take two parallel gravitational shieldings, with χ_1 and χ_2 respectively, then the gravitational masses become: $m_{g1} = \chi_1 m_g$, $m_{g2} = \chi_2 m_{g1} = \chi_1\chi_2 m_g$, and the gravity will be given by $g_1 = \chi_1 g$, $g_2 = \chi_2 g_1 = \chi_1\chi_2 g$.

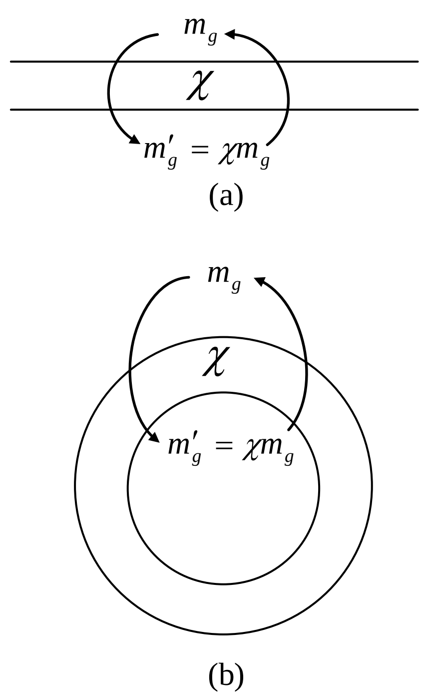

Fig. 3 – *Plane* and *Spherical* Gravitational Shieldings. When the radius of the gravitational shielding (b) is very small, any particle inside the spherical crust will have its gravitational mass given by $m_g' = \chi m_g$, where m_g is its gravitational mass out of the crust.

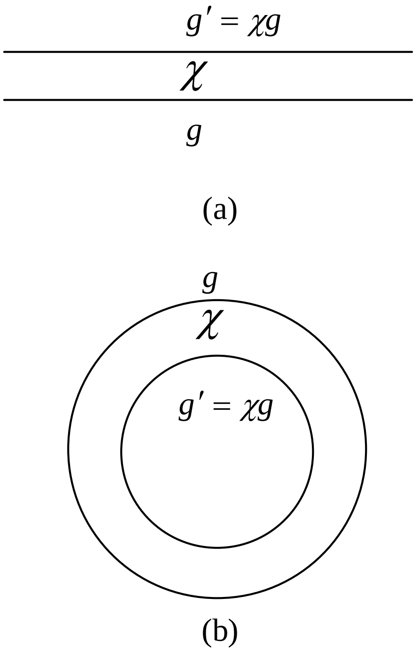

Fig. 4 – The gravity acceleration in both sides of the gravitational shielding.

In the case of multiples gravitational shieldings, with $\chi_{1,}\chi_{2,}...,\chi_n$, we can write that, after the n^{th} gravitational shielding the gravitational mass, m_{gn}, and the gravity, g_n, will be given by

$$m_{gn} = \chi_1\chi_2\chi_3...\chi_n m_g\ ,\quad g_n = \chi_1\chi_2\chi_3...\chi_n g \tag{36}$$

This means that, n superposed gravitational shieldings with different $\chi_1, \chi_2, \chi_3, \ldots, \chi_n$ are equivalent to a single gravitational shielding with $\chi = \chi_1\chi_2\chi_3...\chi_n$. Since the atomic shells K, L, M, N, O, P and Q , work as gravitational shieldings, then they are equivalent to a single gravitational shielding with $\chi = \chi_K\chi_L\chi_M\chi_N\chi_O\chi_P\chi_Q$. Thus, in the case of Uranium, which is simultaneously subjected to a magnetic field with intensity $B_e = 11.68T$, and an oscillating magnetic field with frequency $f_{Bosc} = f_{pr(e)} = 2.798\times10^{10}B_e = 326.8GHz$, the values given by Eq. (35), yield the following value for χ:

$$\chi = \chi_K\chi_L\chi_M\chi_N\chi_O\chi_P\chi_Q \cong 1.4\times10^{-4} \tag{37}$$

Consequently, according to Eq. (9), when a $\gamma - ray$ crosses the atomic shells of Uranium, subjected to the above mentioned conditions, the *momentum* of the $\gamma - ray$, after it leaves the K atomic shell† is given by

$$q = |\chi|\frac{h}{\lambda} = \frac{|\chi|hf}{c} \tag{38}$$

where $\chi = \chi_K\chi_L\chi_M\chi_N\chi_O\chi_P\chi_Q \cong 1.4\times10^{-4}$. Under these conditions, the effect of this $\gamma - ray$ upon the nucleus becomes equivalent to the effect produced by and photon with energy $|\chi|hf$. Thus, if $|\chi|hf << 1MeV$ ‡ [15], the photon will not have sufficient energy to excite the nucleus.

The energy of a photon with $f = 10^{23}Hz$, after crossing the K atomic shell, becomes just $9.3\times10^{-15}\ joules << 1MeV = 1.6\times10^{-13}\ joules$. Under these circumstances, we can say that $\gamma - rays$ with $f \le 10^{23}Hz$, after crossing the K atomic shell, do not are able to excite the Uranium's nucleus.

The effect also extends to particles of matter as *neutrons*, α-particles, β-particles, etc.

For example, consider a faster neutron through a Uranium atom. After crossing the K atomic shell its *momentum*, according to Eq. (8), becomes $q = |\chi|M_i v$ and, according to Eq. (5) its total relativistic energy is $E_g = |M_g|c^2$. The inertial kinetic energy is correlated with the gravitational kinetic energy by means of the following relation [5]:

† Due to the atom's radius be very small, any particle inside the intermediate region between the shells and the nucleus will have its gravitational mass given by $m'_g = \chi m_g$, where m_g is its gravitational mass out of the crust (See Fig.3)). Similarly, if the energy of a photon, out of the atom is hf then, inside the intermediate region, its energy becomes $|\chi|hf$.

‡ A heavy nucleus undergoes fission when acquires energy >5MeV. Some nucleus as the $_{92}U^{235}$ undergo fission when absorbs just a neutron. Others as the $_{92}U^{238}$ needs to absorbs faster neutrons with kinetic energy >1MeV. However, in all cases if the total energy of the incident particle is <<1MeV, the fission does not occurs.

$$K_i = \left(\frac{m_{i0}}{m_g}\right) K_g = \left(\frac{m_{i0}}{m_g}\right)\left(\left|M_g\right| - \left|m_g\right|\right)c^2 =$$

$$= \left(\frac{m_{i0}}{m_g}\right)\left(\left|\frac{m_g}{\sqrt{1-v^2/c^2}}\right| - \left|m_g\right|\right)c^2 =$$

$$= \left(\frac{m_{i0}}{m_g}\right)\left(\frac{\left|\chi m_{i0}\right|}{\sqrt{1-v^2/c^2}} - \left|\chi m_{i0}\right|\right)c^2 \qquad (39)$$

For $v << c$, we get $\left(1 - v^2/c^2\right)^{-\frac{1}{2}} \cong 1 + v^2/2c^2$ and $m_g \cong m_{i0}$. Thus, Eq. (39) reduces to

$$K_i = \left|\chi\right|\left(\tfrac{1}{2} m_{i0} v^2\right) = \left|\chi\right| K \qquad (40)$$

This shows that the *kinetic energy of the particle* will be strongly reduced in the case of a very small value of $\left|\chi\right|$.

According to the equations (37) and (40), the kinetic energy of a neutron, inside the intermediate region between the shells and the nucleus of Uranium, is given by $K_i \cong 1.4\times10^{-4} K$. For $K << 7.14 GeV$ we obtain $K_i << 1 MeV$. This means that, *neutrons* with kinetic energy $K << 7.14 GeV$ (and also particles such as α-particles, β-particles, protons, etc.) *are not able to produce the fission* of an atomic nucleus of Uranium, subjected to the previously mentioned conditions.

It is also necessary consider the case of some nuclei, as the nuclei of ${}_{92}U^{235}$, which undergo fission by the simple absorption of a *neutron neighboring the nucleus*. Also, we must consider the case of *electrons capture* by the nuclei, ($p + e^- \rightarrow n + \nu$). In these cases, if the Uranium atom is subjected to the previously mentioned conditions, both neutrons and the electrons will have their *total energy*, according to Eq. (5), given by

$$E_{gn} = \left|\chi\right| m_{i0n} c^2 \cong 2.1\times10^{-14}\ joules$$

and

$$E_{ge} = \left|\chi\right| m_{i0e} c^2 \cong 1.1\times10^{-17}\ joules$$

These energies are very smaller than $1 MeV$ and therefore, the neutron cannot excitate the nuclei of ${}_{92}U^{235}$ to produce fission, and the electron does not have sufficient energy to interact with a nuclear proton to produce a neutron and a neutrino.

The method here described requires $B_e = 11.68 T$, and an oscillating magnetic field with frequency $f_{Bosc} = 326.8 GHz$.

The spectrometers used in the Nuclear magnetic resonance spectroscopy, most commonly known as NMR spectroscopy, works with up to 1GHz, 23.5 T (AVANCE 1000 MHz NMR spectrometer, launched by Bruker BioSpin). Figure 5 shows a 0.9GHz, 21.1T NMR spectrometer.

By comparing the values required by the method here described with these values, we can conclude that the necessary technology is coming soon.

Fig.5 - A 0.9GHz, 21.1 T NMR spectrometer at HWB-NMR, Birmingham, UK.

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