A prototype of the nuclear cold fusion reaction discovered by theoretical particle physicist

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There are two different types of scientists who believe in the reality of the nuclear cold fusion. The researchers, who observed the excess energy by experiments, belong to the first type. On the other hand, a small number of theoreticians, who are working on the physics of the magnetic monopole, know that the nuclear reaction of the zero incident energy proceeds when the system involves a magnetic monopole. Since the former group still lacks a theory of the nuclear cold fusion based on the first principle of the natural law, I believe it is fruitful to explain to the former group how the theoretician of the particle physics comes to arrive at the conclusion that the nuclear cold fusion must occur if a magnetic monopole exists, in the framework of the quantum theory.

From the charge quantization condition of Dirac, which says that ${}^{\star}ee/c = \hbar/2$, where e and ${}^{\star}e$ are the smallest electric and the magnetic charges respectively, the magnetic counterpart of the "fine structure constant" is determined: ${}^{\star}e^2/\hbar c = 137.036/4$. It means that the monopole is accompanied by a superstrong magnetic Coulomb field $\vec{B} =^{\star} e\hat{r}/r^2$. If we remember that the nucleon has the magnetic dipole moment $\kappa_{tot}(e/2m_p)\vec{\sigma}$, where κ_{tot} is 2.793 and -1.913 for the proton and for the neutron respectively, the interaction hamiltonian between the monopole and the nucleon is $H^{dip} = -(\kappa_{tot}/4m_p)(\hat{r}\cdot\vec{\sigma})F(r)/r^2$, in which $F(r)$ is the form factor of the nucleon. It is remarkable that the strength of this interaction potential H^{dip} is 2 or 3 times larger compared to the nuclear potential V^{nucl} at the separation $r = 0.5 \sim 3$fm..

The kinetic energy term in the external magnetic Coulomb field is $H^0 = (-i\nabla - (Ze/c)\vec{A})^2/2m$, where the vector potential $\vec{A}$ must be chosen such that $rot\vec{A}$ is the magnetic Coulomb field. Since we already know the nuclear potential $V^{nucl}_{i,j}(r_{i,j})$ between the i-th and the j-th nucleon, the total hamiltonian of the nuclear system in the external Coulomb field becomes

$$H_{tot} = \sum_{j=1}^{A} H^0_j + \sum_{j=1}^{A} H^{dip}_j + \sum_{i>j} V^{nucl}_{i,j} \quad .$$

Once the hamiltonian is given, it is the standard exercise of the quantum mechanics to calculate the physical quantities such as the energy level, radius of the orbit and the transition rate. The easiest one is the one-body problem in the external potential. The eigenfunction of the spin 0 charged particle, namely the eigenfunction of H^0, is known for long time (Tamm's solution), whose radial function is:

$$R(r) = \frac{1}{\sqrt{kr}} J_\mu(kr) \quad where \quad \mu = \sqrt{(\ell+1/2)^2 - q^2} > 0 \quad and \quad k = \sqrt{2mE}$$

, in which q is the magnitude of the extra angular momentum, namely $q = Ze\,{}^{\star}e$ and the range of the angular momentum ℓ is $\ell = |q|, |q|+1, |q|+2\cdots$. Since the

Bessel function is oscillatory and does not damp at large r, the system of spin 0 particle and a monopole does not have bound state.

On the other hand, a particle of spin 1/2 forms bound states with the magnetic monopole when the anomalous magnetic moment $(\kappa_{tot} - 1)$ is sufficiently large. For example, the system of the proton and the monopole has bound state, whose binding energy of the ground state is $-E = 0.188$MeV. and its radius of the orbit is $\sqrt{< r^2 >} = 11.0$fm. We can treat the triton and the ^3He in the same way if the deformation of the nuclei is negligible. We found 1.52MeV., 0.245MeV. and 3.82fm., 7.37fm respectively for the triton and for the ^3He. The attractive force, which appear when the magnetic dipole moment of nuclei orients to the opposite direction of the magnetic monopole, is responsible for the formation of the bound state. We shall see the same attractive force changes the repulsive Coulomb barrier completely. Let us consider the $t+p$ reaction. Suppose that the proton and the monopole form the bound state firstly, the potential felt by the approaching triton is the sum of the Coulomb potential and attractive potential mentioned above. The penetration potential V_1 is:

$$V_1(x) = \frac{e^2}{x} - \kappa_{tot}\frac{e}{2m_p}\frac{{}^{\star}e}{x^2} \quad .$$

It is remarkable that although the peak of the Coulomb potential is around 1MeV. , the peak of $V_1(x)$ is lowered to 17keV..

Furthermore if we solve the third eigebvalue problem of the electron-monopole system, we shall find an eigenstate whose radius is one half of the electron Compton wave length namely 193.8fm., and the monopole-proton system is shielded by the electron cloud. Therefore the penetration potential $V_1(x)$ should be changed to the shielded Coulomb:

$$V_2(x) = \frac{e^2}{x}\exp[-2m_e x] - \kappa_{tot}\frac{e}{2m_p}\frac{{}^{\star}e}{x^2} \quad .$$

It is interesting to compare the penetration factor P for various potentials, where P is

$$P = \exp[-2\tau] \qquad with \qquad \tau = \sqrt{2\mu_{red}}\int_a^b \sqrt{V(x) - E}dx/\hbar$$

, where μ_{red} is the reduced mass and $[a, b]$ is the region of the penetration, and we shall put $E \to 0$ hereafter. In vacuum, $V(x)$ is the Coulomb potential, and if we choose $[a, b]$ as [1fm, 1Å], the penetration factor P is 5.33×10^{-106} and 6.78×10^{-92} respectively for $d + d$ and for $p + t$. These values are forbiddingly small. On the other hand, if the magnetic monopole is involved and so V_2 is used in place of V, P of $({}^{\star}e - d) + d$ changes to 6.22×10^{-9}. Concerning the p+t case, there are two ways of penetration, $({}^{\star}e - p) + t$ denotes penetration, in which the proton is trapped by the monopole at first. The penetration factors P of $p+t$ are 5.39×10^{-4} and 2.93×10^{-7} respectively for $({}^{\star}e - p) + t$ and for $({}^{\star}e - t) + p$. Since these P have reasonable values, we can expect to find the double bound state $(d -{}^{\star} e - d)$ or $(p -{}^{\star} e - t)$. However since the size of the orbits are around several fm., the nuclei quickly fuse to become more stable nucleus ^4He. If we remember the spin 0 particle such as ^4He cannot form the bound state with the monopole, the ^4He must be emitted with the kinetic energy around 20MeV.. There remains a fresh magnetic monopole, which starts to attract surrounding nuclei again. In this way the nuclear cold fusion reaction proceeds by a single magnetic monopole. Therefore this theory predicts the ^4He dominance of the d+d reaction.

If we remember the magnetic monopole is the rare particle and if the existence of a monopole in the reaction region is responsible for the nuclear cold fusion, we expect that we have to wait for long time before the cold fusion reaction start to occur. Since in the ordinary experiment, the process that a monopole moves into and stops in the reaction region is governed by the probability, the occurance of the nuclear cold fusion is sporadic, therefore we cannot expect the 100% reproducibility of the nuclear cold fusion. In order to recover the reproducibility of the ordinary sense, we must do the much more difficult experiment to examine the existence of the monopole along with the measurement of the excess energy.