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Electric Spark Discharges in Water: Light Leptonic Magnetic Monopoles and Catalysis of Ordinary Beta Decays in an Extended Standard Model

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Abstract: The topic of this article is “research of accidents induced by supersonic electric spark discharges in water”. Experiments referring to such accidents were published by Urutskoev et al. in 2000 and Urutskoev in 2004. According to Urutskoev these spark discharges should be accompanied by the emission of a new kind of particles, namely leptonic magnetic monopoles, predicted by Lochak in 1985. Later, Lochak considered these monopoles as excited neutrinos. Both Lochak and Urutskoev supposed that these particles can influence weak decays and nuclear transmutations and that by catalysis the monopole effect can be amplified, leading to macroscopic effects, i.e. accidents. Spark discharges in water are connected with CP-symmetry-breaking, forcing the introduction of an extended standard model described in previous papers. There also, a mechanism of the catalytic effect was discussed, which is further studied in this article. For the selected unstable nuclear element $^{51}\text{Mn}$, the effect is demonstrated and numerically evaluated. A simple non-relativistic nuclear state description is applied for these low-energy processes. The extension of these calculations to other unstable nuclei requires higher calculational effort and is not done in this paper. However, the extraordinarily strong catalytic power of the monopoles revealed by the numerical calculation of the above example suggests looking for macroscopic effects of monopoles as an explanation for accidents, for instance, the catastrophe of Chernobyl, which has been the origin of monopole research. A short review of the corresponding experimental observations connected with this accident is also given in this article.

Keywords: Magnetic Monopoles; Nuclear Accidents; Nuclear Transmutations; Supersonic Spark Discharges in Water.

1 Introduction

Nuclear accident research started in the year 1986 with the appointment of Urutskoev as the head of a research team in Chernobyl. Gradually, the connection of the accident with the action of electric short-circuits and magnetic monopoles was recognised (see Section 8). As a theoretical concept, light leptonic magnetic monopoles were introduced by Lochak [1, 2]. Later on, this concept was supplemented by assuming excited neutrinos to be identical to leptonic magnetic monopoles [3, 4, Foreword, sect. 4, p. xiii]. Experimental indications of such monopoles have been found by Urutskoev et al. [5, 6] by analysing experiments with low-energy electric spark discharges in water, from which they concluded that these monopoles were created. However it has to be added, that the conventional nuclear theory can describe reactions from nuclear structure and energy up to processes in stars. But this theory is not able to explain the processes connected with magnetic monopoles described by Russian physicists. The Russian monopole physics is a completely new branch of theoretical physics and step by step the consequences must be evaluated. That is the purpose of the paper at issue.

Furthermore it should be added that the creation of such monopoles is only an indirect process. First, the discharge in water leads to a streamer, which has a velocity of propagation of $5 \times 10^9$ cm/s or even higher and manifests itself by a loud thunder. The supersonic proton currents are the driving forces of the nuclear processes. On account of their supersonic velocities the protons have sufficient energy to penetrate the Coulomb barrier of nuclei [7]. The thus-generated enrichment with protons makes the affected nuclei unstable and induces $\beta^+\text{-decays.}$ In this second step, leptons are emitted and the excited neutrinos of Lochak must compete with ordinary neutrinos. A method to determine which one of these particles is preferred is not known. Experiments performed at...
the Université de Nantes [8–12] show that the emission of a monopole is rather rare. However, if such a monopole is captured, the effects can be enormous as will be demonstrated in this article.

In comparison with the high-energy research at CERN, the energetic expense is tiny. For triggering one spark event in water, Urutskoev needs only 50 KJ [6]. Further information about the generation of spark discharges is given in [7].

From the absence of free neutrons [6, p. 1154], it follows that the monopoles exert no strong nuclear forces. They can only participate in electromagnetic and weak interactions, and it was guessed that they could catalyse weak decays [5, sect. 3, p. 721].

A distinctive mark is that (phenomenologically) the charge-conjugated monopole is identical to the monopole itself [13, sect. 72]. As monopoles, described as excited neutrinos, have to be considered as composites in spinor field theory [14], under CP-symmetry-breaking, the invariance of the monopole states under charge conjugation was rediscovered [15, sect. 4]. CP-symmetry-breaking is achieved by discharge experiments in water and leads in theory to the Extended Standard Model. There, a monopole has no electric charge or dipole moment, i.e. it must be a composite Majorana lepton [16, 17, p. 207].

As excited neutrinos are leptons, it is obvious that these particles themselves can be emitted as decay products of weak decay processes. Usually, in these processes the leptons are emitted as free particles, but it is hard to imagine how free particles drifting away can catalyse further decays of localised nuclei. Therefore, the only possibility of being catalytically active is by forming a bound monopole-nucleus state.

In [18], a non-perturbative mechanism for the calculation of such catalytic effects was formulated based on the above idea that such monopoles can form bound states with the unstable nuclei of the metallic electrodes during discharges in water. The phenomenological analysis of the effects of such discharges has been done in [7] and [14, sect. 4.1], and is central for the understanding of the proceeding in this article.

In short, by the spark discharges in water, protons are collected in the spark avalanche. They get captured by the anode matter, leading to the generation of positive nuclear ions. As the discharge is a thermodynamic nonequilibrium process, the subsequent formation of neutral atoms in thermodynamic equilibrium is prevented, as the electrons needed for electric charge compensation are torn off by the electric current of the avalanche. Hence, the unstable nuclei must contain surplus proton states that are located above an inert core state of the metallic material of the anode. The latter defines the basis of the nuclear structure together with the inner electron shell states, which are strongly bound to the nuclear inert core and are not influenced by the discharge.

The calculations in [18] have been done by means of phenomenological quantities arising from effective quantities of the spinor field theory [14, 15, 19, 20]. It was developed based on the physical ideas of de Broglie and Heisenberg in combination with CP-symmetry-breaking. Their results allow us to give physical reasons for the emergence of accidents like the Chernobyl catastrophe. However, it should be pointed out that in principle the treatment in this paper is not confined only to nuclear accidents but can also be applied to accidents in conventional power plants [6, p. 1162], although we don’t treat this topic here.

2 Bound States of Leptonic Monopoles with Nuclei

In the low-energy discharge experiments of Urutskoev with $^{58}_{22}$Ti as anode material for spark discharges in water, proton captures of the elements in the isotonic step ladder above $^{58}_{22}$Ti are possible [7]. They run under the constraint of constant neutron number because of the comparative independence of the neutron and proton states in the nuclei [21, sect. 2.1].

An important aspect of the nuclear excitation processes by protons is that every nucleus hit by the discharge avalanche can absorb only one proton because, for a constant neutron number, any absorption of a proton is connected with the creation of a new element in the isotonic step ladder. It follows that between the proton captures and the isotonic step ladder a single-valued mapping exists so that the effect of the proton bombardment can be uniquely expressed by the set of nuclei:

$$^{44}_{22}\text{Ti} \rightarrow ^{40}_{22}\text{V}, ^{50}_{24}\text{Cr}, ^{51}_{25}\text{Mn}, ^{52}_{26}\text{Fe}, ^{53}_{27}\text{Co}, ^{54}_{28}\text{Ni}. \quad (1)$$

Elements given in bold type indicate stable or quasi-stable elements, where as those given in normal type indicate unstable elements.

For a constant neutron number, the enforced proton surplus leads to ions because, by the impact of the spark avalanche, the conduction electrons are torn off from the nuclei, leaving behind true nuclear ions. Therefore, because of the discharge as a thermodynamic nonequilibrium process, a charge neutralisation of the positive ions by electron capture is not possible.

On the other hand, the positive electric charges of the energetically lower nuclear core shell states are neutralised by the inner electrons being not influenced by the loss of conduction electrons. After their loss, the
remaining inner electrons are so strongly bound to the nuclear core that the weakly bound magnetic monopoles see only an effective charge zero of the system nuclear core-inner electrons. Hence, this configuration has no electric interaction with the magnetic monopole.

As Lochak’s monopoles are leptons, during low-energy discharges the only way to create leptons are through weak decays. Hence, one can summarise the conclusion of Urutskoev’s observations by the following hypothesis: during low-energy spark discharges in water, Lochak’s monopoles are created by weak decays.

Since during a weak transition of a nucleus of the anode its recoil is absorbed within the material of the anode, all transmuted and newly generated nuclear elements remain at the original position of their creation, i.e. also the bound monopole rests on the position of the destructed proton [22, p. 258].

In addition, for Fermi transitions, each emitted lepton has the orbital angular momentum zero [23, eq. (7.79), 24, p. 216], being the result of an allowed transition. It follows that, if an excited neutrino is under the emitted leptons of a weak decay, its bound state with nuclear matter can only be a state with vanishing orbital angular momentum, which was extensively discussed and calculated in [16, sect. 5.1].

Owing to these rules, an energetically lowest, spherically symmetric state bound state of the leptonic magnetic monopole with a nucleus cannot decay by photon emission because the energetically lower vacuum state has the same symmetry and thus a decay of the s1 state into the vacuum state is forbidden, i.e. such a state must be stable.

If by a spontaneous weak decay a magnetic monopole is generated, it is essential that a stable bound state $M_1$ persists at one and the same position during the interaction with varying but stationary surplus charges in the element list (1). Being bound by the surplus charges, the magnetic monopole $M_1$ itself is the catalyst of renewed further decays of the surplus charges.

For massive magnetic monopoles, the conservation of magnetic charge does not hold [14]. But above it was argued that, apart from conserved electric charges, it is the stable magnetic bound state $s_1$ that guarantees the existence of a conserved magnetic charge in this special configuration.

### 3 Low-Energy Monopole-Matter Weak Interactions

If the monopole is stable, its Hamiltonian exists. For $t = 0$, the low-energy interaction Hamiltonian for weak processes can be written in the following form [18, eq. (31)]:

$$H_{\text{int}} = -\frac{G_F}{2^{1/2}} \int d^3x \left[ j^{s, +}_k(r) \mathcal{J}^s_k(r) \right]$$

$$= -\frac{G_F}{2^{1/2}} \int d^3x \left[ j^{CC}_{0,L}(r) - \left( \frac{g^*}{c} \right)^2 \frac{i}{M_a} A_k(r) \Psi_{a}(r)(P_L) \Psi_b(r) \right]$$

$$\times \left[ j^{CC}_{0,k}(r) - \left( \frac{g^*}{c} \right)^2 \frac{i}{m_\nu} A_k(r) \psi_{a}(r)(P_L) \psi_b(r) \right].$$

(2)

Quantities with subindex 0 refer to a state where no bound leptonic magnetic monopole is present, $G_F$ is the Fermi constant, $j^{CC}_{0,L}(r)$ is the nuclear current, $g^*$ is the magnetic charge of the monopole (for the value of which we make an assumption in Section 7), $c$ is the velocity of light, $M_a$ is the nuclear mass, $A_k(r)$ is the vector potential of the monopole, $\Psi_{a}(r)$ is the outgoing final nuclear state, $\Psi_{b}(r)$ is the incoming nuclear state, $(P_L)$ is the projection operator on left-handed states, $j^{CC}_{0,k}$ is the leptonic current, and $m_\nu$ is the leptonic mass.

The Hamiltonian (2) contains the overlap between nuclear and lepton wave functions. This offers the possibility for estimates, as shown below. Definitely, the term

$$-\frac{G_F}{2^{1/2}} \int d^3x j^{CC}_{0,L}(r) j^{CC}_{0,k}(r)$$

(3)

is indispensable, as it describes the ordinary $\beta^+$-decay without the participation of a magnetic monopole. With the inclusion of a magnetic monopole, the impact on a weak process leads to

$$\frac{G_F}{2^{1/2}} \int d^3x \left( \frac{g^*}{c} \right)^2 \frac{i}{M_a} A_k(r) \Psi_{a}(r)(P_L) \Psi_b(r) j^{CC}_{0,k}(r)$$

(4)

which is indispensable because for bound magnetic monopole-nucleus states the magnetic vector potential $A_k(r)$ of the monopole is located at the same place as the nucleus. This is analogous, for instance, to an electron bound in the hydrogen atom.

On the other hand, the term

$$\frac{G_F}{2^{1/2}} \int d^3x j^{CC}_{0,L}(r) \left( \frac{g^*}{c} \right)^2 \frac{i}{m_\nu} A_k(r) \psi_{a}(r)(P_L) \psi_b(r)$$

(5)

describes the influence of the magnetic monopole on the lepton emission. It is the projection of the lepton states onto the nuclear states. While the nuclear states are located within the volume of the nuclear core of approximately $10^{-13}$ cm diameter, the emitted lepton states are located within a volume of approximately $10^{-8}$ cm
diameter. A projection onto the nuclear states leads to a
cut-off at a volume of $10^{-13}$ cm diameter, which makes the
transition term (5) negligible. Therefore, the effective weak
interaction Hamiltonian must have the form

$$H_{\text{int}} = -\frac{G_F}{4\pi} \int d^3x \left[ j_{0,0,k}^{CC}(x) - \left( \frac{g}{c} \right)^2 \frac{i}{M_a} A_k(x)^* \Psi^*_a(x)(P_L) \Psi_b(x) \right]$$

$$j_{0,0,k}^{CC}(x).$$

(6)

The corresponding matrix element reads [21, sect. 4.3.2]

$$M = \int d^3x \left[ j_{0,0,k}^{CC}(x) - \left( \frac{g}{c} \right)^2 \frac{i}{M_a} A_k(x)^* \Psi^*_a(x)(P_L) \Psi_b(x) \right]$$

$$j_{0,0,k}^{CC}(x).$$

(7)

While in the ordinary treatment of weak decays the
relativistic currents are used, for low-energy processes the
non-relativistic currents are applied, which explains the
"strange" form of (6) and (7) compared to the ordinary form in [25, sect. 2.1.2, p. 281] and in [17, p. 70, eq. (2.58)].

If the bound magnetic monopole is stable, then the
magnetic charge is conserved. Such a state has the effect of
a magnetic point charge acting on the nuclear states after
the monopole $M_1$ has been generated.

Therefore, if the wave functions for the $\beta$-active
elements are inserted into (6), the matrix element $M$ can be
evaluated. For lepton as well as nuclear bound states,
the wave functions to be used are real, and the same holds
for the vector potential. The only imaginary quantity in (7)
is the Lochak $i$ resulting from the axial vector coupling to
massless leptons [13] and generalised in [14–16, 19, 20] to
massive leptons, transferred back to vector potentials by
duality. Then the absolute value of $M$ results from

$$|M|^2 = M^* \cdot M$$

$$= \left( \int d^3x j_{0,0,k}^{CC,+}(x) j_{0,0,k}^{CC}(x) \right)^2$$

$$+ \left( \int d^3x \left( \frac{g}{c} \right)^2 \frac{i}{M_a} A_k(x)^* \Psi^*_a(x)(P_L) \Psi_b(x) \right)^2$$

$$\times \left( j_{0,0,k}^{CC}(x) \right)^2,$$

(8)

where the first term is the ordinary $\beta^+$-decay term, while
the second term represents the influence of the monopole
on the nucleus at issue. On account of this decomposition, we
define

$$|M_0|^2 = \left( \int d^3x j_{0,0,k}^{CC,+}(x) j_{0,0,k}^{CC}(x) \right)^2$$

and

$$|M_1|^2 = \left( \int d^3x \left( \frac{g}{c} \right)^2 \frac{i}{M_a} A_k(x)^* \Psi^*_a(x)(P_L) \Psi_b(x) \right)^2.$$
If (8)–(10) are inserted into (11), one gets \( d\lambda = d\lambda^0 + d\lambda^1 \) with
\[
d\lambda^0 = \frac{e^6}{8\pi^2\hbar} \left( \frac{2.4G_F}{(hc)^3} \right)^2 |M_0|^2 \delta(\Delta mc^2 - E_e) d^3p_e d^3p_e.
\]
(14)
and
\[
d\lambda^1 = \frac{e^6}{8\pi^2\hbar} \left( \frac{2.4G_F}{(hc)^3} \right)^2 |M_1|^2 \delta(\Delta mc^2 - E_e) d^3p_e d^3p_e.
\]
(15)

4 Basics for the Evaluation of the Catalytic Effect

A catalytic effect can be registered if the decay of an unstable element is accelerated by the influence of an external force. In the case at issue, this is reached by supersonic spark discharges in water. [7]. While the electron avalanche is absorbed by the voltage supply, the protons hit the material of the anode, in our case stable titanium atoms, which absorb the protons forming further elements with proton surplus while their conduction electrons are torn off by the avalanche current. So the question arises: What is an appropriate description of these processes by nuclear theoretical methods? From the start it must be said: Owing to their definition [27, p. 444], [23, p. 197], “Compound reactions” have to be disregarded as they refer to the calculation of the collisions of several whole nuclei. Also the use of complicated single particle shell states must be excluded as both of these treatments do not correspond to the physical processes connected with the supersonic spark discharges in water, where protons out of the streamer are absorbed by the titanium electrodes. In nuclear physics these reactions are theoretically treated within the so called “Optical model”, [23, p. 190], where ordinary wave equations, for instance Schrödinger equations, are used. This is the method applied in the paper at issue, with wave functions given by (36). It allows to study elastic and inelastic processes with proton absorption, which equivalently can be considered as “Direct Reactions” [23, p. 208], [21, sect. 3.6]. These reactions are characterised by the fact that the transitions proceed with a minimum of rearrangement within the nucleus, leading to a reaction within \( 10^{-21} \text{–} 10^{-22} \) s. By repeated proton capture, the elements of the isotonic step ladder (1) above titanium can be attained, of which \( \frac{\text{V}}{25} \) \( ^{51} \) and \( ^{50} \) \( ^{24} \) Cr are quasi-stable or stable, while the elements

\[
\frac{\text{Mn}}{25} \text{, } \frac{\text{Fe}}{26} \text{, } \frac{\text{Co}}{53} \text{, and } \frac{\text{Ni}}{28}
\]

are unstable by \( \beta^+ \)-decays, provided the direct decays take place more rapidly than the competing electromagnetic decays.

To make sure that this is possible, we need to anticipate the result of our calculations: Under the influence of a bound monopole \( M_1 \), the catalytic effect is so strong that the possible decays take place almost instantaneously, so that electromagnetic decays are negligible.

As a first step of the numerical evaluation, we start the calculations with the total decay rate \( \lambda^0 \). The corresponding equations can be taken from [21, p. 203, eqs. (4.85)–(4.88)] for \( M = M_0 \). We first consider (14) after integration over the neutrino energy. This leads to
\[
d\lambda^0 = \frac{2}{\pi^3\hbar} \left( \frac{2.4G_F}{(hc)^3} \right)^2 |M_0|^2 \left( \Delta mc^2 - E_e \right)^2 \left( E_e^2 - m_e^2c^4 \right)^{1/2} E_e \, dE_e.
\]
(17)

If, finally, (17) is integrated over the positron energy \( E_e \), one obtains the total rate of an ordinary decay:
\[
\lambda^0 = \frac{2}{\pi^3\hbar} \left( \frac{2.4G_F}{(hc)^3} \right)^2 |M_0|^2 \int_{m_e c^2}^{\infty} \left( \Delta mc^2 - E_e \right)^2 \left( E_e^2 - m_e^2c^4 \right)^{1/2} E_e \, dE_e.
\]
(18)

In the same way, one gets for the monopole-induced decay rate \( \lambda^1 \) the equation
\[
\lambda^1 = \frac{2}{\pi^3\hbar} \left( \frac{2.4G_F}{(hc)^3} \right)^2 |M_1|^2 \int_{m_e c^2}^{\infty} \left( \Delta mc^2 - E_e \right)^2 \left( E_e^2 - m_e^2c^4 \right)^{1/2} E_e \, dE_e.
\]
(19)

As the recoil of the nuclei undergoing such a process can be neglected, (a quasi-stable) magnetic monopole bound to an unstable nucleus can remain in a quasi-stationary state for a long time, i.e. as long as the monopole can find surplus charges of the same nucleus for the continuation of its quasi-stationary bound state. The dependence of the decay calculations on internal parameters like \( \Delta m \) allows the identification of single events.

By definition, owing to (18) and (19), we introduce the kinematic factor
\[
F_{\beta}^{\text{proton}} = \int_{m_e c^2}^{\infty} \left( \Delta mc^2 - E_e \right)^2 \left( E_e^2 - m_e^2c^4 \right)^{1/2} E_e \, dE_e.
\]
(20)
A corresponding factor was exactly calculated for neutron decay in [28, eqs. (9.59) and (9.60)], with the result
\[
F_{\beta}^{\text{neutron}} = \frac{1}{4} \left( m_e c^2 \right)^5 \left[ \frac{1}{15} \left( 2a^4 - 9a^2 - 8 \right) \left( a^2 - 1 \right)^{1/2} + a \ln \left( a + \left( a^2 - 1 \right)^{1/2} \right) \right],
\]
also given in [21, p. 199, eqs. (4.72) and (4.73)], where \( a_{\text{neutron}} = (m_n - m_p)/m_e \). This formula can be applied to proton decay by replacing \( a_{\text{neutron}} \) by \( a_{\text{proton}} = \Delta m/m_e \).

Of importance are the estimates of the energetic turnovers. The key to such estimates is the fact that \( a_{\text{neutron}} \) as well as \( a_{\text{proton}} \) are dimensionless quantities, which, due to the small electron mass compared with the nuclear mass values, satisfy the inequality
\[
a_{\text{neutron}}, a_{\text{proton}} \gg 1.
\]

On account of this inequality, the leading term approximation of (21) yields
\[
F_{\beta}^{\text{neutron}} = \left( m_e c^2 \right)^5 \frac{1}{30} a^5 = \frac{1}{30} \left( (m_n - m_p) c^2 \right)^5
\]
and in the same way
\[
F_{\beta}^{\text{proton}} = \frac{1}{30} \left[ \Delta mc^2 \right]^5.
\]

The values of \( \Delta m \) have to be calculated for the various participants of the decay process. This can be done following [21, p. 14, eq. (1.12)], where the mass of a single nucleus is defined by the formula
\[
M(A, Z)c^2 = (A - Z)m_n c^2 + Zm_p c^2 - B(A, Z)
\]
with \( B(A, Z) = -E_B(A, Z) \) as the common binding energy.

To avoid complications, with the details of (24) and (25) we resign the separate evaluation of (18) and (19) and introduce the fraction
\[
\eta_{\text{cat}} = \frac{\lambda^0 + \lambda^1}{\lambda^0} = 1 + \lambda^1 / \lambda^0,
\]
such that the kinematic factor (20) cancels out, \( \lambda^0 + \lambda^1 \) is the total effective decay rate due to the presence of the \( M_1 \) monopole, and \( \lambda^1 \) is the decay rate in its absence. Looking at the results of Section 7, this process is justified because the catalytic effect of a magnetic monopole is so strong that the values of ordinary \( \beta^+ \)-decays are practically unimportant for the outcome of the monopole effect. All values of \( \lambda^1 / \lambda^0 > 0 \) are due to the catalytic influence of \( M_1 \) on the decay. Equations (18) and (19) yield
\[
\frac{\lambda^1}{\lambda^0} = \left| \frac{M_1}{M_0} \right|^2.
\]

The calculation of this fraction cannot be done without the specification of the nuclear shell structure of the nuclei being involved, for instance, the shell structure of \( ^{22}_{11} \text{Ti} \) used by Urutskoev as the anode metal.

Postulating a mean potential model with spin-orbit interaction for the calculation of nuclear single particle states, a simple example is given by the harmonic oscillator states. For this set, one can define a shell structure that casually fits into the scheme for the various unstable nuclear states owing to proton capture by \( ^{22}_{11} \text{Ti} \) and the resulting states [29, p. 245, fig. 7.5] and [21, p. 87, fig. 210].

They can be collected in a \( 1f_{7/2} \) shell, which has as a full set of states for the eight elements
\[
^{47}_{22} \text{Sc}, \quad ^{48}_{22} \text{Ti}, \quad ^{49}_{22} \text{V}, \quad ^{50}_{24} \text{Cr}, \quad ^{51}_{25} \text{Mn}, \quad ^{52}_{26} \text{Fe}, \quad ^{53}_{27} \text{Co}, \quad ^{54}_{28} \text{Ni}.
\]

The elements in this enumeration that exclusively undergo a \( \beta^+ \)-transition are \( ^{51}_{25} \text{Mn}, ^{52}_{26} \text{Fe}, ^{53}_{27} \text{Co}, \) and \( ^{54}_{28} \text{Ni} \). It is, however, physically reasonable to collect all states that arise by proton capture above \( ^{48}_{22} \text{Ti} \) with a spark discharge in water, which are given by
\[
^{49}_{23} \text{V}, \quad ^{50}_{24} \text{Cr}, \quad ^{51}_{25} \text{Mn}, \quad ^{52}_{26} \text{Fe}, \quad ^{53}_{27} \text{Co}, \quad ^{54}_{28} \text{Ni}.
\]

5 Left-Handed Low-Energy Currents

For the weak semi-leptonic currents as used in (9) and (10) the following statements can be made. They must be left-handed ones which yields for ordinary \( \beta^+ \)-decay without the influence of a magnetic monopole [17]
\[
\mathcal{J}_{\beta}^{\text{CC}} = \Psi_{\bar{\nu}}(1 - \gamma_5)\psi, \quad \mathcal{J}_{\beta}^{\text{EC}} = \bar{\psi}_e(1 - \gamma_5)\gamma_\mu\psi, \quad \mathcal{J}_{\beta}^{\text{EC}} = \bar{\psi}_e(1 - \gamma_5)\gamma_\mu\psi, \quad \mathcal{J}_{\beta}^{\text{EC}} = \bar{\psi}_e(1 - \gamma_5)\gamma_\mu\psi,
\]
where \( \bar{\psi}_e \) is a positron state; the full expression for the currents with monopoles is given in Section 3, (2).

For a Fermi transition, the spin states of the nuclei must be parallel, while the spin states of the leptons have to be anti-parallel and their total angular momentum has to vanish [24, p. 216].

Compared with the nuclear mass, the energy transfers resulting from \( \beta^+ \)-decays are small, which justifies the use of non-relativistic spin states.

This low-energy approximation can be expressed in the currents of Section 3 by \( \gamma_a = 0 \) with \( a = 1, 2, 3 \) [22, p. 258]. Then, for parallel spins one gets the spin factor \( \lambda \) in the nuclear wave functions owing to the orthonormalisation of the spin states. Therefore, the nuclear current in (9) is reduced to
\[
\Psi_{\lambda}(1 - \gamma_5)\psi = \Psi_{\lambda}(1 - \gamma_5)\psi = \Psi_{\lambda}(1 - \gamma_5)\psi = \Psi_{\lambda}(1 - \gamma_5)\psi = \Psi_{\lambda}(1 - \gamma_5)\psi,
\]
Also, the leptons are low-energy states that, however, need more drastic reductions according to the constraint that for Fermi transitions the leptonic spins are anti-parallel and the orbital angular momentum must be zero. This means that $Y_{0,0} = 1/(4\pi)$ has to be used in the nuclear wave function \( \langle \gamma_0 \rangle \) in the next section and leads to $\langle \gamma_0 (1 - \gamma_5) \rangle = 1$, formally expressed by the constant spin-dependent contribution $j_{0,k} = j_{0,k}^{CC}$. (spin).

The latter relation needs an additional justification. In the integral (10), the nuclear density acts as a projector on the other state functions, as this density is confined to the nuclear volume $V$. On the other hand, the ordinary leptonic current resulting from an ordinary $\beta^+$-decay consists of plane waves, which, owing to the projector property of the nuclear density, has to be normalised within $V$. The effect of this normalisation is that the plane waves for positrons as well as neutrinos can be approximated by $V^{-1/2}$. 

An additional complication is the appearance of positrons together with the condition of different spins for positrons and neutrinos. The corresponding spin states must be taken from the relativistic Dirac equation for free leptons because the latter result as free particles from a $\beta^+$-decay. One obtains in the low-energy approximation the following set of electron and positron spin states [28, eq. (7.30)], [22, eq. (5.22)], and [30, eqs. (1.48) and (1.49)]:

$$
\begin{pmatrix}
1 \\
0 \\
0 \\
0
\end{pmatrix}
\begin{pmatrix}
0 \\
1 \\
0 \\
0
\end{pmatrix}
\begin{pmatrix}
0 \\
0 \\
1 \\
0
\end{pmatrix}
\begin{pmatrix}
0 \\
0 \\
0 \\
1
\end{pmatrix}
.$$

(32)

In particular, the first two states are particle states while the last two states are anti-particle states, which in the case at issue are the positron spinors. Particle and anti-particle states are orthogonal. However, with respect to $\gamma_5$ one gets

$$
\langle \text{antiparticle} | \gamma_5 = | \text{particle} \rangle,
$$

(33)

while all other combinations except the inverse relation (33) vanish. The relation (33) just describes the result of the $\beta^+$-decay, where the emitted neutrino is a particle with opposite spin to the anti-particle, i.e. the positron. For further details of the process, refer to [22, sect. 5.3].

From the fact that the $\beta^+$-emitters are embedded in the anode matter, it follows that the recoil of the emitter is absorbed by the whole lattice, i.e. it can be neglected. This means that the incoming and outgoing nucleon wave functions in (9) must be equal if the single-particle states of protons and neutrons are nearly equal.

For convenience, we choose the proton functions as real. Hence, in (9) and (10) the nuclear part is the norm of the proton wave function.

However, for ordinary $\beta^+$-decays the proton wave functions must depend on the prevailing nucleus considered, i.e. not the single-particle nuclear functions are of importance but rather their embedding in the structure of a real existing nucleus. To avoid this complication, an alternative procedure can be the use of phenomenological values for $M_0$ by comparison with experimental values. This has been done in [21, p. 205]: “Generally one has $|M_0|^2 \ll 1$ but for superallowed decays one gets $|M_0|^2 \sim 1$”. We prefer to use

$$
|M_0|^2 = 1
$$

(34)

because with this value the fraction (27) is minimised, which guarantees a catalytic effect of the magnetic monopole if $\lambda^1 > 0$.

Further discussion is now dedicated to the evaluation of $|M_1|^2$.

### 6 Unstable Nuclei as Nuclear Valence States

Generally, in a nuclear shell model a nucleus is described by a set of shells where each shell is composed of single-particle states. As protons and neutrons are different particles, they have to be arranged in independent shell states. Then, for a constant neutron number there exists a unique mapping between the isotonic step ladder above $^{48}_{22}$Ti and each proton capture event.

In Section 4, it was shown that the unstable ionic nuclear states (29) with proton surplus in the isotonic step ladder belonging to $^{48}_{22}$Ti can be collected in a $1f_{7/2}$ shell. If, owing to the low-energy discharge processes, one intends to replace the relativistic proton shell by a corresponding non-relativistic atomic shell system, then the shell must have eight elements too. This can be achieved with a combination of two $2s$ states and six $2p$ states [31, table 8.1, p. 343], [32, vol. 1, probl. 67, p. 174], and [33, p. 194].

For nuclei with surplus protons, the mixture of $s$ states and $p$ states seems to be strange but corresponds to physical reality, which is due to the fact that not all elements of the set (1) are unstable. Only those elements which for constant neutron number arise by proton capture of the basic stable element $^{48}_{22}$Ti are the unstable ones. The latter are the elements collected in the set (1), respectively (29),
with the exception of the nearly stable or stable elements $^{49}_{23}$V, $^{50}_{23}$Cr. These elements are characterised by the more strongly bound 2s states, so that the division into 2s states and 2p states in the atomic shell description offers a natural distinction between inert and unstable nuclei. Therefore, for a constant neutron number, the elements with six 2p states constitute a subspace of the non-relativistic 1f$_{7/2}$ shell. Note that in (29) not only the elements $^{49}_{23}$V, $^{50}_{23}$Cr are characterised by 2s states but also the element $^{53}_{27}$Ni, as the closure of the full 1f$_{7/2}$ shell must have the angular momentum $l = 0$ [29, p. 245]. Thus there remains only the triplet

$$\frac{51}{23}\text{Mn}, \frac{52}{26}\text{Fe}, \frac{53}{27}\text{Co},$$

(35)

which can belong to a 2p representation, where the factor 2 refers to the corresponding spin states, while the corresponding angular momentum states of the 2p representation are given by

$$Y_{1,0} = \frac{1}{2} \sqrt{\frac{3}{\pi}} \cos \vartheta,$$

$$Y_{1,1} = \frac{1}{2} \sqrt{\frac{3}{\pi}} \sin \vartheta \cos \varphi,$$

$$Y_{1,-1} = \frac{1}{2} \sqrt{\frac{3}{\pi}} \sin \vartheta \sin \varphi.$$  

(36)

In spherical coordinates, with the inclusion of non-relativistic spin states, the corresponding associated single-particle wave functions then read [32, probl. 67, p. 173]

$$u_{n,l,m,l} = \frac{1}{r} \chi_{l,n}(r) Y_{l,m}(\vartheta, \varphi) \sigma_l.$$  

(37)

In this nuclear wave function, only one spherical harmonic function appears. This is due to the fact that each element of unstable nuclei can only be formed by the capture of one proton because capturing one proton transmutes this element already into a new one. Hence, if the functions (37) are to describe unstable nuclei, it suffices to consider the excitation by the capture of one proton. Therefore, a set of functions (37) with different spherical harmonics (36) must describe different nuclear elements. For the set (35), this mapping is single-valued.

7 Calculation of the Catalytic Effect

The intensity of the catalytic effect depends on the numerical value of $M_1$ defined by (10). Apart from $A(r)$, all other functions are “standard” functions, while $A(r)$ is singular and not a continuous function but a distribution. Historically, this was described by the Dirac quantisation condition for magnetic monopoles [34, p. 275, eq. (6.153)]. To remove this singularity, Wu and Yang applied a topological construction, but still under the premise of conservation of magnetic charge [35, sects. 3.1 and 4.1]. According to Section 3, this premise can be satisfied if a magnetic monopole is assumed to be in interaction with nuclear matter or, more precisely, with protons as nuclear surplus charges. In this case, a bound magnetic monopole $M_1$ can be formed by a bound state $s_1$, which cannot decay by photon emission and therefore is stable.

Note that this state is rotationally invariant and can be formulated in spherical coordinates, which likewise holds for the Wu-Yang potential construction. For consistency, the latter has to be written without the coupling constant, which is already contained in the Hamiltonian (2). This yields for a magnetic point charge the following vector component:

$$A(r) = \frac{1 - \cos \vartheta}{r \sin \vartheta} \hat{e}_\varphi,$$  

(38)

defined in the northern hemisphere $0 \leq \vartheta < \frac{\pi}{2} + \frac{\pi}{4}$ [35, p. 68, eq. (3.1)]. This potential can be expressed in a similar form for the rotationally invariant $s_1$ state too.

Owing to the fact that for low-energy spark discharges in water only nuclei with $\beta^+\text{-active surplus charges can interact with magnetic monopoles, the matrix element } M_1 \text{ must be calculated with nuclear wave functions of these elements. According to Section 6, the latter elements have to be described by 2p states of atomic physics.}$

For a first inspection, we use the triplet (36), which corresponds to the $\beta^+\text{-active nuclei } (35), \text{ with the complete wave function } (37). \text{ The integral in } (10) \text{ can be evaluated provided some peculiarities have been taken into consideration.}$

1. The recoil of the initial nucleus after a $\beta^+$-decay has to be neglected if this nucleus is embedded in the crystal lattice of the metallic anode. The $\beta^+$-active nuclear valence states are stabilised in their lattice position by the influence of the occupied inert inner shell states of the corresponding unstable nucleus.

2. In low-energy nuclear decay processes, the spins of the unstable nuclei are given by the non-relativistic spin states of quantum mechanics.

3. For Fermi transitions, the spins of the initial and the final nuclear states are parallel, i.e. in (10) the contribution of the nuclear spin part is 1.

4. For ordinary Fermi transitions without the presence of a magnetic monopole, the spins of the two emitted
leptons are anti-parallel \((s = 0)\) and the total angular 
momentum of the leptons vanishes \((j = l + s = 0)\), i.e. the orbital angular momentum of the two-lepton
state must vanish too, \(L = 0\). For allowed transitions, each lepton itself must have orbital angular momentum
\(I = 0\) [24, p. 216].

5. An important part in the weak interaction of a magnetic
current components by

in spherical polar coordinates, too. Denoting the leptonic
scalar product between the magnetic vector potential and
variables

coordinates too. The latter coordinates are defined by the
model, all nuclear states are to be used in spherical polar
coordinates.

To calculate the right-hand side of (43), some estimates are helpful.

First, because of the assumption of light magnetic monopoles, we put

but it has to be kept in mind that the real effective value of
\(g'\) is actually unknown, in particular for unstable magnetic
monopoles [14].

Second, because of the projector property of the nuclear wave functions, we replace the radial coordinate
\(r\) by its expectation value \(< r >\).

Finally, the nuclear radial density \(\chi^2(r)\) can be taken from that of a particle enclosed in a square-well potential
[21, p. 33, fig. 1.10], or, alternatively, of a particle enclosed in a sphere. Since the radial density is normalised to 1
on account of the normalisation condition for the nuclear 
eigenfunctions [32, Probl. 62, eq. (62.7)], the first integral in (43) reads

where all terms of the foregoing calculations are specified including the spherical space element \(d^3x = r^2 \sin d\theta \, dr \, d\theta \, d\varphi\).

To demonstrate the catalytic effect, we select the element requiring the smallest possible calculational effort, which is \(\frac{51}{2}^{157}\text{Mn}\). It is characterised by a wave function where \(Y_{l,0}\) from (36) has to be used. The second integral in (43)
over the angular momenta yields with \(j_{0,\varphi}^{CC} = \frac{1}{2}\) according to the discussion of Section 5

\[
\frac{3}{2V} \int_0^{\pi/2} \sin \theta \, d\theta = \frac{3}{2V} \left( \frac{\pi}{16} - \frac{2}{15} \right).
\]
It follows
\[
M_1 = e^2 (M_0 c^2)^{-1} < r > \frac{3}{2V} \left( \frac{\pi}{16} - \frac{2}{15} \right).
\] (47)

With \(M_0 c^2 = 47,458 \text{ MeV}\) as the energy value of a \(^{51}\text{Mn}\) nucleus, \(V = (4/3)\pi R^3\), \(R = 1.25 \times 10^{-13} \text{A}^{1/3} \text{cm}\) [38, p. 89], \(e^2 = 1.44 \times 10^{-13} \text{MeV cm}\), and \(< r > = R\), we get
\[
M_1 = 3.19 \times 10^5 \frac{1}{\text{cm}}.
\] (48)

Note that, as opposed to [21], in our formalism \(M_0\) and \(M_1\) have the dimension \(1/\text{cm}\), but during further procedure any conversion factors will cancel out. A pre-condition for the application of the results in (27) is that both factors have the same physical dimension. The latter fact is guaranteed by the common derivation of the non-relativistic currents for weak decays [18, Sect. 6]. Then, (34) and (48) yield
\[
\frac{\lambda^1}{\lambda^0} = \frac{|M_1|^2}{|M_0|^2} = 1.02 \times 10^{11}.
\] (49)

Any value of this fraction \(>1\) represents a catalytic effect. Obviously, the very strong catalytic effect can induce quasi-instantaneously a further \(\beta^+\)-decay. If, again, a magnetic monopole would be generated with the same strong catalytic power, this would open the way for a magnetic monopole avalanche. Of course, the effect will be reduced if \(g^r\) is significantly smaller than assumed in (44).

However, such an avalanche has not been observed so far because not every \(\beta^+\)-decay leads to the emission of a magnetic monopole.

8 Chernobyl as the Origin of Monopole Research

The strong catalytic power of the leptonic magnetic monopoles suggests looking for macroscopic effects induced by the action of these monopoles. Indeed, such macroscopic actions have been the origin of systematic monopole research. On the occasion of the Chernobyl accident, Russian physicists registered discrepancies between the official version of the course of this accident and their own interpretation, and observations led them to the idea of the participation of the leptonic magnetic monopoles published in a common paper [39].

Without discussing details of the above paper, we translate parts of a review article of Lochak [40], which contains the description of some facts leading the Russian physicists to the idea of the participation of Lochak’s monopoles in the Chernobyl nuclear disaster.

Apart of de Broglie and Neel nobody of the physicists was interested in the leptonic magnetic monopole, because the majority of physicists expected the discovery of a very heavy bosonic magnetic monopole, cf. [27], sect.15.3 which nobody has ever observed so far. Some years passed and 1986 it occurred the catastrophe of Chernobyl.

A Russian physicist, whom I haven’t known before, Leonid Urutskoev, stayed ten years there on the top of a research team sent by the Kurchatov Institute to investigate the causes of the accident.

At the same time as Urutskoev started his work a commision was sent by the government to investigate the causes of the accident too, whose instruction by the government was as usual: Find human errors and those persons being responsible for that to deliver them to media.

In the meantime Urutskoev and his team had gathered amazing observations: the reactor core was not smelt and the rods of uranium were lying broken on the bottom of the reactor vessel. The coating on the inside wall of the reactor has remained intact, being a proof that the temperature had not exceeded 300 degree.

The rods of graphite supposed to be burnt and responsible for the flachy light phenomena above the reactor were nearly all intact apart of a few. On the other hand 10 tons of aluminium were found, a material which was not used for the construction of the reactor.

In addition slight amounts of various chemical elements were found which likewise have not been used for the construction of the reactor giving evidence for unusual transmutations. Although the reactor was not in operation the fuel rods of uranium were enriched to 20 per cent which usually had to be enriched to 1.1 per cent.

The lid of the reactor containment with the weight of 2500 tons was lifted up and completely intact shifted away from the reactor containment. In contrast to movies which show its explosion and its shattering to pieces, if the lid would have been lifted by an internal pressure the whole reactor would have been exploded. Also the inside wall of the reactor containment was completely intact. However, in a plant room the water pipe of the reactor was parallel to a high tension power cable having been forcibly pushed against the water pipe. Which force had it attracted?

The Russian physicists have put forward the hypothesis that at the instant of the accident the water pipe had carried the magnetic monopoles into the reactor. The transmutations and the other phenomena have led them to the hypothesis that these monopoles play an important role in the catastrophe of Chernobyl.

After having formulated that hypothesis, Urutskoev got aware of my theoretical studies about a light leptonic magnetic monopole and since that time we collaborated, while the Russian physicists dealt with this problem in numerous laboratories, for instance in Moscau, Dubna, Kiev, Kazan, etc.

Ten years later, after the first publications of the Russian physicists their observations and conclusions concerning the light leptonic magnetic monopoles, they have been
continued by French physicists, in particular by members of the Université de Nantes. They published the following results:
1. *Explosion électrique d’un fil de titane dans de l’eau en milieu confiné* [8],
2. *Transmutations et traces de monopoles obtenues lors de discharges électriques* [9],
3. *Tracs of magnetic monopoles* [10],
4. *Experimental report on magnetic monopoles* [11],
5. *Enrichissement d’eau en deutérium lors d’une décharge électrique* [12]

and confirmed in this way the results of the Russian physicists.

Further information about the monopoles can be found in a more general review article by Lochak [41].

An article about the RBMK-1000 reactor type and the nuclear disaster was given in [42], representing the view of foreign physicists.

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