The half-life of particles as a thermodynamics parameter of the selection principle

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Abstract

Data of particle physics were studied for its fitness within a self-selection principle. A plot of mesons and baryons, according to their energy and half-life, reveals an overall tendency of deconfinement and reconfinement of energy, leading to hadrons dominance. The decay of the particles contributes to increment enthalpy along primordial chronology. The strong force opposes to the separation of the constitutive quarks of pions through self-multiplication, incrementing the mass of the system. Sequencing and integrating reactions paths of hadrons and antihadrons, allow for the disappearance of antiprotons and antineutrons, yielding a residue of 2 neutrons. Also, the process emits gamma photons, electrons, positrons, neutrinos, antineutrinos, kaones and piones. The energy of decay and pair-annihilation could be confined in hadrons, in order to prevent a Universe immersed into residual gamma radiation. The generation of the resting mass of hadrons, involves a 99% of releasable energy to form gluons, summing-up to a 1% mass of quarks. Also, an oscillation neutron-proton and antineutron-antiproton cycle captures primordial radiation. Each one absorbs 1 gamma photon, 1 electron and 1 positron, and generates 2 neutrinos and 2 antineutrinos that leak-out of the system. Half-life is a statistical defined parameter, which allows synchronizing events globally disconnected, without introducing an ad-hoc velocity greater than *c*, to allow global connectivity. The phases of particles decay and reconfinement, inputs a statistical convergence allowing parameterization of an evolutionary selection processes.

Introduction

The thermodynamics state of the Universe appears to correspond with a non-equilibrium system, projection to the initial state, requires extrapolation to the quantum level. The increment of free energy to oppose entropy within a system was idealized by J. C. Maxwell as “little red demons”, indicating the need for information linkage [1] itself an energy expenditure. The latter, imply a requirement for a flow of mass and energy into and out of the system [2], this one differentiates open from close thermodynamics.

A thermodynamic perspective allows an enthalpy increment when a particle structure “enters” into a dissipative state, releasing inside a system deconfined energy. This one, coupled to the exit from the system of one of the reactions products like neutrinos, configures also non-equilibrium thermodynamics capable to operate like an open-system within a self-contained Universe.

Prigogine proposed that the second law of thermodynamics for quantum systems could function like a symmetry-breaking selection principle [3, 4]. Symmetries of entropy are precluded, by a multiple specific surging of enthalpy input inside of the system, as quanta decays determine a vector-chronology [4]. A great difference between the half-life of each of the species of primordial particles prevents connectivity of states, allowing asymptotic irreversibility [5] and the plotting of an evolutionary pattern.

Half-life delimits changing composition of particle populations, as a parameter to characterize deconfined states of energy contributing to enthalpy, which supports the expenditure of free energy, and associated increment of entropy in a self-contained Universe.

Energy activation, E_a, is a Gaussian-symmetry distribution for the energy-dependent increment in the number of news particles. Half-life: $t_{1/2} = \tau \,\mathrm{In}2$, is as a statistical decay in particle number. Both processes when coupled generate symmetry-breaking. This, configure differentiating reactive paths between forward and backward sense, which prevent stationary states and allow a continuous deconfinement-reconfinement of energy. This process involves *quantum decoherence* and configures a chronological unidirectional function. Hence, data from the physics of particles was analyzed under this parameter to evidence self-organization [3, 4] as a chronological determinant of a selection process.

Sakharov [6, 7, 8] stated that from an initial symmetric state, a matter-antimatter to develop asymmetry within the primordial universe, involved: I: Violation of the baryonic conservation number. II: Violation of symmetry CP strong. III: Deviations from thermodynamic equilibrium.

The primordial asymmetry [9, 10, 11] is analyzed as a function of the chronology allowing survival to annihilation of a residue of quark-antiquark. It is assumed: I. Baryon number conservation. II. Violation of electroweak CP-symmetry. III. Deviations of thermodynamic equilibrium as a function of a no-null transition time for $W^{\pm}$ bosons [12, 13] and the no-electroweak-interaction of products with leak of neutrinos/antineutrinos [14, 15].

Results

P-Parity allows reversal of helicity, a left-handed electron e_L^- transform into right-handed positron e_R^+. $W^{\pm}$ bosons couple with CP-conjugate e_L^- and e_R^+ but not to C-conjugate e_L^+ or P-conjugate e_R^-. CP-symmetry is violated in neutral K decay [16] and neutral B decay [17]. T symmetry violation occurs in neutral K decays [18]. These violations allow an accumulative residual of matter.

Characterization of particles by resting-mass and half-life

The decay of particle populations generates an increment of enthalpy which supports free energy expenditures. The energy enters into the thermodynamics system by decay, equivalent to dissipation structures maintaining an open system in non-equilibrium.

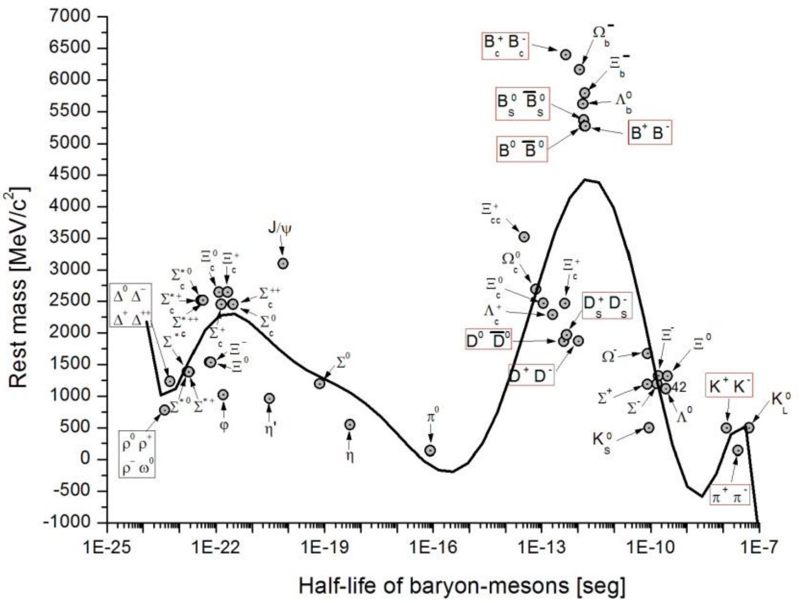


Figure 1: Plot according to their half-life: $t_{1/2}$, and resting-mass: m. *Particles which surge in high-energy colliders like HLC were plotted. The first band groups particles with a $t_{1/2}$ around 10^{-22} s corresponds to strong interaction predominance. The second band groups particles with a $t_{1/2}$ around 10^{-11} s that correspond with electroweak interaction.*

The pattern of energy distribution suggests a chronology, by the changing population of particles showing a tendency of longer half-life: $t_{1/2}$, which configures a chronological self-selection process.

The fit-plot can be used as a model assimilating collider's generated particles to dissipative states of same or similar primordial particles within cosmic chronology. Hence, the obtained tendency curve may manifest a correlation between deconfinement and reconfinement of energy acting as a pacemaker effect along cosmological time.

The first band manifests the presence of the strong interaction:

Mesons: Rho, $\rho^{\pm}$, ρ^0, and Omega, ω^0: 4×10^{-24} s ; Phi, φ, 1.6×10^{-22} s; Eta prima, η', 3×10^{-21} s; J/Psi, J/ψ, 7.2×10^{-21} s; Eta, η, 5×10^{-19} s. Baryons: Delta, Δ^{++}, $\Delta^{\pm}$, Δ^0, 5.58×10^{-24} s; Sigma, Σ^{*-}(1385), 1.67×10^{-23} s; Σ^{*0}(1385), 1.8×10^{-23} s; Σ^{*+}(1385), 1.84×10^{-23} s; Σ_c^{*+}(2520), 3.9×10^{-23} s; Σ_c^{*0}(2520), 4.1×10^{-23} s; Σ_c^{*++}(2520), 4.4×10^{-23} s; Xi, Ξ^{*-}(1530), 6.7×10^{-23} s; Ξ^{*0} (1530), 7.2×10^{-23} s; Ξ_c^{*0}(2645), 1.2×10^{-22} s; Σ_c^{+}, 1.4×10^{-22} s; Ξ_c^{*+}(2645), 2.1×10^{-22} s; Σ_c^{++}, 2.95×10^{-22} s; Σ_c^0, 3×10^{-22} s; Σ^0, 7.4×10^{-20} s; [19].

When the distance between quarks becomes very short, the intensity or interaction decreases. Hence, in between to 10^{-30} to 10^{-10} s the plasma quark-gluon would show asymptotic freedom. This mechanism allows that each quark or antiquark maintains an unstable state of attraction with the others [20].

The particles interact via the strong force, have half-life of 10^{-23} s. The strange particles, which are characterized by the electroweak interaction, have half-lives between 10^{-10} and 10^{-8} s.

Particles and antiparticles have the same spin and mass, but opposite electrical charges, and quantum numbers strangeness S, $\mathrm{S} = -(n_s - \bar{n}_s)$, isospin I_3, lepton number L and baryonic number B. However, Σ^+ and Σ^- are not antiparticles have the same B=1 and masses are not identical. Strong interaction conserves the strangeness S, but after to 10^{-10} s the weak interaction dominates which ignores S and I_3.

Recognition of the specific direction of the longitudinal-spin and handedness for neutrino emission allows selecting different reaction paths.

The released energy by short lived particle decays [21] becomes substrate of subsequent reactions.

A second band results from a latter drop of temperature allowing particles in which electroweak interaction became manifest and the deconfined energy supports the creation of new particles.

As the distances between pions became greater than 1 Fermi, the energy involved by an attempt of quarks separation, becomes greater than the mass of the pions and these multiply [22]. Production of pions $\pi^+[u\bar{d}]$, $\pi^-[\bar{u}d]$, $\mathrm{K}^+[u\bar{s}]$, $\mathrm{K}^-[\bar{u}s]$, $p^+[uud]$, has been detected at 900MeV with ALICE at the LHC [23]. These processes at primordial universe could be expected to prevent accumulation of high energy photons and favor the increase in the population of quarks and antiquarks conforming the quark-gluon plasma at 10^{-10} s [24].

Mesons: Pion, π^0, 8.4×10^{-17} s; neutral D, D^0 and $\overline{D}^0$, 4.1×10^{-13} s; Charmed B, $B_c^{\pm}$, 4.6×10^{-13} s; Strange D, $D_s^{\pm}$, 4.9×10^{-13} s; Charged D, $D^{\pm}$, 1.04×10^{-12} s; Strange B, B_s^0 and $\overline{B}_s^0$, 1.46×10^{-12} s; Neutral B, B^0 and $\overline{B}^0$, 1.53×10^{-12} s; Charged B, $B^{\pm}$, 1.63×10^{-12} s; Kaon-short, K_S^0, 8.9×10^{-11} s; Kaons, $K^{\pm}$, 1.24×10^{-8} s; Pions, $\pi^{\pm}$, 2.6×10^{-8} s; Kaon-long, K_L^0, 5.2×10^{-8} s. Baryons: Xi, Ξ_{cc}^{+}, 3.3×10^{-14} s; Charmed Omega, Ω_c^0, 6.9×10^{-14} s; Ξ_c^0, 1.12×10^{-13} s; Charmed lambda, Λ_c^+, 2×10^{-13} s; Charmed Xi, Ξ_c^+, 4.42×10^{-13} s; Bottom Omega, Ω_b^-, 1.13×10^{-12} s; Bottom Lambda, Λ_b^0, 1.391×10^{-12} s; Xi, Ξ_b^-, 1.56×10^{-12} s; Σ^+, 8.018×10^{-11} s; Omega, Ω^-, 8.21×10^{-11} s; Σ^-, 1.479×10^{-10} s; Ξ^-, 1.639×10^{-10} s; Λ^0, 2.631×10^{-10} s; Ξ^0, 2.9×10^{-10} s (19).

Kaons [25] $K^{\pm}$: m=493.7 MeV/c^2 and pions $\pi^{\pm}$: m=139.6 MeV/c^2, the higher half-life mesons: 1.24×10^{-8} s and 2.6×10^{-8} s respectively.

I.a.1. $K^+[u\bar{s}] \rightarrow \mu^+ + \nu_\mu \wedge$

$$K^+[u\bar{s}] \rightarrow \pi^+[u\bar{d}] + \pi^0[\frac{u\bar{u} - d\bar{d}}{\sqrt{2}}]$$

I.a.2. $K^-[\bar{u}s] \rightarrow \mu^- + \bar{\nu}_\mu \wedge$

$$K^-[\bar{u}s] \rightarrow \pi^-[\bar{u}d] + \pi^0[\frac{u\bar{u} - d\bar{d}}{\sqrt{2}}]$$

I.b.1. $\pi^+[u\bar{d}] \rightarrow \mu^+ + \nu_\mu$, μ^+ antimuon,

I.b.2. $\pi^-[\bar{u}d] \rightarrow \mu^- + \bar{\nu}_\mu$, μ^- muon,

At the lepton Era occurs the annihilation of muons at 9×10^{-5} s, $\mu^{\pm}$: about 200 times the electron mass [21, 26].

I.c.1. Antimuon, 2.2×10^{-6} s and 105.6MeV/c^2: $\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$,

I.c.2. Muon, 2.2×10^{-6} s and 105.6MeV/c^2: $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$,

The muon-antimuon pair's annihilation was shown to be 1% asymmetric [27, 28]. This allows inferring reactions progresses from a primordial CP-violation process, at constant total energy capable to increment the relationship matter/radiation at differences steps of the chronology.

Overall assessment of the sequence allows inferring that the decay of particles produced new ones, gradually more stable. In addition, residual high-energy photons trying to separate the quark-antiquark inside mesons, allows an increment of mesons number.

Integration of Hadrons-Antihadrons reactions

To approach a unitary perspective in terms of Sakharov conditions required solutions on how matter could survive pair annihilation, and to describe conditions that restrict microscopic reversibility.

This reconfinement of the energy allows to enhance of the electroweak CP-asymmetry, reported for the mesons decay [27, 29], as a pathway for the predominance of matter.

Unlike the electron-positron pairs, which are abundant when the temperature is higher than their mass, protons (*stable*) and neutrons appear only at a temperature well below its mass (100 MeV = 10^{12} K), being that mass ≈ 938 MeV corresponds to 10^{13} K.

The residual asymmetry quark-antiquark would restrict the generation of nucleons at 4×10^{-5} s, the generation of antiproton and antineutron. At this time the temperature drops from 10^{12} K to 10^{10} K and density from 10^{14} to 10^4 g/cm^3.

II.a. $n^0 + \gamma \rightarrow p^+ + e^- + \bar{\nu}_e$

II.b. $n^0 + e^+ \rightarrow p^+ + \bar{\nu}_e$

II.c. $p^+ + e^- \rightarrow n^0 + \nu_e$

II.d. $p^+ + \gamma \rightarrow n^0 + e^+ + \nu_e$

The first reaction shows how weak interaction is able to shift the charge of a particle. The neutron/antineutron conversion into proton/antiproton occurs with the release of antineutrinos/neutrinos restricting microscopic reversibility. The antineutrinos emission increase, because as *handedness* [30, 31] carriers, may be produced by the reactions decreasing antimatter.

The free neutron decay, II.a: $n^0 \rightarrow p^+ + e^- + \bar{\nu}_e$, has a half-life of 886 s. But can be activated by interaction with the energy of the environment, according to the sequence:

$$\begin{array}{c} n^0 + e^+ \rightarrow p^+ + \bar{\nu}_e \\ e^- \rightarrow e^- \\ \hline n^0 + e^+ + e^- \rightarrow p^+ + e^- + \bar{\nu}_e \\ \hline n^0 + \gamma \rightarrow p^+ + e^- + \bar{\nu}_e \end{array}$$

This pathway shows as a feedback the modulator effect of energy since the rhythm of gamma photon production controls the decay rate of neutrons.

The following reactions are obtained by charge symmetry and antimatter quality of reactions II [32].

III.a. $\bar{n}^0 + \gamma \rightarrow p^- + e^+ + \nu_e$

III.b. $\bar{n}^0 + e^- \rightarrow p^- + \nu_e$

III.c. $p^- + e^+ \rightarrow \bar{n}^0 + \bar{\nu}_e$

III.d. $p^- + \gamma \rightarrow \bar{n}^0 + e^- + \bar{\nu}_e$

It could be diagram a sequence of reactions allowing a matter survival system:

IV.a $n^0 + p^+ \rightarrow \Lambda^0 + K^0 + p^+$

IV.b $n^0 + p^+ \rightarrow \Lambda^0 + K^+ + n^0$

IV.c $\pi^+ + p^- \rightarrow \Lambda^0 + K^- + \pi^+$

IV.d $\Lambda^0 \rightarrow n^0 + \pi^0$

IV.f $K^+ \rightarrow \pi^+ + \pi^0$

The production of hyperon requires the simultaneous productions of 2 kaons with positive strangeness number [33, 34]. $K^\pm$ kaon decays in 1.24×10^{-8} s, neutral Hyperon $\Lambda^0[uds]$: 1115 MeV, decays in 2.6×10^{-10} s [35, 36, 37]. The production of hyperon requires the simultaneous productions of 2 kaons with positive strangeness number.

Figure 2 shows the sequential integration in of the preceding reactions (II, III, IV) breaking an initial matter-antimatter symmetry (II, III).

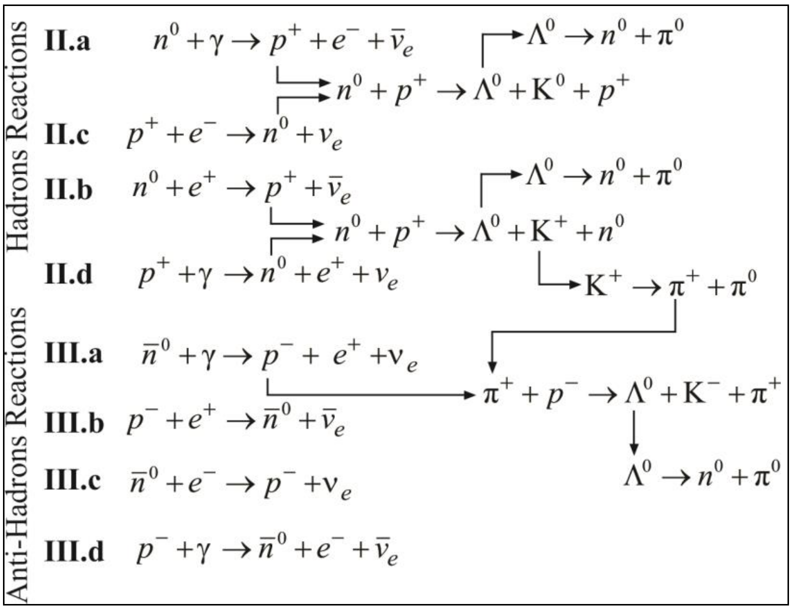


Figure 2: Concatenation of reactive paths*. It is shown that starting from a ratio 1:1 of the reactants: hadrons and antihadrons, by partial integration between their products plus their decay lead to matter predominance.*

The symmetric reactions in the lines **II** and **III** are interconnected. Two protons interact to generate a pion π^+, proton p^+ and a neutron n^0 (**IV.a**). A pion π^+ and antiproton p^- generates K^-, a pion π^+ and neutral hyperon Λ^0 (**IV.b**). The kaon K^- decays into a minus pion π^- and a neutral pion π^0 (**IV.c.**). The Λ^0 hyperon decays into a neutron n^0 and a neutral pion π^0 (**IV.d.**). In order to simplify figure 2, the decay of pions $\pi^\pm$ were not included, but are computed to show a residual: p^+, p^-, 3 e^-, 3 e^+, cancelable by pairs annihilation and matter survival: $4\,n^0 / 2\,\bar{n}^0$, plus: $7\,\nu_e$, $7\,\bar{\nu}_e$.

The disappearance of antinucleons: antiprotons and antineutrons, results in a residual composition of neutrons which by decay also generate protons, and neutrinos, antineutrinos, electrons and positrons.

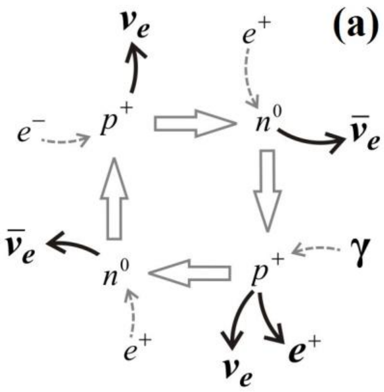
Similar solutions could be to develop pointing to an iterative process which results in a leftover of matter and lead to the exclusion of antimatter.

Table 1: Residual balance of the integration of hadrons and antihadrons reactions. *Since figure 2 also shows the generation of short half-life particles as: neutral kaons, minus kaons, neutral and positive pions it was required a balance. The table tabulates matter-antimatter pair annihilation, generating gamma photons and the disappearance of particles by decay.*

Particle	Antiparticle	Residual balance
Neutron: 4n	Antineutron: $2\,\overline{n}$	2n
Proton: 1 p	Antiproton: $\overline{p}$	2γ
Electron: 2e	Positron: $2\,e^{+}$	2γ
Neutrino: 4v	Antineutrino: $4\,\overline{v}$	Same
Pion: $1\,\pi^{+}$	Antipion: ———	$\pi^{+} \rightarrow \mu^{+} + v_{\mu}$; $\mu^{+} \rightarrow e^{+} + v_{e} + \overline{v}_{\mu}$
Neutral pion: $4\,\pi^{0}$		$\pi^{0} \rightarrow \gamma + \gamma$
Kaon: K^{0} $(\mathrm{K_L}$ or $\mathrm{K_S})$ Difference between the masses of $\mathrm{K_L}$ and $\mathrm{K_S}$: $3.5{\times}10^{-12}$ MeV/c^2		$\mathrm{K_L} \rightarrow \pi^{\pm} + e^{\mp} + v_{e}$; $\mathrm{K_L} \rightarrow \pi^{\pm} + \mu^{\mp} + v_{\mu}$ $\mathrm{K_S} \rightarrow \pi^{+} + \pi^{-}$; $\mathrm{K_S} \rightarrow \pi^{0} + \pi^{0}$
Minus Kaon: K^{-}		$\mathrm{K}^{-} \rightarrow \mu^{-} + v_{\mu}$ (63%); $\mathrm{K}^{-} \rightarrow \pi^{-} + \pi^{0}$ (21%) $\mathrm{K}^{-} \rightarrow \pi^{-} + \pi^{-} + \pi^{+}$; $\mathrm{K}^{-} \rightarrow \pi^{0} + e^{-} + \overline{v}_{e}$

Cycle interaction of hadrons (o antihadrons) to consume gamma radiation and electron-positron

The flow of reactants and products could be organized cyclically. If there is quantitative difference between matter and antimatter, the former could be maximized as a function of the cycle turnover. The relationship between usually accepted total numbers of neutrinos 10^{87} versus number of baryons 10^{78} suggests that the estimate excess of neutrinos may be related to turnover number.



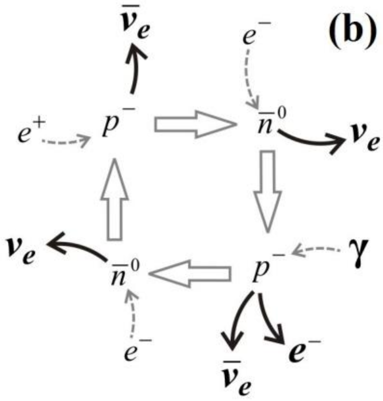


Figure 3: Coupling between reactions allows cycles *a) and b); the balances show that in both cases one electron and one positron are consumed, to absorb gamma radiation, generating two neutrinos and two antineutrinos. Hence, allowing coupling to consume gamma radiation from the residual balance listed in table 1.*

Figure 3 shows that an excess of electrons and positrons, with 10^{-7} s to annihilation, could instead be absorbed as hadrons or antihadrons with a production of neutrinos and antineutrinos. Also the photons could be consumed in quantities much higher than the hadrons presents in the system. The hadrons/antihadrons recycling could support a near stationary state of the ratio: $n_p / n_n = e^{1.29/0.7} \approx 6.25$ [20].

However, starting at 2 s, the free neutron decays to achieve stability through the synthesis of deuterium, 200 s: $n_p / n_n = e^{1.29/0.7} \approx 7.7$ [20].

The annihilation of electron-positron pairs starts at activation temperature 0.511 MeV at 4 s. The pairs are no-longer relativistic and annihilate as photons increasing their temperature: $T = \left(\frac{11}{4}\right)^{1/3} T_v$. The numeric resolution for a Boltzmann equation for annihilation electron-positron shows that the equilibrium lost starts at $T = m_e$ continuing to $T = m_e / 25$, where m_e is electron mass. This process leaves a negligible positron residue as a cold fossil and the electrons resulting from the matter-antimatter interaction. When $T = m_e / 10$, remain 1 per 1000 initial pairs.

Decay of particles and system irreversibility

The figure 1 shows that the regression curve, delimits tendency of the strong and weak forces at about: Fermi 10^{-13} cm (3×10^{-24} s). It is inferred that a particle lacking period, required the surging of electroweak force intermediate vectors bosons $W^{\pm}$, to generate more stable populations of particles. $W^{\pm}$ connectivity 10^{-14} cm (3×10^{-25} s) allows a differentiable interaction, without fragmentation, of polarized helicities at flavor scenarios inside the quarks sea.

Single longitudinal-spin asymmetries violate parity: $\Delta u + \bar{d} \rightarrow W^{+}$, $\Delta d + \bar{u} \rightarrow W^{-}$, and are sensitive to flavor the antimatter plus matter: $\Delta \bar{d} + u \rightarrow W^{+}$, $\Delta \bar{u} + d \rightarrow W^{-}$. This electroweak lepton-antilepton pairs involves γ–Z^0 interference and the production of $W^{\pm}$ [38].

The reaction, $\vec{p} + p \rightarrow W^{+(-)} \rightarrow e^{+(-)} + \nu_e / \bar{\nu}_e$, sensitive to helicity allows either one of the bosons $W^{\pm}$ decay emitting electron or positron. Therefore, the reaction conserves CP-symmetry.

Feynman schemes show color interconversion in the decay neutron$\rightarrow$proton trough the transition $d\rightarrow u$. The diagram of figure 4 shows decay in kinetics and thermodynamics terms [39] to illustrate irreversibility parameters and that the reverse reaction is a differentiable and separate pathway. The very short half-life of $W^{\pm}$ allows that the transition energy dissipate and prevents the mass-action of products. The peaks represent delocalized energy transition at successive steps of the reactions.

The ordinate axis shows the energy release during exothermic conversion $d\rightarrow u$ involves the loss of resting mass 5.6 MeV$\rightarrow$2.3 MeV, which appears as kinetic energy added as inertial mass of the emitted electron.

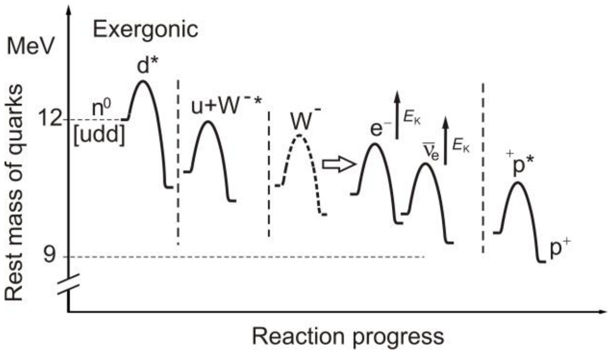


Figure 4: Illustrates the intermediate reaction: $d \rightarrow u + W^{-} \rightarrow u + e^{-} + \bar{\nu}_e$. *The transition states involves the reactions of one quark u plus boson W^{-} which decays in proton, electron and antineutrino. W^{-} confers transition energy and asymmetry. A dotted curve indicates a much shorter half-life of the transition states which in this context prevents the reversibility of products into substrate. The scale is based on the resting mass of two down quarks (d) of 5 MeV each and one up (u) of 2 MeV. (*) Excited or transitions states. The arrow ↑ indicates that the emission of electrons and antineutrinos escape from the system.*

The mediator particles $W^{\pm}$ show recognition of helicity-handedness. Therefore quantity: $n \leftrightarrow \bar{n}$, yield a mirror representation of the disintegration of antineutron: $\bar{n}^0 = p^{-} + e^{+} + \nu_e \therefore \bar{d} \rightarrow \bar{u} + W^{+} \rightarrow \bar{u} + e^{+} + \nu_e$.

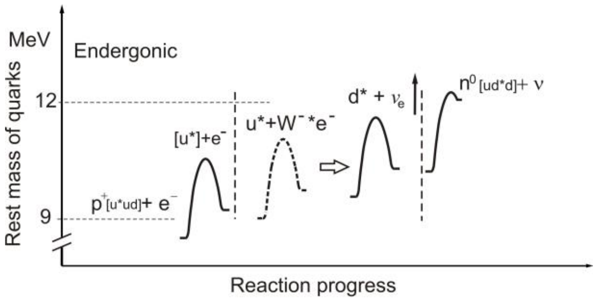


Figure 5: Illustrates the endergonic reaction: $p^{+}+e^{-}\rightarrow n^{0}+v_{e}$, *the combination of a proton and an electron to generate a neutron and a neutrino. The surrounding energy could generate a virtual W^{-} increasing the no-relativistic resting mass of quark u by incorporation of 3 MeV to form a quark d.*

Figure 5 shows a reaction produced in the extreme conditions of the formation of neutron stars [40] and occurs as a differentiable set of reaction with regards to one shows in figure 4. The reaction: $p^{-}+e^{+}\rightarrow \overline{n}^{0}+\overline{v}_{e}$, from antiproton to antineutron, may require the boson W^{+} and could be possible in the primordial quark-hadrons Era. The emergence of neutrinos and their escape generates a non-equilibrium system [41].

Discussion

Activation energy, E_a, is commonly described according to a Gaussian symmetric distribution. The energy released along decay corresponds with the statistical number of particles undergoing disintegration. The time constant **τ** is the "1/e" life (time till only 1/e = about 36.8% remains) rather than the "1/2" life of a radionuclide where 50% remains. Both are related by $N = N_0 \times e^{-t/\tau} = N_0 \times 2^{-t/t_{1/2}}$, N is the number of particles remaining: t=time, N_0=number of initial particles.

The energy value of the difference between the processes of deconfinement-reconfinement allows enthalpy increments which are in opposition to the cooling effects by expansion. This fits an initial quantum state of confined energy as particles, and deconfined by the populations extinction into statistical availability of energy.

The later, allows coupling of events of similar nature in which products became reactants generating new particles within a non-equilibrium system. The difference between the half-lives of particles, functions as a pacemaker, which confers to the primordial chronology its thermodynamics unidirectionality.

Irreversibility of photophosphorylation appears to depend on structural connectivity, allowing an electron carrier with not-uniform distribution of excitation energy (a dipole state) to transfer an electron to the subsequent carrier but not in reverse [42, 43]. The coordinative state of the metal within the carrier functions as a high energy intermediate state. Coupling allows transfer of the electron and excitation energy (a change of dipole state) to the next electron carrier [44, 45, 46]. The phenomena may allow that photon-dependent excitation energy to induce quantum entanglement by the sharing of electrons between carriers [47, 48, 49, 50]. When the entanglement ends, the electrons separate in opposite direction, which prevents reversal of reactions.

A solution to the problem of relating causal connectivity and the homogeneity of the distribution of matter-energy in the all-map of CMB was solved by the Inflationary theory [51, 52, 53]. It has been highlighted the highly improbable conditions required to obtain the parameter of expansion from the initial state of Inflation [54]. Moreover entropy projections do not fit [55]. Objections could be compatibilized, if other forms of connectivity could be integrated into a more inclusive origin of the expansion parameter. These may be: pressure [56], half-life of the populations of particles, etc. The latter, is a statistical defined parameter that allows synchronizing global events, without ad-hoc causal connectivity.

The interaction of several thermal reservoirs in terms of energy fluxes [57] could also be used to describe so-called open systems. The latter, are required for cosmic non-equilibrium flows of energy, between phases of generating a dissipative thermodynamics structures and the dissipative phases themselves.

These ones are also discernible in a structuring phase of matter-energy forming an accretion disk and its dissipative structure phase as a radiating star. The flux of kinetic energy, scaled as temperature, when operating like an open system conforms a non-equilibrium thermodynamic continuum, which manifest itself as a chronology of events.

Particles accelerators have been reaching higher and higher temperatures and obtaining for each temperature range, specific distinct population of particles. Since these results are reproducible, appears to represent quantum parameters that show restricted uncertainty, in terms of temperature control of particle evolutionary parameters. Hence, in the primordial cosmos, could be expected that the contribution of particle decay to support a synchronized global temperature, is a parameter of the arrow of time.

Conclusions

Particle physics suggested relating the increment in half-life as a tendency to show non-equilibrium self-organization patterns. Concatenating reactions, allow pathways for energy transfer, driving the predominance of matter and its stabilization as hadrons. This process was based on a dissipative state phase of a thermodynamic structure releasing confined energy. This mechanism allows the thermodynamics of openness to function within a self-contained Universe.

Half-life is a statistical process in which the individual particles share a decay curve, synchronizing events, even when not casualty connected by *c*. This mechanism does not require the extreme precision, involved in the projections of the expansion parameter. Thus, allowing the preservation of flatness within the Universe [54, 58] as commensurable with a quantum integrated dissipative continuum. This one could be an operator of a primordial selection principle.

A finding of changes in the temperature of the intergalactic gas, as a fossil record of temperature of the early Universe, was found not to fit the predictions of the expansion-parameter [59]. This finding indicates the need to integrate other processes like: half-life of the populations of particles, etc., to allow a better fitting between theory and observations.

Reaction specificity and half-life could synchronize into a chronology. This one, describes quanta evolution that because could be integrated in a system that operate as a thermodynamically open could became manifest as a continuum.

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