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Correspondence Principle for Empirical Equations in Terms of the Cosmic Microwave Background Temperature with Solid-State Ionics

Tomofumi Miyashita

Miyashita Clinic, Osaka, Japan
Email: tom_miya@ballade.plala.or.jp

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Abstract

Previously, we presented several empirical equations using the cosmic microwave background (CMB) temperature that were mathematically connected. Next, we proposed an empirical equation for the fine-structure constant. Considering the compatibility among these empirical equations, the CMB temperature (T_c) and gravitational constant (G) were calculated to be 2.726312 K and 6.673778 × 10^{-11} $m^3 \cdot kg^{-1} \cdot s^{-2}$, respectively. Every equation can be explained in terms of the Compton length of an electron (λ_e), the Compton length of a proton (λ_p) and α. However, these equations are difficult to follow. Using the correspondence principle with the thermodynamic principles in solid-state ionics, we propose a canonical ensemble to explain these equations in this report. For this purpose, we show that every equation can be explained in terms of Avogadro's number and the number of electrons in 1 C.

Keywords

Temperature of the Cosmic Microwave Background

1. Introduction

The symbol list is shown in Section 2. We discovered Equations (1), (2) and (3) [1] [2] [3] expressed in terms of the cosmic microwave background (CMB) temperature. We then attempted to reduce their errors by modifying the values of 4.5 and π [4] [5].

$$\frac{Gm_p^2}{hc} = \frac{4.5}{2} \times \frac{kT_c}{1kg \times c^2} \quad (1)$$

$$\frac{Gm_p^2}{\left(\frac{e^2}{4\pi\varepsilon_0}\right)} = \frac{4.5}{2\pi} \times \frac{m_e}{e} \times hc \tag{2}$$

$$\frac{m_e c^2}{e} \times \left(\frac{e^2}{4\pi\varepsilon_0}\right) = \pi \times kT_c \tag{3}$$

Next, we discovered an empirical equation for the fine-structure constant [6].

$$137.0359991 = 136.0113077 + \frac{1}{3 \times 13.5} + 1 \tag{4}$$

$$13.5 \times 136.0113077 = 1836.152654 = \frac{m_p}{m_e} \tag{5}$$

Equations (4) and (5) may be related to the transference number [7] [8]. Next, we proposed the following values as deviations of the values of 9/2 and π [8] [9].

$$3.13201(\mathrm{V} \cdot \mathrm{m}) = \frac{\left(\frac{m_p}{m_e} + \frac{4}{3}\right) m_e c^2}{ec} \tag{6}$$

$$4.48852\left(\frac{1}{\mathrm{A} \cdot \mathrm{m}}\right) = \frac{q_m c}{\left(\frac{m_p}{m_e} + \frac{4}{3}\right) m_p c^2} \tag{7}$$

Then, $\left(\frac{m_p}{m_e} + \frac{4}{3}\right)$ has units of $\left(\frac{\mathrm{m}^2}{\mathrm{s}}\right)$. Using the redefinition of Avogadro's number and the Faraday constant, these values can be adjusted back to 9/2 and π [9].

$$\pi(\mathrm{V} \cdot \mathrm{m}) = \frac{\left(\frac{m_p}{m_e} + \frac{4}{3}\right) m_{e\_new} c^2}{e_{new} c} \tag{8}$$

$$4.5\left(\frac{1}{\mathrm{A} \cdot \mathrm{m}}\right) = \frac{q_{m\_new} c}{\left(\frac{m_p}{m_e} + \frac{4}{3}\right) m_{p\_new} c^2} \tag{9}$$

Furthermore, every equation can be explained in terms of the Compton length of an electron (λ_e), the Compton length of a proton (λ_p) and α [10]. However, these equations are difficult to follow. Our purpose in this report is to consider the physical meanings. Using the correspondence principle with the thermodynamic principles in solid-state ionics, we propose a canonical ensemble to explain these equations. For this purpose, we show that every equation can be explained in terms of Avogadro's number and the number of electrons in 1 C. The remainder of this paper is organized as follows. In Section 2, we present the list of symbols used in our derivations. In Section 3, we discuss the purpose of this report. Using the correspondence principle with the thermodynamic principles in solid-state ionics, we try to show the canonical ensemble to explain these equations. In Section 4, we propose several equations that are functions of Avogadro's number and the number of electrons in 1 C. In Section 5, using these equations, we explain our main equations. The remaining problems are discussed. In Section 6, our conclusions are described.

2. Symbol List

2.1. MKSA Units (These Values Were Obtained from Wikipedia)

G: gravitational constant: 6.6743 × 10^{-11} ($m^3 \cdot kg^{-1} \cdot s^{-2}$)
(we use the compensated value 6.673778 × 10^{-11} in this report)
T_c: CMB temperature: 2.72548 (K)
(we use the compensated value 2.726312 K in this report)
k: Boltzmann constant: 1.380649 × 10^{-23} ($J \cdot K^{-1}$)
c: speed of light: 299792458 (m/s)
h: Planck constant: 6.62607015 × 10^{-34} (J s)
ε_0: electric constant: 8.8541878128 × 10^{-12} ($N \cdot m^2 \cdot C^{-2}$)
μ_0: magnetic constant: 1.25663706212 × 10^{-6} ($N \cdot A^{-2}$)
e: electric charge of one electron: −1.602176634 × 10^{-19} (C)
q_m: magnetic charge of one magnetic monopole: 4.13566770 × 10^{-15} (Wb)
(this value is only a theoretical value, $q_m = h/e$)
m_p: rest mass of a proton: 1.6726219059 × 10^{-27} (kg)
(we use the compensated value 1.672621923 × 10^{-27} kg in this report)
m_e: rest mass of an electron: 9.1093837 × 10^{-31} (kg)
Rk: von Klitzing constant: 25812.80745 (Ω)
Z_0: wave impedance in free space: 376.730313668 (Ω)
α: fine-structure constant: 1/137.035999081
λ_p: Compton wavelength of a proton: 1.32141 × 10^{-15} (m)
λ_e: Compton wavelength of an electron: 2.4263102367 × 10^{-12} (m)

2.2. Symbol List after Redefinition

$$e_{new} = e \times \frac{4.48852}{4.5} = 1.59809\text{E}-19\left(\text{C}\right) \tag{10}$$

$$q_{m\_new} = q_m \times \frac{\pi}{3.13201} = 4.14832\text{E}-15\left(\text{Wb}\right) \tag{11}$$

$$h_{new} = e_{new} \times q_{m\_new} = h \times \frac{4.48852}{4.5} \times \frac{\pi}{3.13201} = 6.62938\text{E}-34\left(\text{J}\cdot\text{s}\right) \tag{12}$$

$$Rk_{\_new} = \frac{q_{m\_new}}{e_{\_new}} = Rk \times \frac{4.5}{4.48852} \times \frac{\pi}{3.13201} = 25958.0\left(\Omega\right) \tag{13}$$

We observe that Equation (13) can be rewritten as follows.

$$Rk_{new} = 4.5\left(\frac{1}{\text{A}\cdot\text{m}}\right) \times \pi\left(\text{V}\cdot\text{m}\right) \times \frac{m_p}{m_e} = 25957.9966027\left(\Omega\right) \tag{14}$$

$$Z_{0\_new} = \alpha \times \frac{2h_{new}}{e_{new}^2} = 2\alpha \times Rk_{new} = Z_0 \times \frac{4.5}{4.48852} \times \frac{\pi}{3.13201} = 378.849\left(\Omega\right) \tag{15}$$

We observe that Equation (15) can be rewritten as follows.

$$Z_{0\_new} = 4.5\left(\frac{1}{\mathrm{A}\cdot\mathrm{m}}\right)\times\pi\left(\mathrm{V}\cdot\mathrm{m}\right)\times 2\alpha\times\frac{m_p}{m_e} = 378.8493064\left(\Omega\right) \tag{16}$$

$$\mu_{0\_new} = \frac{Z_{0\_new}}{c} = \mu_0\times\frac{4.5}{4.48852}\times\frac{\pi}{3.13201} = 1.26371\mathrm{E}-06\left(\mathrm{N}\cdot\mathrm{A}^{-2}\right) \tag{17}$$

$$\varepsilon_{0\_new} = \frac{1}{Z_{0\_new}\times c} = \varepsilon_0\times\frac{4.48852}{4.5}\times\frac{3.13201}{\pi} = 8.80466\mathrm{E}-12\left(\mathrm{F}\cdot\mathrm{m}^{-1}\right) \tag{18}$$

$$c_{\_new} = \frac{1}{\sqrt{\varepsilon_{0\_new}\mu_{0\_new}}} = \frac{1}{\sqrt{\varepsilon_0\mu_0}} = c = 299792458\left(\mathrm{m}\cdot\mathrm{s}^{-1}\right) \tag{19}$$

The Compton wavelength (λ) is as follows.

$$\lambda = \frac{h}{mc} \tag{20}$$

This value (λ) should be unchanged since the unit for 1 m is unchanged. However, in Equation (12), the Planck constant is changed. Therefore, the units for the masses of one electron and one proton should be redefined.

$$m_{e\_new} = \frac{4.48852}{4.5}\times\frac{\pi}{3.13201}\times m_e = 9.11394\mathrm{E}-31\left(\mathrm{kg}\right) \tag{21}$$

$$m_{p\_new} = \frac{4.48852}{4.5}\times\frac{\pi}{3.13201}\times m_p = 1.67346\mathrm{E}-27\left(\mathrm{kg}\right) \tag{22}$$

From the dimensional analysis in the previous report [9],

$$kT_{c\_new} = \frac{4.48852}{4.5}\times\frac{\pi}{3.13201}\times kT_c = 3.7659625\mathrm{E}-23\left(\mathrm{J}\right) \tag{23}$$

Next, to simplify the calculation, G_N is defined as follows.

$$G_N = G\times 1\,\mathrm{kg}\left(\mathrm{m}^3\cdot\mathrm{s}^{-2}\right) = 6.673778\mathrm{E}-11\left(\mathrm{m}^3\cdot\mathrm{s}^{-2}\right) \tag{24}$$

Now, we hope that the value of G_N remains unchanged. However, G_N should change [9].

$$G_{N\_new} = G_N\times\frac{4.5}{4.48852}\left(\mathrm{m}^3\cdot\mathrm{s}^{-2}\right) = 6.69084770\mathrm{E}-11\left(\mathrm{m}^3\cdot\mathrm{s}^{-2}\right) \tag{25}$$

2.3. Symbol List in Terms of the Compton Length of an Electron (λ_e), the Compton Length of a Proton (λ_p) and α

The following equations were proposed in a previous report [10].

$$m_{e\_new}c^2\times\left(\frac{m_p}{m_e}+\frac{4}{3}\right)^2\left(\frac{\mathrm{J}\cdot\mathrm{m}^4}{\mathrm{s}^2}\right) = \frac{\pi}{4.5}\left(\mathrm{V}\cdot\mathrm{m}\cdot\mathrm{A}\cdot\mathrm{m} = \frac{\mathrm{J}\cdot\mathrm{m}^2}{\mathrm{s}}\right)\times\lambda_p c\left(\frac{\mathrm{m}^2}{\mathrm{s}}\right) = 2.76564\mathrm{E}-07\left(\frac{\mathrm{J}\cdot\mathrm{m}^4}{\mathrm{s}^2}\right) = \text{constant} \tag{26}$$

$$e_{new}c\times\left(\frac{m_p}{m_e}+\frac{4}{3}\right)\left(\frac{\mathrm{A}\cdot\mathrm{m}^3}{\mathrm{s}}\right) = \frac{1}{4.5}\left(\mathrm{A}\cdot\mathrm{m}\right)\times\lambda_p c\left(\frac{\mathrm{m}^2}{\mathrm{s}}\right) = 8.80330\mathrm{E}-08\left(\frac{\mathrm{A}\cdot\mathrm{m}^3}{\mathrm{s}}\right) = \text{constant} \tag{27}$$

$$m_{p\_new}c^2 \times \left(\frac{m_p}{m_e} + \frac{4}{3}\right)^2 \left(\frac{\mathrm{J \cdot m^4}}{\mathrm{s^2}}\right) = \frac{\pi}{4.5}\left(\frac{\mathrm{J \cdot m^2}}{\mathrm{s}}\right) \times \lambda_e c \left(\frac{\mathrm{m^2}}{\mathrm{s}}\right) = 5.07814\mathrm{E}-04 \left(\frac{\mathrm{J \cdot m^4}}{\mathrm{s^2}}\right) = \text{constant} \tag{28}$$

$$q_{m\_new}c \times \left(\frac{m_p}{m_e} + \frac{4}{3}\right)\left(\frac{\mathrm{V \cdot m^3}}{\mathrm{s}}\right) = \pi(\mathrm{V \cdot m}) \times \lambda_e c \left(\frac{\mathrm{m^2}}{\mathrm{s}}\right) = 2.28516\mathrm{E}-03 \left(\frac{\mathrm{V \cdot m^3}}{\mathrm{s}}\right) = \text{constant} \tag{29}$$

$$kT_{c\_new} \times \frac{2\pi}{\alpha} \times \left(\frac{m_p}{m_e} + \frac{4}{3}\right)^3 \left(\frac{\mathrm{J \cdot m^6}}{\mathrm{s^3}}\right) = \frac{\pi}{4.5}\left(\frac{\mathrm{J \cdot m^2}}{\mathrm{s}}\right) \times \lambda_p c \times \lambda_e c = 2.011697\mathrm{E}-10 \left(\frac{\mathrm{J \cdot m^6}}{\mathrm{s^3}}\right) = \text{constant} \tag{30}$$

$$G_{N\_new}\left(\frac{\mathrm{m^3}}{\mathrm{s^2}}\right) \times \left(\frac{m_p}{m_e} + \frac{4}{3}\right)\left(\frac{\mathrm{m^2}}{\mathrm{s}}\right) = (\lambda_p c)^2 \left(\frac{\mathrm{m^4}}{\mathrm{s^2}}\right) \times c\left(\frac{\mathrm{m}}{\mathrm{s}}\right) \times \frac{9\alpha}{8\pi} = 1.22943\mathrm{E}-07 \left(\frac{\mathrm{m^5}}{\mathrm{s^3}}\right) = \text{constant} \tag{31}$$

3. Purpose

The purpose of this report is to explain the empirical equations through the correspondence principle with thermodynamic principles in solid-state ionics.

3.1. Introduction to the Thermodynamic Principles in Solid-State Ionics

A solid oxide fuel cell (SOFC) directly converts the chemical energy of a fuel gas, such as hydrogen or methane, into electrical energy. A solid oxide film is used as the electrolyte, where the main carriers are oxygen ions and the minor carriers are electrons. When samarium-doped ceria (SDC) electrolytes are used in SOFCs, the open-circuit voltage (OCV = 0.80 V at 1073 K) becomes lower than the Nernst voltage (V_{th} = 1.15 V at 1073 K), which is obtained when using yttria-stabilized zirconia (YSZ) electrolytes. The canonical ensemble is shown in Figure 1.

Then, we noticed the following equations, which can be explained by Jarzynski's equality [11] [12].

$$OCV = V_{th} - (1 - t_{ion}) \times \frac{E_a}{2e} \tag{32}$$

where t_{ion} is the transference number of ions near the anode. E_a is the activation energy for ions. When SDC electrolytes are used, t_{ion} near the anode is 0. E_a is 0.7 eV. Thus,

$$OCV = 1.15\ \mathrm{V} - \frac{0.7\ \mathrm{eV}}{2e} = 0.80\ \mathrm{V} \tag{33}$$

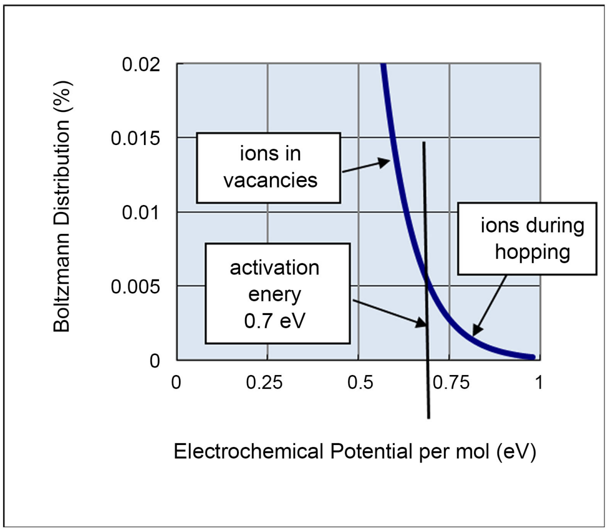

Figure 1. Canonical ensemble in SOFCs.

To explain Equation (32) by the electrochemical method, the following equations are proposed.

$$\eta_i = \mu_i + z_i F \varphi \quad (34)$$

$$\eta_{i\_hopping} = \eta_{i\_vacancies} \quad (35)$$

$$\mu_{i\_hopping} = \mu_{i\_vacancies} + N_A E_a \quad (36)$$

$$Z_i F \phi_{hopping} = Z_i F \phi_{vacancies} - N_A E_a \quad (37)$$

where η_i, μ_i, Z_i, F, φ and N_A are the electrochemical potential energy of ions, the chemical potential energy of ions, valence of species i, the Faraday constant, the electrical potential and Avogadro's number. $\eta_{i\_hopping}$, $\eta_{i\_vacancies}$, $\mu_{i\_hopping}$, $\mu_{i\_vacancies}$, $\varphi_{hopping}$, and $\varphi_{vacancies}$ are the electrochemical potential energy of hopping ions, electrochemical potential energy of ions in vacancies, chemical potential of hopping ions, chemical potential of ions in vacancies, electrical potential of hopping ions, and electrical potential of ions in vacancies, respectively.

From Equation (37),

$$\varphi_{hopping} = \varphi_{vacancies} + \frac{E_a}{2e} \quad (38)$$

This electrical potential is neutralized by free electrons and dissipated. Therefore, the energy loss due to dissipation ($E_{loss\_dissipation}$) is

$$E_{loss\_dissipation} = \left(1 - t_{ion}\right) \times E_a \quad (39)$$

3.2. Correspondence Principle with the Thermodynamic Principles in Solid-State Ionics

The fine structure constant is the interaction coefficient. Thus,

$$\alpha = 1 - t_{ion} \quad (40)$$

We thought that kT_c is related to the energy loss due to dissipation. From Equations (39) and (40),

$$E_{a\_space} = \frac{E_{loss\_dissipation}}{1-t_{ion}} = \frac{kT_c}{\alpha} = 0.03219\ (\text{eV}) \tag{41}$$

where E_{a_space} is the activation energy of the space. The canonical ensemble from the correspondence principle is shown in **Figure 2**. From Equations (36) and (41),

$$\frac{\mu_{i\_vacancies}}{N_A} = \frac{\mu_{i\_hopping}}{N_A} - \frac{kT_{c\_new}}{\alpha} > 0 \tag{42}$$

Therefore, the minimum mass (M_{min}), which may be related to our main Equation (2), is

$$M_{min} = \frac{E_{space}}{c^2} = \frac{kT_c}{\alpha \times c^2} = 5.739210\text{E}-38\left(\text{kg}\right) \tag{43}$$

3.3. Our Image for the Proposed Canonical Ensemble from the Correspondence Principle

From the correspondence principle, there should be inevitable dissipations from the wave situation to the particle situations. In the area of solid-state ionics, the dissipations recover immediately after ion hopping.

Gravity is not directly related to the dissipation energy and is related to the activation energy (kT_c/α). In the area of solid-state ionics, the activation energy becomes small when the vacancies increase. From the correspondence principle, a large mass has a smaller activation energy due to the increase in the number of vacancies. Then, one large mass has a smaller dissipation energy than the sum of dissipation energies from the two separated masses.

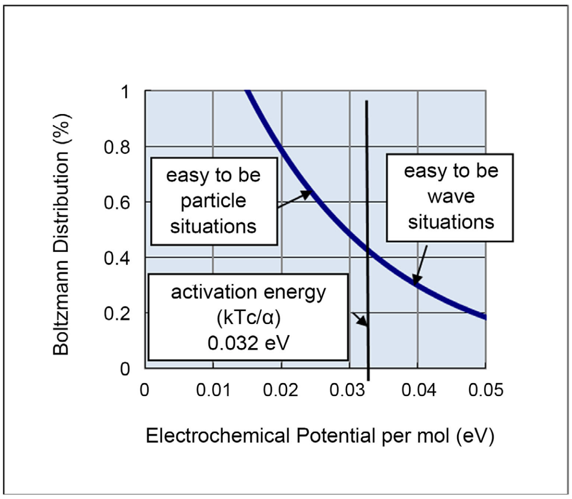

Figure 2. Canonical ensemble from the correspondence principle.

4. Methods

4.1. Introduction to Avogadro's Number and the Number of Electrons in 1 C

Avogadro's number is $6.02214076 \times 10^{23}$. This value is related to the following value.

$$N_A = \frac{1g}{m_p} = 5.978637\text{E}+23 \tag{44}$$

Using the redefined values, the new definition of Avogadro's number is

$$N_{A\_new} = \frac{1kg_{new}}{m_{p\_new}} = 5.975649\text{E}+26 \tag{45}$$

From Equations (44) and (45),

$$N_{A\_new} = N_A \times \frac{4.5}{4.488520} \times \frac{3.132011}{\pi} \times 1000 \tag{46}$$

The number of electrons in 1 C (N_e) is

$$N_e = \frac{1C}{e} = 6.241509\text{E}+18 \tag{47}$$

Using the redefined values,

$$N_{e\_new} = \frac{1C_{new}}{e_{new}} = 6.257473\text{E}+18 \tag{48}$$

From Equations (47) and (48),

$$N_{e\_new} = N_e \times \frac{4.5}{4.488520} \tag{49}$$

4.2. List of Important Equations

We propose the following 7 equations using N_{A_new} (5.975649.E+26), N_{e_new} (6.257473E+18), c and α.

$$m_{p\_new} = \frac{1}{N_{A\_new}} \tag{50}$$

$$m_{e\_new} = \frac{m_e/m_p}{N_{A\_new}} \tag{51}$$

Here, m_p/m_e (=1836.1526) is not changed after redefinition.

$$e_{new} = \frac{1}{N_{e\_new}} \tag{52}$$

$$q_{m\_new} = \frac{4.5\pi \times m_p/m_e}{N_{e\_new}} = 4.148319\text{E}-15 \tag{53}$$

$$h_{new} = \frac{4.5\pi \times m_p/m_e}{\left(N_{e\_new}\right)^2} = 6.62938382\text{E}-34 \tag{54}$$

$$kT_{c\_new} = \frac{4.5 \times c^3 \times \alpha}{2\pi \times N_{e\_new} \times N_{A\_new}} = 3.7659625\text{E}-23 \tag{55}$$

$$G_{N\_new} = \frac{4.5^3 \times m_p/m_e \times N_{A\_new} \times c^2 \times \alpha}{4 \times N_{e\_new}^3} = 6.6908477\text{E}-11 \tag{56}$$

5. Results

From this section onward, the values used are those obtained after redefinition. Strictly speaking, m_e should therefore be written as m_{e_new}. However, we omit the subscript "*new*" to avoid unnecessarily notational complexity.

5.1. Explanation of Our First Equation

For convenience, Equation (1) is rewritten as follows.

$$\frac{Gm_p^2}{hc} = \frac{4.5}{2} \times \frac{kT_c}{1kg \times c^2} \tag{57}$$

So,

$$\frac{G_N m_p^2}{hc} = \frac{4.5}{2} \times \frac{kT_c}{c^2} \tag{58}$$

The left side in Equation (58) is rewritten as

$$\frac{G_N m_p^2}{hc} = \frac{\dfrac{4.5^3 \times m_p / m_e \times 5.975649\text{E}+26 \times (299792458)^2 \times \alpha}{4 \times (6.257473\text{E}+18)^3 \times (5.975649\text{E}+26)^2}}{\dfrac{4.5\pi \times m_p / m_e}{(6.257473\text{E}+18)^2} \times 299792458} \tag{59}$$

Therefore,

$$\frac{G_N m_p^2}{hc} = \frac{4.5^2 \times 299792458 \times \alpha}{4\pi \times 6.257473\text{E}+18 \times 5.975649\text{E}+26} \tag{60}$$

The right side in Equation (58) is

$$\frac{4.5}{2} \times \frac{kT_c}{c^2} = \frac{4.5}{2} \times \frac{4.5 \times (299792458)^3 \times \alpha}{2\pi \times 6.257473\text{E}+18 \times 5.975649\text{E}+26 \times (299792458)^2} \tag{61}$$

Therefore,

$$\frac{Gm_p^2}{hc} = \frac{4.5}{2} \times \frac{kT_c}{1kg \times c^2} \tag{62}$$

5.2. Explanation of Our Second Equation

For convenience, Equation (2) is rewritten as follows.

$$\frac{Gm_p^2}{\left(\dfrac{e^2}{4\pi\varepsilon_0}\right)} = \frac{4.5}{2\pi} \times \frac{m_e}{e} \times hc \tag{63}$$

Therefore,

$$\frac{G_N m_p^2}{hc} = \frac{4.5}{2\pi} \times \frac{m_e}{e} \times \left(\frac{e^2}{4\pi\varepsilon_0}\right) \tag{64}$$

According to Equation (60), the left side in Equation (63) is

$$\frac{G_N m_p^2}{hc} = \frac{4.5^2 \times 299792458 \times \alpha}{4\pi \times 6.257473\text{E}+18 \times 5.975649\text{E}+26} \tag{65}$$

Regarding the right side in Equation (63),

$$\frac{4.5}{2\pi}\times\frac{m_e}{e}\times\left(\frac{e^2}{4\pi\varepsilon_0}\right)=\frac{4.5}{2\pi}\times m_e\times\frac{ec}{4\pi\varepsilon_0 c}=\frac{4.5}{2\pi}\times m_e\times\frac{ec}{4\pi}\times Z_0 \tag{66}$$

For convenience, Equation (16) is rewritten as follows.

$$Z_0=9\pi\times\alpha\times\frac{m_p}{m_e} \tag{67}$$

Therefore,

$$\frac{4.5}{2\pi}\times\frac{m_e}{e}\times\left(\frac{e^2}{4\pi\varepsilon_0}\right)=\frac{4.5}{2\pi}\times m_e\times\frac{ec}{4\pi}\times 9\pi\times\alpha\times\frac{m_p}{m_e}=\frac{4.5}{8\pi}\times 9m_p\times ec\times\alpha \tag{68}$$

Hence,

$$\frac{4.5}{8\pi}\times 9\alpha\times ec\times m_p=\frac{4.5^2}{4\pi}\times\alpha\times\frac{299792458}{6.257473\text{E}+18\times 5.975649\text{E}+26} \tag{69}$$

From Equations (65) and (69), we obtain

$$\frac{G_N m_p^2}{hc}=\frac{4.5}{2\pi}\times\frac{m_e}{e}\times\left(\frac{e^2}{4\pi\varepsilon_0}\right) \tag{70}$$

Therefore,

$$\frac{Gm_p^2}{\left(\frac{e^2}{4\pi\varepsilon_0}\right)}=\frac{4.5}{2\pi}\times\frac{m_e}{e}\times hc \tag{71}$$

5.3. Explanation of Our Third Equation

For convenience, Equation (3) is rewritten as follows.

$$\frac{m_e c^2}{e}\times\left(\frac{e^2}{4\pi\varepsilon_0}\right)=\pi\times kT_c \tag{72}$$

The left side in Equation (72) is

$$m_e c^2\times\frac{e}{4\pi\varepsilon_0}=m_e c^2\times\frac{ec}{4\pi\varepsilon_0 c}=m_e c^2\times\frac{ec}{4\pi}\times Z_0 \tag{73}$$

Therefore, using Equation (16), we obtain

$$m_e c^2\times\frac{ec}{4\pi}\times Z_0=m_e c^2\times\frac{ec}{4\pi}\times 9\pi\times\alpha\times\frac{m_p}{m_e}=m_p c^2\times ec\times\frac{9}{4}\alpha \tag{74}$$

Therefore,

$$m_p c^2\times ec\times\frac{9}{4}\alpha=\frac{9}{4}\alpha\times\frac{(299792458)^3}{5.975649\text{E}+26\times 6.257473\text{E}+18} \tag{75}$$

The right side in Equation (72) is

$$\pi\times kT_c=\frac{4.5\times(299792458)^3\times\alpha}{2\times 6.257473\text{E}+18\times 5.975649\text{E}+26} \tag{76}$$

From Equations (75) and (76), we obtain the following equation.

$$m_e c^2 \times \frac{e}{4\pi\varepsilon_0} = \pi \times kT_c \tag{77}$$

5.4. Compatibility between Two Lists

The compatibility between the list shown in Section 2.3 and the list shown in Section 4.2 is explained in this section. The Faraday constant is

$$\begin{aligned} 1F_{new} &= e_{new} \times N_{A\_new} \left(\frac{\mathrm{C}}{\mathrm{mol}}\right) = \frac{5.97564907\mathrm{E}+26}{6.25747328\mathrm{E}+18}\left(\frac{\mathrm{C}}{\mathrm{mol}}\right) \\ &= 9.5496198\mathrm{E}+07\left(\frac{\mathrm{C}}{\mathrm{mol}}\right) \end{aligned} \tag{78}$$

This value is rewritten as follows:

$$9.5496198\mathrm{E}+07 = \frac{c}{\pi} \times \left(\frac{m_p}{m_e} + \frac{4}{3}\right) \times \frac{m_e}{m_p} = \frac{299792458 \times 1837.485988}{\pi \times 1836.152654} \tag{79}$$

Next,

$$\frac{\pi ec}{m_e c^2} = \frac{\pi \times 5.97564907\mathrm{E}+26 \times 1836.152654}{6.25747328\mathrm{E}+18 \times 299792458} = 1837.485988 = \left(\frac{m_p}{m_e} + \frac{4}{3}\right) \tag{80}$$

$$\frac{q_m c}{4.5 m_p c^2} = \frac{Rk \times 5.97564907\mathrm{E}+26}{4.5 \times 6.25747328\mathrm{E}+18 \times 299792458} = 1837.485988 = \left(\frac{m_p}{m_e} + \frac{4}{3}\right) \tag{81}$$

Consequently, Equation (82) is related to the Faraday constant.

$$\left(\frac{m_p}{m_e} + \frac{4}{3}\right) = \frac{q_m c}{4.5 m_p c^2} = \frac{\pi ec}{m_e c^2} \tag{82}$$

5.5. The Problem of the Number of Real Microstates

The canonical ensemble is related with Boltzmann's entropy formula as follows.

$$S = k \ln W$$

where S and W are the entropy and the number of real microstates, respectively. The main problem is that we cannot calculate W. Strictly speaking, we need years to do it. However, the hints are shown in this section.

5.5.1. More Suitable Expression for G and kT_c

Equations (30) and (55) for kT_c are very complex. Equations (31) and (56) for G are very complex, too. We discovered a more suitable expression. For kT_c, there are the following two equations.

$$kT_c = \frac{\alpha}{2\pi} \times \frac{1}{\pi}\left(\frac{1}{\mathrm{V}\cdot\mathrm{m}}\right) \times q_m c \times m_e c^2 = 3.76596254\mathrm{E}-23 \tag{83}$$

$$kT_c = \frac{\alpha}{2\pi} \times 4.5\left(\frac{1}{\mathrm{A}\cdot\mathrm{m}}\right) \times ec \times m_p c^2 = 3.76596254\mathrm{E}-23 \tag{84}$$

In Equations (83) and (84), 2π is dimensionless. For G, there are the following two equations.

$$G_N = \frac{\alpha c}{4\pi} \times (4.5 \times ec)^2 \times \frac{q_m c}{m_p c^2} = 6.69084770\mathrm{E}-11 \tag{85}$$

$$G_N = \frac{\alpha c}{4\pi} \times (4.5 \times ec)^3 \times \frac{\pi}{m_e c^2} = 6.69084770\text{E}-11 \tag{86}$$

In Equations (85) and (86), 4π is dimensionless. In a previous report [10], there seemed to be two definitions for 1 kg. However, the definition of 1 kg is only one. The definition of G_N should be more complex.

5.5.2. Schwarzschild Radius of Electrons

We calculated the Schwarzschild radius of electrons (r_g) using redefined values.

$$r_g(\text{m}) = \frac{2G_N \times m_e}{1kg \times c^2} = \frac{6.690848\text{E}-11 \times 9.113939\text{E}-31}{299792458^2} = 1.356988\text{E}-57(\text{m}) \tag{87}$$

Then, using Equations (51) and (56),

$$r_g(\text{m}) = \frac{2G_N \times m_e}{1kg \times c^2} = \frac{4.5^3 \times \alpha}{2 \times (6.257473\text{E}+18)^3} = 1.356988\text{E}-57(\text{m}) \tag{88}$$

So, using Equation 52,

$$r_g(\text{m}) = \frac{\alpha}{2} \times (4.5 \times e)^3 = 1.356988\text{E}-57 \tag{89}$$

We hope that these equations will be the solution for the black hole entropy.

5.5.3. Unexplained Issues

Regarding the protons, the positive charge and the mass ratio with the electrons are unexplained, which will be explained in a future report.

6. Conclusions

We tried to explain empirical equations by using the correspondence principle with the thermodynamic principles in solid-state ionics. We proposed a canonical ensemble from the correspondence principle. We proposed the existence of a minimum mass of 5.7420807E-38 kg. Our images for kT_c and G are explained. We showed that every equation can be explained in terms of Avogadro's number (N_{A_new}) and the number (N_{e_new}) of electrons in 1 C.

$$m_{p\_new} = \frac{1}{N_{A\_new}} \tag{90}$$

$$m_{e\_new} = \frac{m_e/m_p}{N_{A\_new}} \tag{91}$$

$$e_{new} = \frac{1}{N_{e\_new}} \tag{92}$$

$$q_{m\_new} = \frac{4.5\pi \times m_p/m_e}{N_{e\_new}} = 4.148319\text{E}-15 \tag{93}$$

$$h_{new} = \frac{4.5\pi \times m_p/m_e}{(N_{e\_new})^2} = 6.62938382\text{E}-34 \tag{94}$$

$$kT_{c\_new} = \frac{4.5 \times c^3 \times \alpha}{2\pi \times N_{e\_new} \times N_{A\_new}} = 3.7659625\text{E}-23 \tag{95}$$

$$G_{N\_new} = \frac{4.5^3 \times m_p / m_e \times N_{A\_new} \times c^2 \times \alpha}{4 \times N_{e\_new}^3} = 6.6908477\text{E}-11 \quad (96)$$

Using these seven equations, we have proven our three main equations. The main problem in the proposed correspondence principle is that we cannot calculate W (the number of real microstates). Strictly speaking, we need years to do it. However, we tried to show the hints to calculate W. About the protons, the positive charge and the mass ratio with the electrons are unexplained, which will be explained in the future report.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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