

ON THE DIFFERENCE OF THE VALUES THE FARADAY CONSTANT

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The numerical value of the Faraday constant as the charge of one mole of electrons has slight differences depending on the experimental technique of its measurement. An original explanation to this fact is set forth. The values of the free fall acceleration for different elements are slightly different.

Keywords: Faraday constant, electrochemical equivalent, mass spectrometry, free fall acceleration

The Faraday constant as a fundamental physical value has its peculiar features, which make it standing out of the other physical constants. According to the official documents of NIST [1], this constant has two values:

$$F = 96485.33289 \pm 0.00059 \text{ C/mole and}$$

$$F^* = 96485.3251 \pm 0.0012 \text{ C/mole.}$$

The second value refers to the "ordinary electric current". The values are determined according to different experimental techniques. The difference amounts 0.000008%, which is a tiny difference, however, such a discrepancy is not characteristic for other physical constants. The present work aims at revealing and analyzing the possible causes for such a discrepancy.

A classical technique for determining of the Faraday constant is the electrochemical method. This technique has multiple variations, since various reactions on the electrodes during electrolysis are available. In the simplest case pertinent to reactions in water solutions on the anode,



or on the cathode,



in order to determine the Faraday constant, we need to perform the experimental measurement of the total electrical charge transferred by current during the whole time of the electrolysis process. Subsequently, the cathode (anode) should be weighted to measure the difference in mass before and after the electrolysis. The Faraday constant calculation based on the experimental data is realized according to the following formula

$$F = \frac{QM}{zm}, \quad (3)$$

where Q is the full charge of electrolysis, m is the increment (decrement) of the mass of the anode (cathode), M is molar mass of the sedimented (dissolved) substance.

The first works on the exact determination of the electrochemical equivalents and the Faraday constant date back to the end of XIXth – beginning of XXth century. In the second half of the past century, precision measures of the electrochemical equivalents were conducted for several elements [2-7]. These results give certain discrepancies in the values of the Faraday constant, which were interpreted in different ways. In [2], the wrong determination of the molar mass of the elements is considered as a principal cause for the discrepancies. Thus, an exact value of the molar mass of zinc was found from the *a priori* known value of the Faraday constant and experimental values of the electrochemical equivalent of zinc. In [3], the analysis of possible reasons, which brought to discrepancies in the results of electrochemical experiments performed for determination of the Faraday constant, has been fulfilled. Among others, wrong determination of the Avogadro constant, changes in the definition of the ampere, insufficient purity of the electrode materials, and other reasons were listed. The analysis allowed to draw a conclusion that till now no satisfactory reason for such discrepancies has been found. The problem was also considered in [4]. The Figure in this work and its refined version in [5] shows

that the Faraday constants, measured by different electrochemical techniques, are discordant. Besides that, there are discrepancies, which are above the measurement tolerance thresholds in the Faraday constant determination by the nonelectrochemical techniques, in particular, by a mass spectrometry [8]. According to this technique, one measures experimentally the ratio of the ion mass $m(X^{z\pm})$ to its charge:

$$I = \frac{m(X^{z\pm})}{ze}. \quad (4)$$

To calculate the Faraday constant, it is necessary to know the molar mass of the element, M , forming the ion

$$F = \frac{M}{zI'}. \quad (5)$$

The difference in the mass of the atom and its ion is taken into account from the charge of the ion and electron mass, m_e :

$$I' = \frac{m(X^{z\pm}) \pm zm_e}{ze}. \quad (6)$$

The principal difference between the electrochemistry and mass spectrometry based techniques is in the methods of determining masses for the elements and their ions. In the electrochemical techniques, weighting of electrodes is performed, and their mass is determined from the weight. It should be noted that

the calculation is performed by a slightly different formula, as opposed to (3):

$$F = \frac{QMg}{zP}, \quad (7)$$

where P is the difference in the electrode weight before and after electrolysis, g is the free fall acceleration (FFA) in the experiment.

In the mass spectroscopy based technique, the ratio of the mass and charge is computed from the Lorentz force, with no weight, but rather ion mass involved. It is this fact that can explain the difference of the Faraday constant value obtained using different techniques.

Let us assume that the free fall acceleration for different elements is slightly different. The difference does not exceed 0.000008%. Then, the difference in the experimentally determined values of the Faraday constant is eliminated, since electrode masses in the electrochemical techniques are determined from their weights. Therefore, if for any two elements the following relation is observed:

$$\frac{g_1}{g_2} = \frac{F_2^{ex}}{F_1^{ex}}, \quad (8)$$

then the difference in the Faraday constant values (F_1^{ex} and F_2^{ex}) from the electrochemical methods is eliminated. The free fall acceleration values for different elements can be connected with the reference value g_{ref} , which was used for the determination of the electrode mass change from their weight

$$g_1 = \frac{F}{F_1^{ex}} g_{sm}. \quad (9)$$

F is the value of the Faraday constant obtained using mass spectrometry or any other non-electrochemical technique.

The difference in the free fall acceleration for different elements can be either proved or disproved experimentally by high precision measurements [9]. The supposed order of discrepancies should not exceed 79 microgals (0.000008%), which is quite within the accuracy of modern experimental techniques.

The difference in the free fall acceleration for different elements contradicts the principle of equivalence of gravitational and inertial masses, so it needs a clear substantiation. One of the explanations of the suggested hypothesis is given in [10]. It is based on the existence of quanta as carriers of the gravitational interaction. The idea on the gravitons (hypothetical particles with spin of 2) has been put forth rather long ago. Till now, it was not experimentally evidenced, although the gravitational waves have already been detected experimentally.

Therefore, a conventional point of view is that the gravitational interaction is realized through Higgs bosons.

A possible alternative mechanism with gravitons is suggested in [10]. According to the estimations, the cross section of the gravitational process with gravitons must be apparently below 10^{-11} m²/kg. This corresponds to the crosssections of processes with neutrino. Probably, this can explain the experimental difficulties with the detection of the hypothetical particles.

REFERENCES

- [1] https://physics.nist.gov/cgi-bin/cuu/Value?f90|search_for=physchem_in!
- [2] Marinenko G., Faley R.T., *Journal of research of the NBS – A. Physics and Chemistry* **79A** 747 (1975)
- [3] Diehl H., *Analytical Chemistry* **51** 318A (1979)
- [4] Bower V.E., Davis R.S., *Journal of research of the NBS* **85** 175 (1980)
- [5] Bower V.E. et al., *Journal of research of the NBS* **87** 21 (1982)
- [6] Craig D.N. et al., *Journal of research of the NBS* **64A** 381 (1960)
- [7] Koch W.F., Hoyle W.C., Diehl H., *Talanta* **22** 717 (1975)
- [8] Sommer H., Hipple J.A., *Nat. Bur. Stand. Circ.* **524** 21 (1953)
- [9] Kuznetsov V.V., *20 Lectures in Physics of Earth* Gorno-Altaiisk: Gorno-Altaiisk State University, 2012
- [10] Zevatsky Yu.E., *Bulletin of the Saint Petersburg State Institute of Technology (Technical University)* **41(67)** 3 (2017)