The Relationship of the Mole and Charge

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Abstract: In this paper, the mole and charge are related by deriving Avogadro's number from three constants: the Bohr radius, the Planck length and Euler's number.

Introduction

In 1834, Michael Faraday established a relationship between charge and an amount of substance accumulated in electrolysis, which would later become known as the mole, represented by Avogadro's number [1]. In 1910, Robert Millikan published the first of his oil drop experiments to measure the charge of the electron and refined it by 1913 publishing more accurate results in *On the Elementary Electrical Charge and the Avogadro Constant* [2]. By accurately measuring the elementary charge, Millikan was able to calculate a value of Avogadro's number that is nearly the value used today. However, neither Faraday's work nor Millikan's work can explain why Avogadro's number is the specific count of a substance in the mole. Yet, by relating the mole to other constants known in physics, there may be a potential answer.

The Relationship of Charge and a Substance

In *The Relationship of Mass and Charge* by Yee and Gardi [3], the electron's mass and Coulomb's law were related by an energy equation describing standing and traveling longitudinal waves. It was proposed that charge was wave amplitude, thereby changing units of Coulombs to distance, resolving equations across matter and electrical domains.

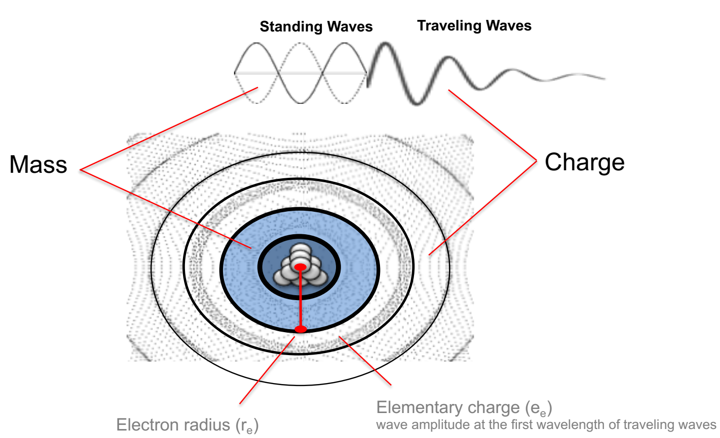

Fig. 1 – The relationship of mass and charge as waves (electron in blue)

It was further proposed that a substance exists in space that allows the transfer of energy, in oscillations that are measured as wave amplitude, declining in amplitude from the source. It was referred to as a *granule* in the paper. Here, in this paper, the following question is proposed. If such as substance exists to create the mass of particles and is responsible for the particle's charge, how many of these granules exist between two particles affected by charge?

If granules do exist in the space between particles like the electron and proton, it can be assumed that they would be significantly smaller than a particle if they are truly the cause of mass. The electron's mass, calculated from electrical properties, is revisited from *The Relationship of Mass and Charge:*

$$m_e = \frac{\mu_0 e_e^2}{4\pi r_e} = 9.109 \cdot 10^{-31}\ (kg) \quad \textbf{(1)}$$

The constants used in Eq. 1, and the remainder of this paper, use CODATA values as follows [4]:

- μ_0 – Magnetic constant (1.2566 x 10^{-6} kg /m)*
- e_e – Elementary charge (1.6022 x 10^{-19} m)*
- r_e – Electron radius (2.8179 x 10^{-15} m)
- q_P – Planck charge (1.8755 x 10^{-18} m)*
- l_P – Planck length (1.6162 x 10^{-35} m)
- a_0 – Bohr radius (5.2918 x 10^{-11} m)
- e – Euler's number (2.71828)

* Coulombs (C) is calculated as distance (m) and explained as wave amplitude. When this conversion is made, units resolve correctly.

Size and Separation Distance of Granules

A hypothesis is made that the Planck length (l_P) is the radius of granules responsible for mass and charge. The Planck length fits the criteria of a size that is considerably smaller than a particle. In fact, it is on the order of 10^{20} times smaller than the electron's classical radius. It also appears in physics equations without meaning, so this potential explanation gives the value a purpose. If it is a radius of one Planck length, then the diameter would be two Planck lengths ($2l_P$).

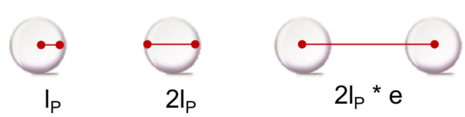

Fig. 2 – Size and separation of a granule

A second hypothesis is made that granules are separated at equal distances, but it is their motion from equilibrium that is measured as charge (longitudinal wave amplitude). The proposed separation distance is one diameter times Euler's number (e). Euler's number not only appears in equations for waves, but it also appears in equations for growth and decay functions as the base of the natural logarithm. And if granules are indeed the substance in between particles that form atoms, it also gives meaning to Euler's number.

A question remains about the structure of a granule. Is it three-dimensional? Is it spherical? A hint may come from the Planck unit system. Although the meaning of Planck mass (m_P) is not known in the context of Eq. 2, its value can be accurately calculated from the magnetic constant, Planck charge and Planck length. Note the similarities between Eqs. 1 and 2, with the only difference being the Planck charge (versus elementary charge) in the numerator and the Planck length (versus electron radius) in the denominator. Given this similarity, it is quite possible that Planck length may be the radius of something spherical.

$$m_P = \frac{\mu_0 q_P^2}{4\pi l_P} = 2.1765 \cdot 10^{-8}\,(kg) \qquad \textbf{(2)}$$

Calculating Avogadro's Number

Returning back to the question of the number of granules that exist in space between two particles, the separation distance of granules can be used to calculate the answer. In the universe, the majority of atoms are hydrogen, which is a single proton and electron. In fact, heavier atoms may be formed from hydrogen, so the calculation of the substance between particles starts with the lowest common denominator, which is ground state hydrogen.

The most probable distance between an electron and proton in ground state hydrogen is known as the Bohr radius (a_0). Although certainly not to scale, granules are illustrated in the next figure with a separation distance between the two midpoints of each granule ($2l_P$ * e).

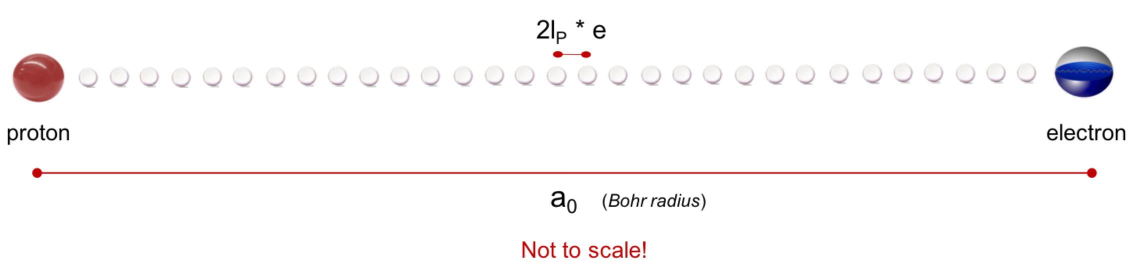

Fig. 3 – Calculating the number of granules between a proton and electron in hydrogen

The calculation of the number of granules is straightforward. It is the Bohr radius divided by the separation of each granule from their midpoints.

$$\frac{a_0}{(2l_P)\,e} = 6.022 \cdot 10^{23} \qquad \textbf{(3)}$$

Eq. 3 resolves to be a *dimensionless* count of particles: 6.022×10^{23}. By comparison, the CODATA value for **Avogadro's number** is $6.022140857(74) \times 10^{23}\ mol^{-1}$.

Conclusion

Although it remains a possibility of being a coincidence, Avogadro's number can be calculated from a combination of the Planck length, Bohr radius and Euler's number. It was Michael Faraday that established there was a relationship between the mole (Avogadro's number) and charge. And charge may indeed be a substance in the form of traveling waves, described in *The Relationship of Mass and Charge*. Max Planck may have found that the smallest unit of length represents this component of space responsible for charge, and gave it the name Planck length without knowing or understanding what it represented. If these calculations are not coincidental, then Avogadro's number has a logical definition. It is the number of granules with radius of Planck length, that travel as longitudinal waves to form the charge between an electron and proton in ground state hydrogen. It becomes the mole. And all other elements measured as the mole can be formed from hydrogen, which causes Avogadro's number to be constant.

References

1 Ehl, R. G., Ihde, A., 1954. Faraday's Electrochemical Laws and the Determination of Equivalent Weights. *Journal of Chemical Education*, **31** (May): 226–232.

2 Millikan, R. A., 1913. On the Elementary Electric Charge and the Avogadro Constant. *Phys. Rev.* **2** (2): 109-143.

3 Yee, J., Gardi, L., 2019. The Relationship of Mass and Charge. *ResearchGate*. Online: https://www.researchgate.net/publication/332083618.

4 Mohr, P., Newell, D. and Taylor, B., 2014. CODATA Recommended Values of the Fundamental Physical Constants, *Rev. Mod. Phys. 88*, 035009.