TITLE: Initial velocities of hydrated ions under an electropotential field, their molar masses, and total hydration numbers

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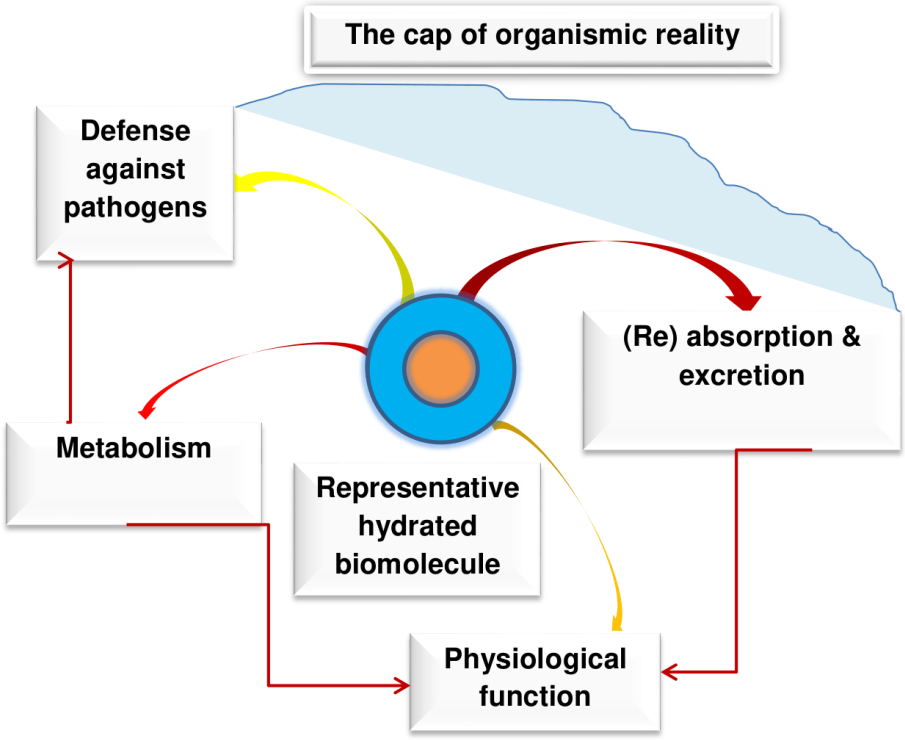
https://doi.org/10.26434/chemrxiv.15002544/v1

Abstract
The inner hydration shell, where water is electrostricted, has always been the main area of study. But it appears that the bulk water, which is affected by the ion electric field, is not given the same degree of attention. This largely theoretical study aims to develop equation-based models that can be used to calculate the initial velocities of ions when an electrical potential gradient is applied, as well as the total number of water molecules pulled to the ions and their molar masses (including the mass of the electrostricted water). Theoretical and computational approaches were employed to analyze literature-based data. The initial velocity was approximately 3.8 *exp.* (–8) m/s for cobalt ions and 26 *exp.* (–8) m/s for oxonium ions. The equivalent total hydration number ranged from 4 for oxonium ions to 60 for cobalt ions. Initial velocities ranged from 1.65 *exp.* (–8) m/s for epinephrine to 2.88 *exp.* (–8) m/s for glycinate, and the corresponding total hydration number ranged from 38 for glycinate to 64 for epinephrine. The molar masses of the hydrated ions ranged from 765 g/mol for glycinate to 1,333 g/mol for epinephrine and from 85.81 g/mol for oxonium ions to 1,137.8 g/mol for cobalt ions. The trajectory and biological function of biomolecules can be impacted by their hydrated mass. The lowest and highest velocities are associated with the highest and lowest total hydration numbers per unit charge. Future research could focus on determining the electrophoretic mobilities of all physiologically active biomolecules at physiological pH and body temperature.
Keywords: Biomolecules, Total hydration numbers, Initial velocities, Electropotential gradient, Molar mass of hydrated ions.

Graphical abstract



1.0 Introduction

Motion is essential for life, as it aids survival in plants that exhibit positive geotropism. Various forms of motion—translational, rotational, and vibrational—are crucial at molecular levels (micromolecular, macromolecular, supramolecular) and higher levels (cell, tissue, organ, system, and organism). Biological reality operates effectively through regulated molecular motion, enhancing the well-being of biological systems. This is why hydration that impact on the mobility of biomolecules of all complexity is important.

Although electrophoretic mobility is determined by NMR electrophoresis, knowledge of hydrodynamic friction, as indicated by the diffusion coefficient measured by pulsed-field gradient NMR, is required for all electrophoretic measurements. The effective charge per molecule, determined by an unclear balance of forces between hydrodynamic friction and the electric field acting on the charges, is also necessary (Bölme & Scheler, 2007). If the hydrodynamic radius of spheroids is accurately known, the Stokes–Einstein equation appears to be necessary.

Known electrophoretic mobilities of charge-bearing solutes are crucial for the determination of hydration numbers; "the electrophoretic mobility, μ (m^2/Vs), is the observed electrophoretic velocity, v (m/s), divided by electric field strength, E (V/m)" (Charcosset, 2014). Without a doubt, drift or diffusivity (*i.e.*, motion, displacement, etc.) is one of the most important indicators of life. Due to the hydration number, the molecular component in regular flux behaves in a mass-dependent manner. In biological fluids, the mass is greater than the dry mass. The diffusivity in biological fluids is undoubtedly higher than that of packed cellular milieus, synaptic clefts, and membranes, but it may be comparable to that of dilute aqueous solutions. Given that excitatory and inhibitory neurotransmitters, respectively, are responsible for the generation of action potentials, subsequent impulse transmission, and its termination, the biological significance of hydration number, which increases the molar mass of solutes, makes it essential for a serious study. This is impossible without hydrated, relative mass-dependent diffusivities of the transmitters and associated inorganic ions, Na^+, Ca^{2+}, K^+, Cl^- *etc*., However, the ions' initial motion, which is regulated by temperature and viscosity, has a velocity that cannot be disregarded; if this motion is disrupted for any cause, the coordinated functions of the organism's many parts may become disoriented and dysfunctional.

The battle against pathogens is clearly the function of antibodies, which must be mobilized to the necessary location. Knowledge of the hydration number and wet molar mass of immunoglubulins could be helpful in designing antibodies and drugs. Knowledge of electrophoretic mobility is crucial for determining the hydration number and, consequently, for drug design. A study showed that the mobilities of Na^+ and ACh^+ in Single-Walled Carbon Nanotube (SWNT) are several folds lower than previous results (Ellison et al., 2025). The drift velocity of Na^+ ions in infinitely dilute aqueous solution under the influence of a 10 V cm^{-1} electric field at 298.15 k is 5.3 *exp.* (5) m s^{-1}(Usenik *et al.*, 2024)

Research into new instrumentation is a regular occurrence in rich, advanced countries that have established a culture of scientific inquiry. One such means of measuring protein mobility is laser Doppler electrophoresis (Corbett *et al.*, 2011). The pH and temperature of the medium must be known. Surface modification of Polydimethylsiloxane (PDMS) for electrophoretic applications for bioassays is also known (Kiran & Chakraborty, 2020). Using sophisticated methods and related tools or equipment, electric mobility is also investigated in a gas-phase medium. Ion mobility spectrometry (IMS) is the new method. IMS is the study of how ions flow in gases when subjected to an electric field (Dodds & Baker, 2019). The optimal

techniques are often determined by structural factors, such as crystal structure and dynamics, dehydration and hydration kinetics, and degree of hydration. The latter is of interest in this study due to the hydration number. Some of these techniques include X-ray diffraction, powder X-ray diffraction, differential scanning calorimetry, thermogravimetric analysis, gravimetric (dynamic vapor sorption), solid-state nuclear magnetic resonance spectroscopy, Fourier-transformed infrared spectroscopy, Raman spectroscopy, quantum mechanics (QM), molecular dynamics, and computational molecular mechanics (Jurczak et al., 2020).

The importance of hydration, hydration number, electrophoretic mobility, and related factors, as well as techniques for analyzing these parameters, has been highlighted in the previously stated studies. However, there has been no discussion of how to calculate beginning velocity in the absence of an ATPase-sustained transmembrane potential in vivo and an electric potential gradient in vitro. The inner hydration shell, where water is electrostricted (Marcus, 1991) is the main area of study. But it appears that the bulk water, which is affected by the ion electric field (Marcus, 1991), is disregarded. This largely theoretical study aims to develop equation-based models that can be used to calculate the initial velocities of ions when an electrical potential gradient is applied, as well as the total number of water molecules pulled to the ions and their molar masses (including the mass of the attracted water).

2.0 Theory

The masses, hydration numbers, and the initial velocities at 298.15 K of hydrated ions following the introduction of an electropotential gradient were calculated using an entirely novel approach.

$$u = h/m\,v\,\tau_0, \tag{1}$$

The Planck constant and gas-phase velocity of a hypothetical particle whose mass is equal to the hydrated ion's rest mass (m) in solution are represented by the symbols h and v, respectively; u denotes the ionic species' velocity before reaching terminal velocity in solution at a specific thermodynamic temperature. Therefore, $|u| < |v|$. In line with Helm's axiomatic theory from 1898 that there are "extensive and intensive thermodynamic properties"(Redlich, 1970), it should be noted that the de Broglie wavelength ($\lambda = h/m\,v$) can be compared to the displacement covered in a time period designated as τ_0. As long as the particle continues to move in accordance with Newton's law of motion, its displacement has no limit, making it an extensive parameter (one that has no definite magnitude). Georg Ferdinand Helm (in 1898) is also credited with creating the term "mathematical chemistry." Usurpation has no foundation. This part of the text definitively corrects the record. The terms were employed so extensively by the latter author that it seemed to attribute the words' origin to writers like Tolman (1917).

Furthermore, it is imperative to opine that $1/\tau_0$ is not frequency given as $k_B T/h$ where k_B and T are the Boltzmann constant and thermodynamic temperatures respectively. Besides,

$$u = h/m\,s, \tag{2}$$

where $s = v\,\tau_0$. The details about the origin of Eq. (2) can be found in the appendix section. Besides, de Broglie wavelength can be equivalent to the displacement of a particle (the same or another particle, real or hypothetical) in motion at some time. The converse could be true. Note that translational momentum and displacement are particle properties. There is a strong need to take into account that in any potential gradient that strongly influences particles, the motion is less random if not totally directional. This perspective will guide subsequent derivations.

The main goal is to use the concept of wave-particle duality to connect two systems: a hypothetical free-state system and a real solution system with extremely high cohesive forces.

The equation, which can be found in the appendix section in another fashion, is as follows: $\phi = v/u$ (Where, $\phi \gg 1$) (3). So,

$$\phi^2 = k_B T/m\,u^2, \tag{4}$$

Because,

$$v^2 = k_B T/m \tag{5}$$

The underlying assumption of equation (5) is as follows: Jain *et al*. (2012) derived another equation related to the Einstein-Smoluchowski equation using the equipartition theorem (Cartesian molecular models) for kinetic energy; however, the main issue is treatment in one dimension and taking into account the original Einstein-Smoluchowski equation given as $6\pi\eta r D = k_B T = \langle mv^2 \rangle$.

Next, a relationship between $'\tau_0'$ and 'ϕ' needs to be established in a simple way as follows. Substitute the square of Eq. (1) into Eq. (4) to give the equation as follows:

$$\phi^2 = \frac{k_B T (v m \tau_0)^2}{m h^2} \tag{6}$$

Equation (6) in which ($k_B T = mv^2$) is simplified to yield the following result.

$$\phi = k_B T \tau_0 / h, \tag{7}$$

Therefore,

$$\tau_0 = \frac{\phi h}{k_B T}, \tag{8}$$

Now, the role of the electric field has to be introduced because of its effect on ionic mobility. Meanwhile, the velocities of ions contribute largely to the high conductivities of aqueous solutions. But the question is, does higher temperature enhance the speed of ions under a known electric potential gradient? This question reminds the reader that the ions are always in motion at a velocity to be determined before migration at a higher velocity under the influence of an electric potential gradient.

$$u_e^2 = \frac{2e\Delta V q}{m\Phi^2} + \frac{k_B T}{m\phi^2} - \frac{e\Delta V q s}{d\Phi^2 m}, \tag{9}$$

where $u_e, \Delta V, q, d, e,$ and Φ are the velocity of the ion under electric field, electric potential difference, valence (or magnitude of the charge), distance between electric poles or plate, charge of an electron, and a parameter similar to the expression indicated by Eq. (8).

$$\tau_e = \frac{\Phi h}{2e\Delta V q}, \tag{10}$$

Equation (9) arises because with the introduction of electric field (electric potential gradient), the velocity of any ion increases, though, with time, it decreases to a lower terminal velocity which may be higher than the thermal velocity.

Like Eqs (4) and (5) the factor Φ^2 expresses the number of times $2e\Delta V q$ is greater than mu_e^2. To find alternative equations for ϕ and Φ, there is also a need to find alternative equations for the time; but first, recall that $= \tau_o v$. The following steps could serve the purpose of deriving the equation for u_e. First,

$$\left(\frac{s}{v}\right)^2 = \left(\frac{\phi h}{k_B T}\right)^2, \tag{11}$$

Next Eq. (5) is substituted into Eq. (11) to give, after rearrangement, the following:

$$\phi^2 = m k_B T \frac{s^2}{h^2}, \tag{12}$$

Also,

$$\left(\frac{s}{v_e}\right)^2 = \left(\frac{\Phi h}{2e\Delta V q}\right)^2, \tag{13}$$

where v_e is the speed of the ion whose mass remains designated as m but hypothetically free from the effect of the solvent and without cohesive force (*i.e.* $v_e^2 = 2e\Delta Vq/m$). Therefore, like Eq. (12),

$$\Phi^2 = 2me\Delta Vq\, s^2/h^2, \tag{14}$$

Next, substitute Eqs (12) and (14) into Eq. (9) for ϕ^2 and Φ^2 respectively, to yield the following:

$$u_e^2 = \frac{2h^2}{m^2 s^2} - \frac{h^2}{2sdm^2} \tag{15}$$

$$m^2 = \left(\frac{2h^2}{s^2} - \frac{h^2}{2sd}\right)/u_e^2 \tag{16}$$

$$m = \left(2 - \frac{s}{2d}\right)^{½} \frac{h}{u_e s}, \tag{17}$$

Given Eq. (2), the equation for u can be restated as follows: $u = u_e/\left(2 - \frac{s}{2d}\right)^{½}$.

Meanwhile there could be a scenario whereby two particles of different masses possess the same momentum such that,

$$mv = m_0 v_0, \tag{18}$$

where $m_0 < m$ and $v_0 > v$; Eq. (18) is the beginning of derivations in the appendix section. The velocity v_0 and mass m_0 are hypothetical. $m/m_0 = v/v_0 = \phi$. For such a particle whose mass is m_0, the time it could take to cover the displacement, D at v_0 is τ_0. Since v_0 is ϕv, then, if $s = D/\phi$ the obtainable equation is as follows:

$$\tau_0 = D/\phi v = D/\phi^2 u = Du/v^2, \tag{19}$$

where $\phi u = v$. The frequency (ζ_0) is for a particle whose mass is m_0: Therefore,

$$m_0 v_0^2 \equiv m_0 \phi^2 v^2 = h\zeta_0, \tag{20}$$

Furthermore,

$$mv^2 = h\zeta_0/\phi \equiv h\zeta, \tag{21}$$

where $\zeta_0/\phi = \zeta$ and it is the frequency of a particle whose mass is m. As in the appendix section, $v_0/u = \phi^2$ and if D is very large and while $k_B T/mu^2 = \phi^2$, then, the equation as follows is likely.

$$k_B T/mu^2 = \tau_0 \zeta_0, \tag{22}$$

Substitution of Eq. (19) for ζ_0 into Eq. (22) gives the following:

$$k_B T/mu^2 = Du\,\zeta_0/v^2, \tag{23a}$$

$$k_B T\phi^2/mv^2 = Du\phi\,\zeta/v^2, \tag{23b}$$

Equation (23b) is stated as such because $u^2 = v^2/\phi^2$, and $\zeta_0 = \phi\,\zeta$; Rearrangement and simplification of Eq. (23b) gives the following:

$$k_B T\phi^2 = D\zeta mv, \tag{24}$$

Equation (24) is restated as follows:

$$k_B T = D\zeta mv/\phi^2 = s\zeta mu, \tag{25}$$

where s and u are used in place of D/ϕ and v/ϕ respectively.
The postulation is that

$$\zeta mu = 6\pi\eta au \tag{26}$$

In line with earlier Stokes-Einstein law, the radius of the hydrated solute migrating in an electric field (along electrical potential gradient) is given as follows:

$$a = e\Delta Vq/6\pi\eta u_e d \tag{27}$$

Next Eqs (17) and (27) are substituted for m and a respectively, into Eq. (26) to give the following:

$$\frac{\left(2-\frac{s}{2d}\right)^{½} h\,\zeta}{2u_e s} = \frac{e\Delta Vq}{du_e} \tag{28a}$$

Substituting $k_B T/h$ for ζ and simplifying gives the following:

$$\frac{\left(2-\frac{s}{2d}\right)^{½} k_B T}{2s} = \frac{e\Delta Vq}{d} \tag{28b}$$

Taking the square of Eq. (28b) and translate into a quadratic equation gives the following:

$$\left(\frac{2se\Delta Vq}{k_B T d}\right)^2 + \frac{s}{2d} - 2 = 0 \tag{29}$$

$$s = \frac{\left[-\frac{1}{2d} \pm \left(\frac{1}{4d^2} + 32\left(\frac{e\Delta Vq}{k_B T d}\right)^2\right)^{½}\right] k_B^2 T^2 d^2}{8e^2 \Delta V^2 q^2} \tag{30}$$

Of the two roots, the positive one is considered appropriate for computation. Thus,

$$s = \frac{\left[-\frac{1}{2d} + \left(\frac{1}{4d^2} + 32\left(\frac{e\Delta Vq}{k_B T d}\right)^2\right)^{½}\right] k_B^2 T^2 d^2}{8e^2 \Delta V^2 q^2} \tag{31}$$

2.1 Equation for the velocity (u) based on Eq. (15) before the onset of electric potential gradient

Equation (15) is rearranged to give, first, the following:

$$\frac{h^2}{m^2 s^2} = \frac{u_e^2}{2} + \frac{h^2}{4sdm^2} \tag{32}$$

Taking the square root of Eq. (32) gives the following:

$$\frac{h}{ms} = \left(\frac{u_e^2}{2} + \frac{h^2}{4sdm^2}\right)^{½} \tag{33}$$

With reference to Eq. (2) it is obvious that,

$$u = \left(\frac{u_e^2}{2} + \frac{h^2}{4sdm^2}\right)^{½} \tag{34}$$

However, when the values of s and m are unknown, neither Eq. (2) nor Eq. (34) can be used to compute u. Therefore, deriving the equation for s is required. This study has determined the method for calculating the value of s; therefore, an alternate equation for calculating the hydrated mass of the solutes must be derived.

2.2 Alternative method for the determination the mass of hydrated solutes

Solving for a in Eq. (26) gives the following:

$$a = \zeta m/2 \times 6\pi\eta \tag{35}$$

Therefore, Eq. (35) and Eq. (27) are the same. Hence,

$$\zeta m/6\pi\eta = 2e\Delta Vq/6\pi\eta u_e d \tag{36}$$

Having defined ζ as $k_B T/h$ earlier in the text and substituting into Eq. (36) gives after solving for m, the equation as follows:

$$m = \frac{2e\Delta Vqh}{k_B T u_e d} \tag{37}$$

3.0 Methods

The theoretical work is evaluated using online data on electrophoretic mobility. By posting a question regarding these parameters online, one can learn more about the electric mobility of inorganic and organic solutes carrying charge in a solution of infinite dilution at a selected temperature of 298.15 K and physiological pH. In this study, the needed equations are derived. These include Eqs. (2) and (34), which yield the same result when calculating u; Eqs. (17) and (37), which yield the same result when calculating m; and Eq. (31), for the computation

of *s*. The charge of an electron, Planck constant, and Boltzmann constant were adopted as recorded in the literature (Tiesinga *et al.*, 2021).

3.1 Statistics

The values of the parameters known in the literature were adopted without statistical analysis. Even in the same circumstances, multiple sources may yield different values for the same parameter.

4. Results and discussion

The molar mass of the biologically important and useful inorganic and organic ions in their hydrated state were computed in this study. Expectedly, the values for the physiologically important bioorganic molecules were higher those of the "dry" molar masses. These range from 765 g/mol for glycinate to 1,333 g/mol for epinephrine. The initial velocities range from approximately 1.65 *exp*. (–8) m/s for epinephrine to 2.88 *exp*. (–8) for glycinate, depending on the total water of hydration, which ranged from 38 to 64 (Table 1). The hydration number of acetylcholine appears to be 38 (Fedotova *et al.*, 2020) based on the way it is presented in the literature; this figure is comparable to the value of 40 in this study, unless it is just a coincidence. The onium and carbonyl groups have 23 and 2 hydration waters, respectively (Fedotova *et al.*, 2020). Earlier study showed that the hydration number of histamine is 51 (Pire *et al.*, 2014). Such figure is less than 56 in this study.

The hydration number corresponds to the total number of water molecules that are kinetically retarded (*i.e.*, slow water) due to presence of ions in the solution. Based on the combination of molecular dynamic simulations and the terahertz spectroscopy the number of tightly-bound water molecules per protein was estimated to be about 200 – 250. MD simulations showed ~230 water molecules directly hydrogen-bonded to the surface of a myoglobin around physiological temperature; ~200 – 225 per myoglobin at most temperatures was reported for myoglobin; Debye fitting confirmed that a total of 670 ± 50 water molecules are captured in the tightly and loosely bound layers of a lysozyme molecule at 35°C (Doan *et al.*, 2022). These figures (including lysozyme, in particular) are about 4 to 10 fold greater than figures reported for some transmitters in this study. This is reasonable because protein is larger than amino acid and short polypeptide. Starting with the molar mass, the ranges for the bioinorganic ions were 85.81 g/mol for oxonium ions and 1,137.8 g/mol for cobalt ions, with corresponding waters of hydration ranging from 4 to 60. The initial velocities ranged from approximately 3.8 *exp*. (–8) m/s for cobalt ions to approximately 26 *exp*. (–8) for oxonium ions (Table 2). Note that when exposed to an electropotential gradient, the ions do not instantly reach their maximum velocity. This velocity then declines due to solvent resistance at a given temperature. Furthermore, it was found that the value of *m* for a sodium ion subjected to 1,000 V/m at 298.15 K in an earlier study by Usenik *et al.* (2024) was approximately 9.732 *exp*. (−25) kg. This number is comparable to Table 2's value for 1 V/m (see Table 2's footnote). Since the rest mass should stay constant, this outcome is to be expected.

Table 1: Mass of the hydrated neurotransmitters, their hydration numbers, and initial velocities

*Neurotransmitter (organic compounds)	*Elect vel./*exp*. (–8) m/s	*Dry molar mass/g/mol	Hydrated particle mass/*exp*. (–24) g/mol	Number of water of hydration(n_{hyd})	Int. vel./exp. (–8) m/s
Histamine	2.76	111.50	1.868827604	56	1.956051824
Epinephrine	2.33	183.20	2.213718536	64	1.651304619
Adrenaline	3.17	183.20	1.62711804	45	2.24662474

Noradrenaline	2.51	169.18	2.054965812	59	1.778873217
Glutamate	3.10	146.12	1.663859415	48	2.19701473
Acetylcholine	3.60	146.21	1.43276783	40	2.551371944
Glycinate	4.06	75.07	1.270434527	38	2.877380586
Dopamine	2.67	153.18	1.931821793	56	1.892267391
Serotonin	2.51	177.10	2.054965812	59	1.828483232
Norepinephrine	2.58	169.18	1.999210922	57(57.487)	1.82848323
Aspartate	2.67	133.10	1.931821793	57 (~57.237)	1.892118855

The asterisk (*) represents information available on the internet and obtained upon posting queries to it; Elect, Int, and Vel stand for electric, initial (without electric potential gradient), and velocity, respectively. The values of s for the charges, 1 and 2 are respectively, 0.018126186 and 0.009083704317 (This is applicable to Table 2)

Tables 1 and 2 demonstrate that initial thermally dependent speeds were lower than electropotential-dependent velocities. The total water of hydration, not merely the coordination number (the number of water molecules in the initial coordination shell), is responsible for the higher molar mass and varying velocities. Marcus's (1991) thermodynamics-based study revealed completely different values for the total water of hydration or the inner hydration number for hydrogen, hydroxide, chloride, and cobalt ions. These values were 12, 2.7, 2, and 9.6, respectively; the corresponding values in this study were 4 (specifically, oxonium ion), 7, 20, and 60 (Table2). Since the hydrogen ion (or proton) has the highest electric and "thermal" velocities in this study and forms a dative bond with a water molecule, it is worthwhile to think about why, when the effect of higher charge density is included, it might have more hydration than even divalent ions. “It may imply that a surveillance jet built from a metal heavier than lead should fly higher and faster than another built from duralumin; if so, that may be within the realm of the American James Bond series”. There is a need for urgent scientific answer!

Table 2: Mass of the hydrated biologically active inorganic ions and their hydration numbers

*Biol active ions	*Elect vel/*exp.* (–8) m/s	*Dry molar mass/g/mol	Hydrated particle mass/*exp.* (–25) g/mol	Number of water of hydration(n_{hyd})	Int. vel./exp. (–8) m/s
$Na^{+}_{(aq)}$	5.190	22.99	9.93827395	32	3.678227892
$K^{+}_{(aq)}$	7.619	39.10	6.769870308	20 (~20.477)	5.399695235
$Ca^{2+}_{(aq)}$	6.166	40.08	16.73034119	54	4.360017601
$Mg^{2+}_{(aq)}$	5.500	24.31	18.77562334624	61	3.889084791
$Mn^{2+}_{(aq)}$	5.550	54.94	18.58735834	59	3.92444017
$Li^{+}_{(aq)}$	3.900	6.941	13.2255492	44	2.763986273
$Zn^{2+}_{(aq)}$	5.470	65.39	18.85910124	59 (~59.463)	3.867433047
$Co^{2+}_{(aq)}$	5.460	58.933	18.89364171	60	3.860800538
$Cl^{-}_{(aq)}$	7.910	35.45	6.520814397	20	5.605931133
$H_3O^{+}_{(aq)}$	36.200	19.00	1.424851983	4	25.65546238
$OH^{-}_{(aq)}$	20.500	17.00	2.516080092	7 (~7.473))	14.52864579

Biol means “biologically”. See the footnote in Table 1 for the values of *s*. For $Na^{+}_{(aq)}$ subjected to 1000 V/m at 298.15 K (Usenik *et al.*, 2024), the values of *s* and *m* were 1.816735567 *exp.* (–5) and ~ 9.732 *exp.* (–25) kg respectively.

In the first coordination shell of a core ion (or any solute), the coordination number is the number of water molecules (ligands) closest to the functional group(s) (electrophiles or

nucleophiles) to which they are bound. Hydration water, also known as the hydration number, is the average number of water molecules associated with ions (organic or inorganic chemical species) in solution. The first coordination shell, as well as any others that travel with the ion and are only slightly affected by the nucleus, are frequently included in this number. In any case, all the water molecules that accompany a solute influence its velocity in a solution because of the mass and weight associated with the coordination number, as well as other weakly bonded water molecules in different coordination shells. This scenario is similar to an object pushing through sand with its appendages. Removing solvent molecules can concentrate the solution infinitesimally because the bulk solution is indefinitely diluted. This does not, however, remove the solvent's resistance to the mobility of the solute. The solutes are unable to move freely and unrestrictedly due to the strong cohesive forces in the solution. Unfortunately, much of the advanced equipment used to study and evaluate hydration appears to be limited to coordination numbers and, at most, secondary coordination. Typical of the issue of coordination number is that illustrated with the coordination number of sodium ion given as $Na^+(H_2O)_5$ based on the outcome of a comprehensive genetic algorithm combined with density functional theory on global search, followed by high-level *ab initio* calculation (Wang *et al.*, 2019). The current models derived from this study can generate all of the water molecules associated with solutes, physiologically relevant inorganic ions, and neurotransmitters

Irritability has two sides, made possible by a sequential cycle of polarization and depolarization. Excitatory neurotransmitters (*e.g.*, ACh and Glu) open cation channels to allow positively charged ions, such as Na^+, to diffuse into the cell. This depolarizes the neuron (changing the resting charge from negative to positive), creating an excitatory postsynaptic potential. The other side of the coin is repolarization, whereby inhibitory neurotransmitters such as GABA and glycine open anion channels to allow negative ions (*e.g.*, Cl^-) to diffuse into the nerve cell. This halts further impulse or excitability.

Globulins are a group of proteins that are sub-classified into alpha-1, alpha-2, beta-1, beta-2, and gamma globulins based on their electrophoretic mobility. One of the main clinical applications of serum protein electrophoresis is aiding in the diagnosis of disorders associated with gamma globulin alterations (Ramanathan *et al.*, 2020). Other benefits of measuring electrophoretic mobilities include determining the hydrated mass of soluble solutes, whose faulty biological role may be traced to changes in hydration number if compromised.

One example of an ATPase is the P-type ATPase, or cation pump. A common example of this type is the sodium-potassium pump (Na^+/K^+ ATPase), which maintains a higher concentration of Na^+ outside the cell and a higher concentration of K^+ inside it. This mechanism maintains the resting membrane potential and enables the reabsorption of nutrients. Sodium-glucose co-transporter 1 (SGLT1) drives the "uphill" transport of sugar from the intestinal lumen into the cell against its concentration gradient by coupling it with the downward movement of sodium ions. This process utilizes the sodium-potassium pump, which is crucial for post-digestion activities such as glucose absorption in the small intestine (Gorboulev *et al.*, 2012) and reabsorbing nearly 3% of the filtered glucose load in renal proximal tubule segment 3 (Rieg *et al.*, 2014). The sodium-potassium pump is illustrated in the diagram (Figure 1) available in the literature (Gagnon & Delpire, 2021).

In order to sustain the electrogenic pumping function and fluxing ions, the apparatus must be in excellent working condition with normal hydration levels, including the coordination number. Velocities are usually affected by the hydration state. The underlying biochemistry that supports the availability and flux of biomolecules required for energy production, defense

against illness or infection, and overall physiological well-being can be hampered by irregular states of hydration. The idea that the effects of strong alcoholic beverages and hard drugs can be linked to the initial changes in ion flow that modify normal impulse transmission at rest is likely to be accepted by neurologists and physiologists. This is where the initial ion flux rate or velocities at physiologically normal or abnormal temperatures are important.

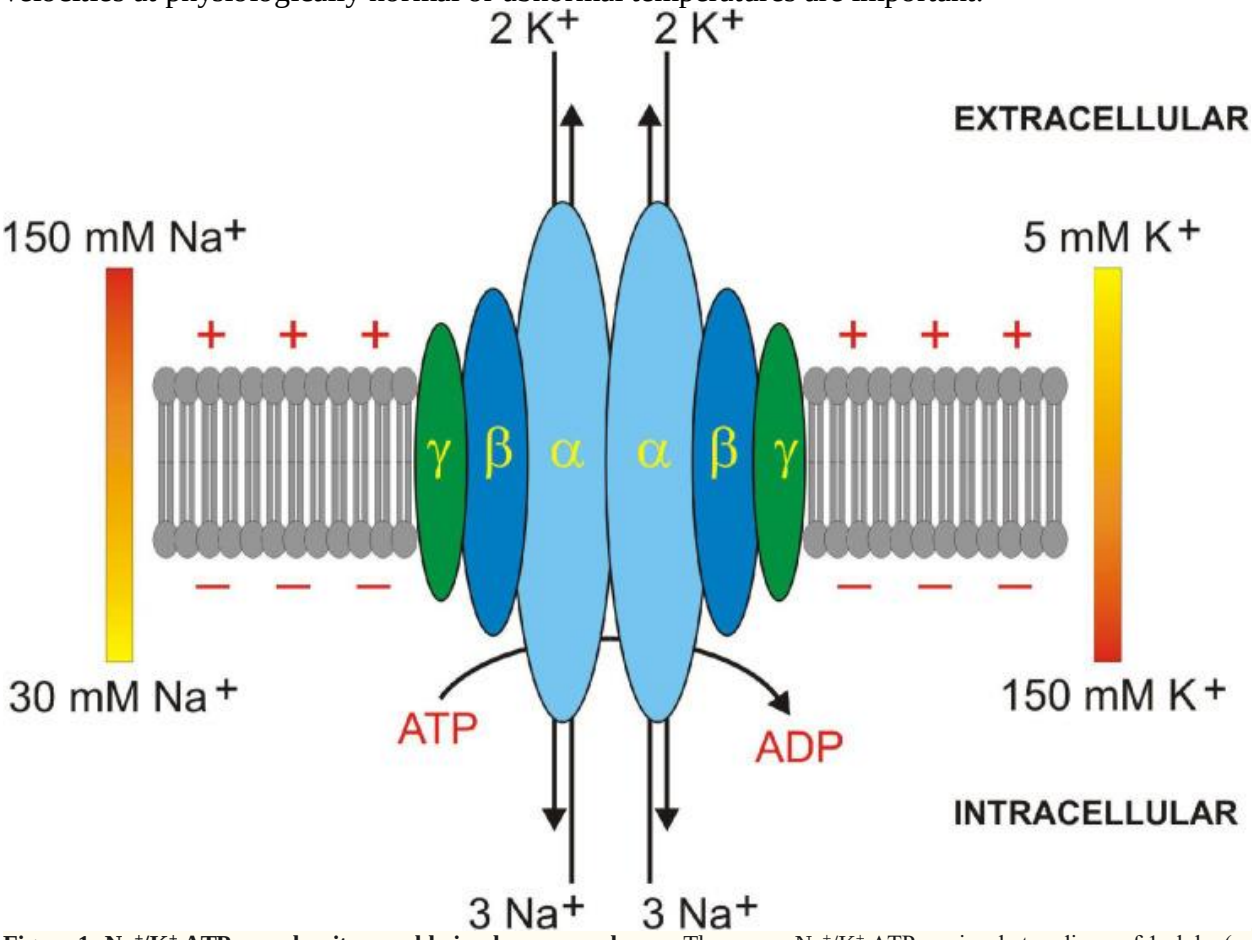


Figure 1: Na^+/K^+ ATPase subunit assembly in plasma membrane. The pump, Na^+/K^+ ATPase, is a heterodimer of 1 alpha (α, light blue) and 1 beta (β, dark blue) subunit. A regulatory gamma (γ, dark green) subunit sometimes oligomerizes in some tissues. 3 Na^+ and 2 K^+ ions are translocated across the plasma membrane by hydrolysis of 1 ATP to 1 ADP molecule. Extracellular to intracellular ionic gradients for Na^+ (150–30 mM) and K^+ (5–150 mM) are shown. Positive and negative signs depict membrane potential created by Na^+ and K^+ ion translocation. Source: Gagnon and Delpire (2021).

Motion can be considered a prerequisite to life. Although trees and most other plants are positively geotropic, they require some form of motion to survive. This motion can be translational, rotational, or vibrational, and each contributes different functionalities that are specific to the organism's needs. These situations can occur at molecular levels, including micromolecular, macromolecular, and supramolecular levels. Other higher levels include cell, tissue, organ, system, and organism. Real life, or biological reality, occurs at the cellular, tissue, system, and multisystem (organismic) levels. Controlled and regulated motion of molecules within biological entities promotes the well-being of biological objects.

Plants produce carbohydrates by transporting carbon dioxide through the stomata to the mesophyll tissue via passive diffusion. There, photosynthetic organelles known as chloroplasts convert the carbon dioxide into carbohydrates. The lack of neurotransmitters and minerals such as sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and chloride (Cl^-) can prevent irritability.

Some of these ions move passively or are transported. There are many examples in the literature; these are just a few. Therefore, it is not surprising that scientists study the transport characteristics of biological media inside and outside of the electric potential gradients that define biological membranes, particularly those of nerve cells. They also study the transport of biologically important inorganic and organic substances. Biological reality operates effectively through regulated molecular motion, enhancing the well-being of biological systems. This is why hydration that impact on the mobility of biomolecules of all complexity is important.

5.0 Conclusion

Equations were derived for computing the initial velocity following the application of an electropotential gradient. These equations can generate not only the initial velocities but also the total hydration numbers and the molar mass of the hydrated biomolecules. Biomolecules with higher hydrated molar masses have lower velocities and higher total hydration numbers per unit charge. Biomolecules with an appropriate level of hydration, beyond the inner hydration number, are essential for biological functions and life itself. Future studies should focus on determining the electrophoretic mobilities of biomolecules in dilute solutions at physiological pH and temperature.

Acknowledgment

I deeply appreciate the financial support of my siblings.

Funding: Funding was privately provided.

Author Contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Dedication

I dedicate this study to all my secondary school teachers (1973-1979) at Anglican Grammar School, Ubulu-Uku; Akwukwu-Igbo Grammar, Akwukwu-Igbo; and Saint Patrick's College, Asaba, Delta State, Nigeria.

Disclaimer (Artificial intelligent)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, *etc*.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interest

The sole author has declared that he has no known competing interest(s). The only challenge is the significantly less than two USD per day in monthly pension.

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APPENDIX

Derivation of Eq. (1)

Since thermodynamics can be described as an aspect of science concerned with the relationship between heat and other forms of energy there is a need to determine the velocity of dissolved particles (inorganic and organic ions) in aqueous medium at a known thermodynamic temperature. If v_0 is ϕ times the velocity, v of a particle whose mass is m, then if $\mathcal{L}$ is the distance covered by the object (any particle) at v, the distance covered at v_0 should be $\phi\mathcal{L}$ at the same time, t. However, the mass (m_0) of another particle, either real or hypothetical, whose velocity is v_0 is such that,

$$mv = m_0 v_0, \tag{A.1}$$

It follows therefore, that m is ϕ times m_0. The equations as follows are based on Eq. (A.1).

$$v = v_0/\phi, \tag{A.2}$$

$$v = \mathcal{L}/t, \tag{A.3}$$

$$v_0 = \phi\mathcal{L}/t, \tag{A.4}$$

Application of de Broglie principle to Eq. (A.4) yields the following:

$$\phi\mathcal{L}/t = h/m_0\lambda, \tag{A.5}$$

where λ is the de Broglie wavelength. Solving for λ yields the following:

$$\lambda = ht/\phi\mathcal{L}m_0, \tag{A.6}$$

But,

$$\lambda\zeta = v_0/\phi\,, \tag{A.7}$$

where ζ is the frequency related to mv^2 which is equated to $k_B T$; the basis of this has been highlighted in the text. Substituting Eq. (A.6) for λ in Eq. (A.7) yields the following:

$$v_0 = ht\zeta/\mathcal{L}m_0, \tag{A. 8}$$

Substitute the solution of $\mathcal{L}$ in Eq. (A.3) for it in Eq. (A.8) to yield the following:

$$v_0 = \phi h\zeta/mv, \quad \text{(Note that } m_0 = m/\phi\text{)} \tag{A. 9}$$

Since $v_0 > v$, the time (t_1) that may be required to cover the distance $\mathcal{L}$ at v_0 should be less than the time, t required to cover the same distance at v. Therefore,

$$\mathcal{L}/t_1 = \phi h\zeta/mv, \tag{A.10a}$$

With time, as translational motion continues, there must be a time τ_0 at v at which the following is a possibility.

$$\phi = \zeta\tau_0, \tag{A.10b}$$

At v, the distance (s) covered in such time (*i.e.*, τ_0) is greater than $\mathcal{L}$. However, at v_0 the distance ($\mathcal{J}$) that could be covered is derivable by multiplying Eq. (A.9) by τ_0. Thus,

$$\mathcal{J} = \tau_0\phi\,\zeta h/mv, \tag{A.11}$$

Substituting Eq. (A. 10b) for $\zeta\tau_0$ in Eq. (A.11) gives the following:

$$\mathcal{J} = \phi^2 h/mv, \tag{A.12}$$

If Eq. (A.12) is divided by ϕ an equation analogous to Bohr-de Broglie notions serving a theoretical context, quantization and multiplicity of de Broglie wavelength is the outcome. Though implicitly located elsewhere the equation below needs to be stated for orderly reference as follows:

$$\lambda = h/mv, \tag{A.13}$$

Therefore, Eq. (A.12) becomes the following:

$$\mathcal{J} = \phi^2\lambda, \tag{A.14}$$

Meanwhile,

$$\mathcal{J} = \phi s, \tag{A.15}$$

where s is the regarded as the distance (it can also be the de Broglie wavelength of a hypothetical particle in motion) covered in time, τ_0 at the velocity, v, which is ϕ times less than, v_0. Therefore, dividing Eq. (A.14) by ϕ yields the following:

$$s = \phi\lambda, \tag{A.16}$$

Solving for ϕ in Eq. (A.16), gives the following:

$$\phi = \mathrm{s}/\lambda, \tag{A.17}$$

Or,

$$\phi = v\tau_0/\lambda\,, \tag{A.18}$$

Equation (A.18) implies that $s = v\tau_0$ as stated earlier. Substituting Eq. (A.13) for λ in Eq. (A.18) gives the following:

$$\phi = mv^2\tau_0/h, \tag{A.19}$$

Substituting respectively, Eq. (A.19) and Eq. (A.13) for ϕ and λ in Eq. (A.14) gives the following:

$$\mathcal{J} = mv^3\tau_0^2/h, \tag{A.20}$$

Dividing Eq. (A.20) by τ_0 gives the following:

$$v_0 = mv^3\tau_0/h, \tag{A.21}$$

Where $v_0 = \mathcal{J}/\tau_0$

At this juncture, there may be a need to recall the fact that both particles of the same momentum possess the same wavelength, and so, the following equation is a possibility.

$$\zeta_0 = v_0/\lambda, \tag{A.22}$$

Substituting Eq. (A.21) into Eq. (A.22) to give the following:

$$\zeta_0 = mv^3\tau_0/h\,\lambda, \tag{A.23}$$

In place of λ in Eq. (A.23) Eq. (A.13) could be used to obtain the following:

$$\zeta_0 = m^2v^4\tau_0/h^2, \tag{A.24}$$

Recall and square Eq. (A.19) and obtain after rearrangement the following:

$$\phi^2\tau_0^2 = m^2v^4/h^2, \tag{A.25}$$

Next, substitute Eq. (A.25) into Eq. (A.24) to give the following:

$$\zeta_0 = \phi^2/\tau_0, \tag{A.26}$$

Meanwhile, $\zeta = \phi/\tau_0$ and so,

$$\zeta_0 = \phi\,\zeta, \tag{A.27}$$

Thus,

$$\zeta_0 = \phi mv^2/h \tag{A.28}$$

Note that,

$$h\zeta = mv^2, \tag{A.29}$$

Equation (A.28) is rearranged to give the following:

$$h\,\zeta_0 = \phi mv^2, \tag{A.30}$$

Divide Eq. (A.30) by ϕ^2 to give the following:

$$h\,\zeta_0/\phi^2 = m_0v^2, \tag{A.31}$$

Multiplying Eq. (A.31) by m_0 to give the following:

$$m_0h\,\zeta_0/\phi^2 = m_0^2v^2 \tag{A.32}$$

Taking the square root of Eq. (A.32) gives the following:

$$m_0 v = \left(m_0 h\, \zeta_0/\phi^2\right)^{½},$$

$$= \left(mh\, \zeta_0/\phi^3\right)^{½} \text{ (Recall that } m_0 = m/\phi), \quad \text{(A.33)}$$

Substituting Eq. (A.28) into Eq. (A.33) gives the following:

$$m_0 v = \left(m^2 v^2/\phi^2\right)^{½}, \quad \text{(A.34)}$$

Next, substitute Eq. (A.19) into Eq. (A.34) to give the following:

$$m_0 v = (m^2 v^2 h^2/m^2 v^4 \tau_0^2)^{½} = h/v\tau_0, \quad \text{(A.35)}$$

However,

$$m_0 v = mv/\phi = mu = h/v\tau_0, \quad \text{(A.36)}$$

Thus,

$$u = h/mv\,\tau_0, \quad \text{(A.37)}$$

Or,

$$u = h/ms, \quad \text{(A.38)}$$