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Surface tension mediation by Na-based ionic polarization and acidic fragmentation: Inference of hypertension

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ABSTRACT

Overdosing of Na(Cl, $C_5H_8NO_4$) can raise one's blood pressure but moderately intaking of $C_6H_8O_6$ ascorbic and $C_2H_4O_2$ acetic acids effects contrastingly with mechanisms yet to be clear. From the perspective of hydrogen bond (O:H—O or HB with ":" being electron lone pairs of oxygen) cooperativity, we show phonon-spectrometrically that solvation of the Na-based doses raises their solution surface tension by ionic polarization, but solvation of the organic acids performs contrastingly by dipolar fragilization. The Na-based doses dissolve into Na^+ cations and anions that serve each as a charge center to cluster, stretch, and polarize the solvent O:H—O bonds, raising the viscosity of the solution. However, the acidic dipoles break the solvation network into small fragments, helping to the blood flowing. Findings could offer workable mechanisms for hypertension medication and prevention.

1. Introduction

Having been recognized as increasing risk for coronary artery disease [1,2], heart failure [3,4], stroke [5], chronic kidney disease [6,7], and cardiovascular diseases [8], hypertension or high blood-pressure has affected an increase number of people, estimated up to 1.5 billion by 2025, all around the world without receiving deserved attention [9]. Compared with many other diseases, hypertension has no apparent symptoms, so it is called the "silent killer" that threatens the human health gradually [10,11]. The British Hypertension Society guidelines [12] and those outlined by the US National High BP Education Program [13] suggested that one has to change lifestyle to prevent hypertension by reducing dietary aginomoto and salt intake and eating more fruits and vegetables of slightly acidic.

Salt (NaCl) and sodium glutamate ($NaC_5H_8NO_4$) are widely used in food to enhance flavor and to provide umami sodium glutamate [14]. However, overdosing both of them can raise the systolic and the diastolic blood pressure [15–19]. In 1968, Kwok [20] firstly realized that sodium glutamate is the main cause of the "Chinese restaurant" syndrome – people like eating food with heavily-dosed aginomoto. The fact of Na-based ingredient on raising blood pressure was explained as that the Na-based doses reset the hypothalamic neuronal activity [18].

Moderate intaking fruits and vegetables that are rich in ascorbic acid (vitamin C) can lower the blood pressure, instead [21], and hence, ascorbic acid is a useful adjunctive therapy for effectively relieving hypertension [22–25]. Mullan et al. [23] studied the hemodynamic effect of oral supplementation of ascorbic acid in a random double-blind trial and suggested that ascorbic acid lowers the blood pressure by enhancing endothelial nitric-oxide biological activity. What is more, acetic acid, which is abundant in vinegar, as another familiar acid can lower blood pressure by reducing renin activity and Angiotensin II according to Kondo et al. [26]. However, the underlying mechanism for the acid and salt effect on meditating blood pressure is still unclear though focus has been on the pathology wise.

Blood is composed of its cells and 70% water that dissolves the Na-based salt into Na^+ cations and anions and the organic acids into individual molecular dipoles surrounded asymmetrically by H^+ and electron lone pairs ":". These solutes react with the hydrogen-bonding network and blood cells in turn through ionic polarization [27,28] and dipolar fragilization [29] as the H↔H anti-HB does in the H-based acid [30]. These facts may clarify how the Na(Cl, $C_5H_8NO_4$) and the $C_6H_8O_6$ ascorbic and the $C_2H_4O_2$ acetic acid mediate the blood pressure. Consistence between theory predictions and the spectrometric and surface-tension detection reported here verifies that the ionic polarization enhances but the molecular fragilization relieves the hypertension. Understanding may offer insight into the physical fundamentals behind hypertension toward effective medication and prevention though medication field may use different terms.

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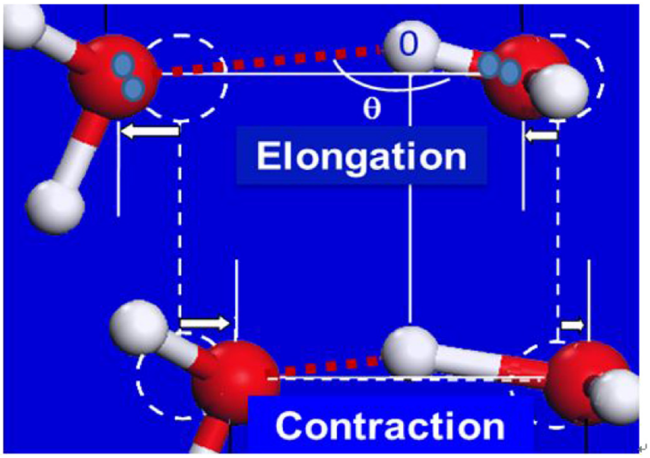

Fig. 1. O:H-O bond segmental length cooperativity. Any relaxation of the O:H—O bond proceeds by elongating one part and contracting the other with respect to the H^+ coordination origin. The softer O:H always relaxes more than the stiffer H—O does. The ∠O:H—O containing angle θ contributes insignificantly to the segmental length and energy (reprinted with copyright permission from [31]).

2. Principles

2.1. O:H—O bond cooperativity

Fig. 1 illustrates the O:H-O bond cooperativity notion [31]. As the basic motif of water ice and the solution matrix, the O:H-O bond intergrates the stronger intramolecular H—O bond (length $d_H - 1.0$ Å, energy $E_H - 4.0$ eV, vibration frequency $\omega_H - 3300$ cm^{-1}) and the weaker intermolecular O:H nonbond ($d_L - 1.7$ Å, $E_L - 0.1$ eV, $\omega_L - 200$ cm^{-1}) under the ambient conditions, which forms an asymmetrical, short-range oscillator pair coupled by O—O Coulomb repulsion [31]. The O:H—O segmental disparity and the O—O repulsivity dictate the extraordinary adaptivity, flexibility, recoverability, and sensitivity of water and ice under perturbation [28]. An external excitation dislocates O^{2-} anions (red) along the O:H—O bond in the same direction but by different amounts associated with polarization that stiffens the entire O:H—O bond. The longer and softer O:H always relaxes more than the H—O bond.

2.2. Vibration frequency and surface tension

Raman scattering has been widely used to resolve relaxation of the entire HB network under external perturbation. One can probe the variation of the O:H—O bond segmental (length d_x, energy E_x, vibration frequency $\omega_x \propto \sqrt{E_x/d_x}$) upon perturbation [31]. The subscript x = L and H corresponds to the low-frequency O:H non-bond vibration and the high-frequency H—O phonons, respectively.

Variation of contact angle between the glass substrate and the liquid droplet features the solution viscosity and surface tension. Ionic polarization raises the surface tension but acid fragmentation performs contrastingly [28,31]. With the aid of Raman differential phonon spectrometrics and contact angle detection, we have resolved the transition of the HB from the mode of ordinary water to hydration upon solvation of acid [30,32], base [33], salt [27,34], alcohol [35], sugar [36], and

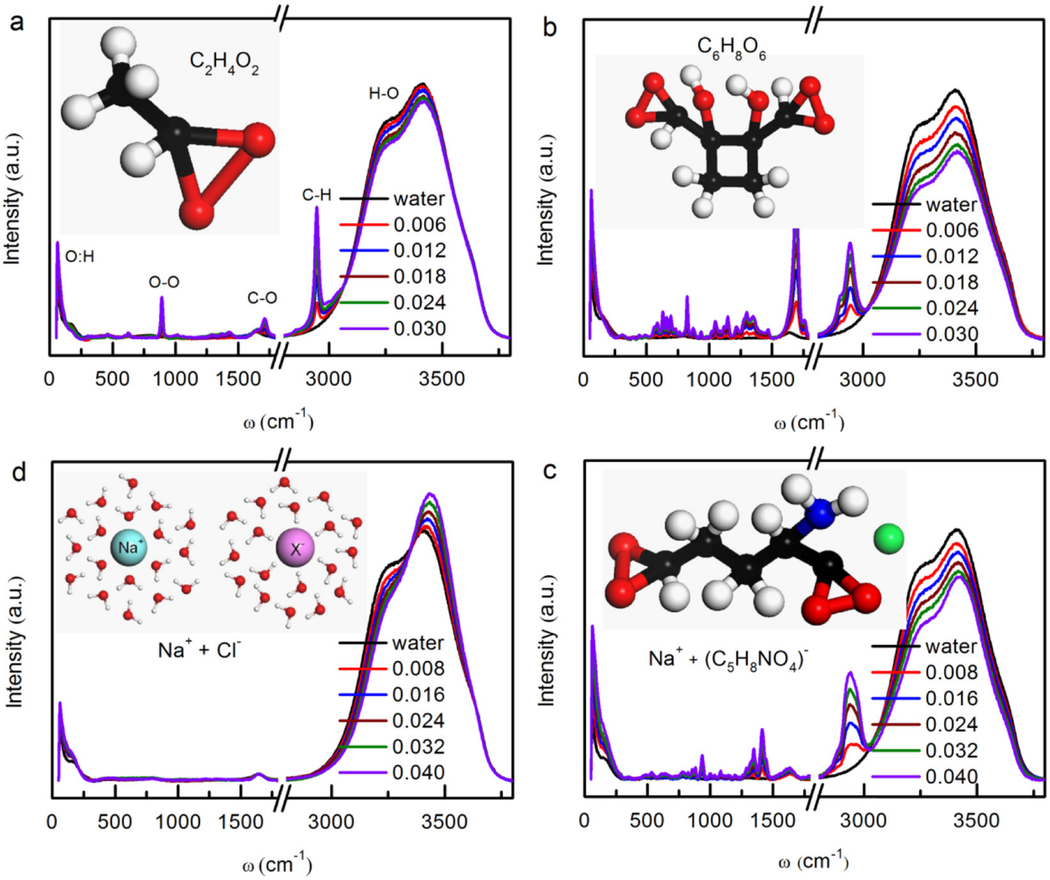

Fig. 2. Full-frequency Raman spectra for the concentrated (a) $C_2H_4O_2$ acetic acid, (b) $C_6H_8O_6$ ascorbic acid, (c) $NaC_5H_8NO_4$ glutamate and (d) NaCl salt. Panel (a) denotes the solute intramolecular bond vibrations within 500 and 3000 cm^{-1} regime. Insets show the corresponding molecular structures surrounded by H^+(white) and lone pairs associated to O^{2-} (red), and Carbon (black). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)