Preparation of High-Concentration Charged Solutions via a Dual Electrostatic Method for Ice Crystallization and Desalination

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Date: 2024-03-26T00:00:00+00:00

Abstract

Under typical circumstances, it is commonly believed that solutions carrying a single type of charge are either non-existent or unstable. We have investigated the principles of high-concentration charged solution preparation techniques, employing methods such as electrostatic attraction, gravity separation, positive feedback, and self-powered mechanisms to effectively separate anions and cations in solution. Through electrostatic repulsion and the use of electrostatic separation networks, the partition of homoelectric ions has been achieved. Through water and electric separation, the capability for sustained accumulation of single-charge species has been attained, thus overcoming application bottlenecks and establishing evidence for the existence of charged solutions. We have proposed voltage limits and predicted phenomena such as electrostatic boiling, topological ice crystals, and strange ice crystals, thereby opening new perspectives and possibilities for enriching the understanding and research of electrostatics and electrochemistry. The introduction of the high-concentration charged solution and its controllable preparation are expected to facilitate or pioneer research in various fields including seawater desalination, wastewater treatment, hydrovoltaic power generation, and topological ice crystals, etc. This advancement holds the potential to rectify relevant discussions in textbooks. Implementing the dual electrostatic method for self-powered desalination and purification, coupled with wind, solar, and pumped hydro storage technologies, can aid in mitigating the intermittency and waste of wind and solar power, thus advancing the cause of seawater for land.

Full Text

Preparation of High-Concentration Charged Solutions through Dual Electrostatic Method for Ice Crystals and Desalination

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Abstract

Under typical circumstances, solutions carrying a single type of net charge are commonly believed to be either non-existent or unstable. We have investigated the fundamental principles underlying the preparation of high-concentration charged solutions, employing methods such as electrostatic attraction, gravity separation, positive feedback mechanisms, and self-powered systems to effectively separate anions and cations in solution. Through electrostatic repulsion and the deployment of electrostatic separation networks, we have achieved the partitioning of like-charged ions. By separating water from electric charge, we have attained the capability for sustained accumulation of single-charge species, thereby overcoming critical application bottlenecks and establishing definitive evidence for the existence of charged solutions. We propose voltage limits and predict phenomena including electrostatic boiling, topological ice crystals, and strange ice crystals, opening new perspectives and possibilities for advancing the understanding and research of electrostatics and electrochemistry. The introduction of high-concentration charged solutions and their controllable preparation are expected to facilitate or pioneer research across various fields including seawater desalination, wastewater treatment, hydrovoltaic power generation, and topological ice crystals. This advancement holds the potential to rectify relevant discussions in textbooks. Implementing the dual electrostatic method for self-powered desalination and purification, coupled with wind, solar, and pumped hydro storage technologies, can help mitigate the intermittency and waste of renewable energy, thus advancing the cause of utilizing seawater for terrestrial applications.

Keywords: Dual electrostatic method; Charged solution; Topological ice crystal; Desalination and water purification; Electrostatic boiling

1. Introduction

It is generally believed that solutions with a single type of net charge are either nonexistent or unstable. Fundamental questions—such as whether a glass of water can sustain tens of thousands of volts, how to induce such high voltage in water, and what its macroscopic and microscopic states would be—have rarely been addressed. Research on high-concentration charged solutions remains largely unexplored across four key unresolved scientific questions: (1) the very existence of charged solutions and high-concentration charged solutions; (2)

methods for preparing such solutions; (3) the distribution and specific properties of ions, charges, and charged particles within them, including storage limits and stability; and (4) their application scenarios and underlying technological principles.

The introduction and controllable preparation of high-concentration charged solutions could catalyze theoretical research and practical applications in electrostatics, electrochemistry, seawater desalination [?], wastewater treatment, nuclear wastewater treatment, hydrovoltaic power generation [?], frictional electricity [?], clean energy, water splitting, crystal preparation, strange metals, the Hall effect, electrostatic boiling, topological ice crystals, and beyond. This may give rise to a series of related materials, devices, and apparatus for fundamental research and technological development, offering a plethora of application scenarios.

This paper proposes and explores ten novel concepts: charged solutions, high-concentration charged solutions, charged ice crystals, topological ice crystals, conductive ice crystals, strange ice crystals, electrostatic boiling, anomalous Hall effect of dual-state charge carriers in equipotential bodies, self-powered desalination with dual electrostatic method, and seawater for land.

As human activities expand and environmental pollution worsens, the scarcity of clean water is becoming increasingly severe [?]. Water pollution is considered the most pressing issue in global public health challenges, with nearly one-third of the world' s population lacking access to clean drinking water. For example, in coastal desert regions, power outages from disasters can shut down desalination plants, creating severe dehydration crises for local residents. The World Health Organization reports that millions of children under five die annually from diarrheal diseases related to unsafe water containing heavy metal ions [?]. Nuclear wastewater typically contains large amounts of radioactive elements such as uranium, plutonium, cesium, strontium, iodine, and cobalt in dissolved charged forms, which must be removed during seawater desalination.

Xu Xiao et al. conducted experiments using a laboratory-made vertical electric field electrophoresis device to study desalination of simulated seawater, investigating the effects of initial chloride concentration (466.4–862.0 mg/L NaCl solution), retention time (2–10.3 hours), and voltage (10–36 volts) on desalination rate, energy efficiency, and distribution ratio, achieving a maximum desalination rate of 69.5% [?]. The positive feedback dual electrostatic method for self-powered desalination proposed in this paper offers five advantages over traditional electrophoresis: (1) External power sources are non-essential; the system can provide stable voltages of 1–10 kilovolts or higher through metal containers, stainless steel mesh, and conductors, making it suitable for emergencies; (2) Easy modification—only a positive feedback loop needs to be added at the lower end of traditional instrument outlets; (3) Traditional electrophoresis uses positive and negative electrodes to generate an electric field directly in seawater, where mutual attraction between ions tends toward uniform distribution. Weak fields yield insignificant desalination, while strong fields increase mutual attraction, separation difficulty, and energy consumption. Our dual electrostatic method with positive feedback achieves separation through electrostatic attraction under gravity, then further separates ion-containing water (pipe edge) from clean water (pipe center) via electrostatic repulsion, avoiding uniform distribution and improving desalination rates; (4) Wind and photovoltaic technologies can lift water for energy storage while preparing pure water in situ at sea; and (5) Using stainless steel meshes for water-permeable power generation enables potential energy recovery and desalination, advancing the exploration of seawater for land.

This article initiates exploration in the following research areas: charged solutions, high-concentration charged solutions, charged ice crystals, topological ice crystals, conductive ice crystals, strange ice crystals, electrostatic boiling, anomalous Hall effect of dual-state charge carriers in equipotential bodies, self-powered desalination with dual electrostatic method, and seawater for land. The application prospects include: (1) Desalination, seawater desalination, and nuclear wastewater treatment; (2) Hydrovoltaic power generation, sterilization, sensing, warning, and rainwater utilization; (3) Absorption of abandoned wind and solar energy, in-situ clean water production at sea, and water supply for islands; (4) Preparation of CuCl crystals through comproportionation of Cu^{2+} and Cu; (5) Photolysis of water; (6) Providing new reaction pathways and raw materials for chemistry, biology, chemical engineering, and pharmaceuticals; and (7) Preparation, properties, and applications of charged ice crystals, topological ice crystals, conductive ice crystals, and strange ice crystals, potentially inspiring photolithography techniques.

2. Methodology

This study employs the CASTEP software package based on density functional theory (DFT) using the first-principles plane-wave method. The exchange-correlation term is treated within the generalized gradient approximation (GGA) using the Perdew-Burke-Ernzerhof (PBE) functional, with the Grimme method correcting long-range interactions between molecular crystals or substrates and gas molecules. As a comprehensive introduction to novel concepts and frameworks in a new field involving numerous models, detailed parameter settings will be thoroughly explained in forthcoming papers. For example, when simulating graphene adsorbing water molecules, a 5$×5×1supercellischosenwitha2nmvacuumlayerinthez−direction, aplane−wavecutoffenergyof575eV, k−pointgridsof3×3×1and6×6×1forgeometryoptimizationandelectronicstructu
consistentfieldconvergencecriterionof5×10^{-7}$ eV. The Sorption module uses the grand canonical Monte Carlo (GCMC) method to simulate water adsorption on graphene under high-temperature fixed gas pressure conditions, employing a 14$×14×1supercellwitha3nmvacuumlayer, Metropolissampling, theUniversalforcefield, andtheE
and precision set to Ultra-fine. VASP, Forcite, and COMSOL Multiphysics packages will be gradually employed in subsequent studies.

Similarly, material processing involves specific procedures tailored to different subjects. Given the broad scope and extensive content, details will be elaborated in subsequent series of papers. Based on the research content, the project adopts the following experimental methods: (1) Solution method—using water or volatile liquids to ultrasonically disperse micro/nano particles/fibers, preparing materials such as Al_2O_3, SiO_2, amino-functionalized carbon nanotubes, carboxyl-functionalized carbon nanotubes, graphene, amino-functionalized graphene, carboxyl-functionalized graphene, and ferrite; (2) Material functionalization—using mechanical grinding, high-temperature treatment, acid-base modification, hydrothermal modification, and plasma methods; (3) Molten salt and H_2O_2 exfoliation methods—intercalating $FeCl_3$ into graphite via molten salt method and exfoliating $FeCl_3$ interlayers with H_2O_2 to prepare graphene; (4) "Concrete" assembly/sintering method—assembling micro/nano particles with metal conductive grids to construct capillary network channels; (5) Cold extraction and freeze-drying methods—for preparing quasi-one-dimensional nano coils or three-dimensional agglomerates; (6) Cutting and processing method—purchasing commercial metal foam and cutting it into curved surfaces that closely combine with external metal barrels; (7) Welding method—using electric welding to curve external metal barrels; (8) Instrument characterization methods—using X-ray diffractometer, transmission electron microscope, scanning electron microscope, and Fourier transform infrared-Raman spectrometer to determine material structure; and (9) Performance testing methods—using static electricity testers, micro/nano ammeters, multimeters, and digital oscilloscopes to measure current, voltage, open-circuit voltage, and short-circuit current, with ion content measured by titration.

3. Results and Discussion

As shown in Figure 1a [Figure 1: see original paper], under an external electric field, Cl^- and Na^+ in aqueous solution migrate to opposite sides. The electrodes do not contact the solution, quickly dividing it into two parts. In theory, a solution with a single net charge type can be obtained without violating charge conservation or other physical and chemical laws. This simple model has not appeared in textbooks or academic research at any level, and the lack of theoretical investigation has prevented definitive answers regarding the existence of high-concentration charged solutions. After preparing a single-charge solution, questions remain about its stable existence, the state of microscopic ions, and its charge-bearing limit. Referring to charge distribution in metal conductors under electrostatic equilibrium—where charges reside stably on the surface—a charged solution should similarly achieve stability within an acceptable range through Coulomb repulsion. Ions, charges, and charged particles distribute within an atomic-scale surface layer, enabling research into quantum size effects, topological insulators, and multiple areas spanning forces, magnetism, optics, acoustics, heat, electricity, superconductivity, and chemistry. Meanwhile, the fluidity of solutions endows charged solutions with unique physicochemical properties and diverse applications. For instance, in "strange metals," electricity flows like water, contradicting Landau' s Fermi liquid theory [?]. The electrical properties of strange metals have long puzzled quantum physicists, who cannot explain why charges seem to "dissolve" inside them. The flow of high-concentration charged solutions into capillary/nano-conductive network structures composed of hydrovoltaic materials with opposite electrical properties can be viewed as a larger-scale model of strange metals, potentially enhancing understanding and leading to reassessment of charge transport mechanisms and discovery of novel phenomena.

The single electrostatic method uses electrostatic plates (which can be removed; shown in Figure 2 [Figure 2: see original paper] for clarity) to generate an initial electrostatic field, creating differential distribution of positive and negative ions near the outlets. Under gravity, water droplets carrying corresponding ions fall through hollow conductive rings into different metal buckets. The buckets connect to opposite hollow conductive rings via wires to form equipotential bodies. As one side continuously accumulates anions or cations, the opposite hollow conductive ring generates more like charges, producing increasingly strong electrostatic forces that attract more oppositely charged water droplets. At this point, the electrostatic effect from the hollow conductive ring far exceeds the initial field from the electrostatic plate. This positive feedback mechanism [**?**] exponentially increases ion concentrations in both buckets, forming charged solutions. However, the limited bucket volume cannot accommodate more solution, terminating the process once filled.

Experimental Video: https://www.bilibili.com/video/BV1DZ4y1J7Uj/?spm_{{{id}}*{{from}}}=333.999.0*

The designed dual electrostatic method has achieved effective separation of anions and cations (Figure 2, electrostatic attraction, gravity coercion) using a strategy of removing water while retaining charges (Figure 3 [Figure 3: see original paper], electrostatic repulsion, hydroelectric separation). Based on electrostatic repulsion principles (Figure 3a, where no charges exist inside equipotential bodies), like-charged ions in the solution are forced outward, causing fewer ions to exit while more charged droplets enter, increasing total charge and achieving water-permeable power generation. This crucially enables continuous charge replenishment, allowing preparation of high-concentration charged solutions within minutes at static voltages of 27,000 volts. As shown in Figures 3c-d, using metal foam as a base and filling the interior with stainless steel mesh (average pore size 0.03 mm) creates a simple water-electricity separation network. Water flows continuously with an average voltage around 22,000 volts (Figure 3b), laying the foundation for overcoming application bottlenecks.

Experimental Video: https://www.bilibili.com/video/BV1RA4m157Nz/?spm_{{{id}}*{{from}}}=333.337.*
card.all.click&vd{source}=d1aa9b9c9480b62215fc589302004419

However, our current makeshift device considers too few influencing factors and has not reached its voltage limit. The material selection, structural design, and charge accumulation stability in the water-electricity separation zone (the electrostatic repulsion/charge accumulation zone), along with overall device architecture, urgently require optimization. We have multiple proposals from various perspectives—force interactions, charge distribution, splash prevention, internal/external interference, constrained pipelines, equipotential body segmentation, high-pressure jetting, reflow/reseparation mechanisms, ePTFE phase-change dewatering, central liquid extraction, etc. For example, future designs will optimize the structure shown in Figure 3b. The conductive plate encasing the separation network will feature high-curvature tips to support high charge surface density and facilitate charge export (power output), while water outlets will be located at gentle, small-curvature arc tops. The small curvature yields lower charge density, and the arc top position generally leans inward compared to bottom tips, favoring charge movement to exterior bottom tip positions. Additionally, water outlet apertures should be minimized while controlling flow rates to avoid charge loss. When exploring voltage limits, high-voltage insulating rings could separate outlets from conductive plates/networks, with ring voltage exceeding that of the charged solution to repel ions inward while allowing water molecules to flow freely. However, for practical desalination applications, the self-generated voltage (>1000 volts) from stainless steel mesh far exceeds electrodialysis reference values (10–36 volts), making high-voltage insulation rings unnecessary for pursuing limit voltages.

As shown in Figure 4a [Figure 4: see original paper], a metal basin containing charged solution was detached from the preparation apparatus and exposed to air while measuring electrostatic voltage at a distance using an electrostatic voltmeter (SIMCO FMX-004). Starting at 6200 V, voltage decreased to 3600 V after 60 s, 970 V after 300 s, and 370 V after 600 s. The charged solution remained stable in air, maintaining relatively high voltage within one minute. Placing it in a sealed space filled with like-charged gases (e.g., negative ion air) or common gases like nitrogen or neon (even simple hood coverage can deplete charge in limited air volume) may significantly delay voltage decline. For reference, Van de Graaff generators take several minutes to tens of minutes to discharge after stopping operation in air. Solid-state Van de Graaff generators can reach 5 million volts in air, while thunderclouds (gaseous/mixed states of water, ice crystals, and air) range from tens of millions to billions of volts. What is the voltage limit for high-concentration charged solutions (liquid state)? With ions/charges/charged particles confined to the liquid surface within a solid container, can the liquid withstand significant electrostatic repulsion with container assistance? Is there an insurmountable theoretical limit? Theoretically, electrostatic repulsion exceeding surface tension would tear the liquid apart. However, when a charged solution is stored in a solid container, the container can bear all or part of the electric field repulsion, bypassing Rayleigh' s limit. Therefore, the upper voltage limit of charged solutions should approach that of solids, offering tremendous enhancement potential. Figure 4b depicts the predicted "electrostatic boiling" phenomenon and its principles. A charged solution within insulating walls is drawn from the center while protective inert gas is introduced at the top. As charged ion concentration increases, electrostatic forces strengthen. When repulsion exceeds surface tension, the solution surface tears apart, creating a "boiling" phenomenon.

In pure ice, strong hydrogen bonding between water molecules forms an ordered lattice structure that impedes ion movement, making saltwater ice almost non-conductive because chloride and sodium ions are bound and immobile (Fig. 5a [Figure 5: see original paper]). "Charged solution" is produced by treating low-temperature or supercooled water with the dual electrostatic method, then freezing in liquid nitrogen or a refrigerator to obtain "charged ice crystals" (Fig. 5b). While ions cannot move within solid ice, they can be positioned during expansion before freezing, creating a single electrical charge on the ice crystal surface. This "solid-liquid transition" enables preparation of "topological ice crystals." Based on their unique electronic structure, the conductivity, electric field distribution, potential difference, dielectric properties, electrostatic effects, electrical breakdown, refraction, and scattering behavior of ice crystals will all change. Contrary to expectations, our study of ion-doped ice surfaces revealed that quasi-two-dimensional pure ice has a band gap of 0.138 eV, while charged quasi-two-dimensional ice exhibits a band gap of 3.526 eV (Fig. 5c-f).

The existence of two-dimensional ice has been experimentally verified by Chinese scientists in recent years, termed "2D Ice I phase." However, specific research on its conductivity lacks definitive information in current literature, necessitating further investigation. While ice is an insulator, two-dimensionalization may alter its physical and chemical properties, including conductivity. Current research remains insufficient for conclusive outcomes, with significant discrepancies in band gap values among few-layer to multi-layer configurations, different exposed facets, various charge doping modes, and distinct structural arrangements (Fig. 6c [Figure 6: see original paper]). The asymmetrical and non-equilibrium configurations of elements, orientations (Fig. 6a), arrangements, charges, electric fields, magnetic fields, and force fields (Fig. 6b) can unravel the "Pandora' s box" of "strange ice crystals," presenting infinite possibilities.

As shown in Figure 7a [Figure 7: see original paper], we explore the voltage limit for preparing charged solutions using the positive feedback dual electrostatic method from multiple perspectives: force interactions, charge distribution, splash prevention, internal/external interference, constrained channels, equipotential body segmentation, high-pressure jetting, reflow/reseparation mechanisms, and ePTFE phase-change dewatering. If positive hydrovoltaic materials (e.g., amino-functionalized carbon nanotubes) and negative hydrovoltaic materials (e.g., carboxyl-functionalized carbon nanotubes) are assembled with metal conductive grids in a "concrete" structure, water droplets contacting the amino-functionalized carbon nanotubes become positively charged, while freely mobile negative charges ionize and exit with the water through the outlet. Consequently, the water-electricity separation network containing amino-functionalized carbon nanotubes exhibits overall positive charge, inducing positive charges on interconnected hollow conductive rings that attract negative charges in the water tank to the opposite side. Similarly, carboxyl-functionalized carbon nanotubes induce negative charges that attract positive charges. The positively charged network receives positive droplets while the negatively charged network receives negative droplets, forming an enhanced positive feedback loop. After charged droplets enter and fully contact the conductive grids, electrostatic repulsion forces countless moments of motion into a static equilibrium where charges exist only on the conductor surface, moving toward the network periphery. Since the network itself carries fixed positive or negative charges, mobile charges experience additional repulsion, accelerating toward the edges.

Periodic charge structures such as gratings, photonic crystals, or periodically arranged nanostructures can control light by modulating interference, diffraction, and scattering. In charged photonic crystals, charge distribution can modulate refractive index, affecting light propagation (Figure 7b). "Charged ice crystals," "topological ice crystals," "conductive ice crystals," and "strange ice crystals" offer new avenues for researching topological conductors, electro-optical effects, optoelectronic devices, optical communication, sensing, imaging, fluorescence labeling, quantum structure fabrication, lithography, and superconductivity. This research can provide "charged solutions" of specific elements. With frozen ion movement constrained, alternating freezing and stacking of anion/cation charged solutions (Figure 7c) can construct periodic structures several molecular layers thick (Figures 7f-g) exhibiting semiconductor properties (Figure 7e).

As shown in Figures 8a-b, the original copper foil used for graphene growth (CVD method) has a flat, glossy surface with excellent conductivity and ductility, suitable for conductive container walls. We rapidly prepared sheet-like, three-dimensional, rod-like, and hollow cubic CuCl crystal materials on copper foil surfaces using copper chloride solution at the solid-liquid interface (Figure 8d), obtaining ultra-thin CuCl sheets only a few nanometers thick (Figure 8e). This occurred without catalysts or additional conditions—simply dripping copper chloride solution onto copper foil caused instantaneous reaction, transforming the glossy surface into a rough, earthy yellow color (Figure 8a). Initially, during graphene preparation, $FeCl_3$ was used to corrode copper substrates to obtain various CuCl crystals, but only preparation conditions and characterization results were recorded (CrystEngComm, 2016, 18, 3340-3342) [?] without thorough mechanism analysis. Currently, opportunities exist to combine our method with: (1) using the positive feedback dual electrostatic method to separate $CuCl_2$ solution, creating Cu^{2+}-excess and Cl^--excess sides, where copper containers or inserts enable $Cu + CuCl_2 \rightarrow 2CuCl\downarrow$ to eliminate incompletely separated Cu^{2+} and prepare pure Cl^- charged solutions; (2) investigating how Cl^- and Cu^{2+} separately affect CuCl crystal growth at interfaces, enriching morphology and exploring mechanisms, where Cu^{2+} may play a role similar to Fe^{3+}; and (3) constructing solution models for in-depth research using theoretical calculation tools and crystal growth knowledge. Our method provides specific multi-ion interfaces with unique advantages for enriching crystal morphology and studying formation mechanisms.

As shown in Figure 9a [Figure 9: see original paper], seawater/saline water flows in a zigzag path through ion separation tubes configured to enhance solution flow and electrostatic interaction time. Due to electrostatic attraction from plates (lasting minutes to hours), anions and cations flow to respective sides. The bottom layer has three outlets: two side outlets for primary ionized water (anion and cation solutions) and a central deionized water outlet extending to the next saline tank for further electrostatic separation (similar to traditional electrophoresis but self-powered and high-voltage). Below the deionized water outlet, a cylindrical extended electrostatic separation duct contains a turbine for potential energy recovery. External electrostatic plates stabilize and attract static electricity. When charged water enters the duct, self-repulsion drives charges peripherally (self-propulsion), while external plates with opposite charges cause ion accumulation at edges, enabling decentralized separation in spiral ducts. Secondary ion tanks store anions and cations separately. Connecting electrostatic plates on both sides of the ion separation tube with lead wires forms a positive feedback loop, causing exponentially increasing charged ions in secondary tanks and sharply increasing electrostatic voltage. Multiple ion separation tube stages can further improve desalination efficiency. This model utilizes dual electrostatic attraction/repulsion and positive feedback to generate strong electric fields for efficient anion/cation separation, preparing high-concentration charged solutions and pure water to increase desalination rates.

Utilizing wind power, photovoltaics, and pumped storage can absorb wasted renewable energy, enabling in-situ pure water production offshore. Stainless steel meshes enable water-permeable power generation, aiding potential energy recovery and desalination, providing theoretical feasibility for “seawater for land.” As shown in Figure 9b, Yancheng City’ s average elevation is less than 5 meters and Beijing’ s is 43.71 meters, making the “seawater for land” project comparatively feasible. Referencing Phase I of the South-to-North Water Diversion Project, water is pumped from the Huangjinxia intake at 70 cubic meters per second into a tunnel 119 meters above water level, achieving natural flow. Taking Yancheng as an example, photovoltaic and wind power can elevate seawater to 30 meters, creating height differences with the land. Transportation pipelines slope gently downward at 0.5-1 meter per kilometer, allowing natural flow. Electrostatic plates are installed on both sides, with power generation/diversion nodes and concentrated saltwater pipelines between adjacent sections. Nodes have 1-meter height differences with clean water and brine tanks at the upper end. Demineralized water flows forward along the slope, while brine tank water flows down through hollow metal barrels into water-electricity separation zones. Stainless steel mesh serves as the conductive framework, with wires connecting separation networks and hollow conductive rings to form positive feedback circuits. This converts gravitational potential energy into electrical energy, providing voltage to metal rings and electrostatic plates. Beneath the separation network center is the demineralized water pipeline, with concentrated saltwater pipeline at the edge. Low-ion water flows out to continue forward, while high-concentration water flows out for potential energy recovery and salt production. After ten pipeline sections with repeated separation, seawater salinity decreases to freshwater range, achieving "seawater for land." Beijing, over 100 kilometers from the coast, could elevate water to 60 meters, eliminating diversion nodes and allowing direct city flow. Long-distance, slow movement benefits electrostatic attraction efficiency and facilitates multi-stage desalination, self-power generation, self-flow, self-purification, and salt production.

What special properties do high-concentration charged solutions possess? The Hall effect, known as the queen of solid-state transport experiments, can play roles both in preparation and in exploring related laws: (1) Magnetic fields can induce directional polarization of water' s dipole molecules, altering electron clouds to bend and locally break hydrogen bonds, enabling single-molecule water movement that increases diffusion coefficients and decreases viscosity, benefiting ion migration and improving electro-adsorption; (2) Magnetic fields affect magnetic force couples on salt molecules/ions, altering hydration states and modifying salt solubility to eliminate crystallinity and prevent large crystal formation; (3) Moving charged particles experience Lorentz force in magnetic fields, with research value for synergistic ion removal and conditions for anomalous Hall effect (isopotential body dual-state carrier anomalous Hall effect), potentially increasing hydrovoltaic conversion efficiency tenfold; (4) Short-term magnetic exposure can act as a "catalyst" changing activation energy to overcome barriers; (5) Hall and anomalous Hall effects have obvious phenomena, widespread applications, and reliable detection; and (6) Based on stable apparatus and precise laws, future research can combine hydrovoltaic materials with capillary structures to construct high-scale "strange metal" channels.

In non-magnetic metals or semiconductors, electrons (or holes) driven by electric field (E) undergo Lorentz force deflection under perpendicular magnetic field (B), creating potential difference (V_H) and charge accumulation on sample surfaces—the Hall effect (Figure 10a [Figure 10: see original paper]). However, magnetic fields are not necessary for the Hall effect. The anomalous Hall effect occurs without external magnetic fields when ordered spontaneous magnetization (M) in magnetic materials deflects electron trajectories (Figure 10b). Near the Fermi surface, unequal spin-up and spin-down electron populations deflect in opposite directions under electric field due to spin-related scattering and spin-orbit coupling, creating spin polarization (spin current) and potential difference (V_H) at interfaces. Gravity drives ion-containing water flow through permanent magnetic water-electricity separation networks with abundant capillary channels, where the network acts as an external magnetic field source for each capillary flow (consistent with normal Hall effect), causing directional separation of liquid carriers (Na^+ or Cl^-). Countless capillary flows with like charges in ferromagnetic materials are equivalent to countless currents with statistically significant directional flow, acting on the permanent magnet as a whole to meet anomalous Hall effect conditions and causing solid-state carriers to appear at both ends.

As shown in Figure 10d, compared to traditional Hall and anomalous Hall effects, integrated bipolar carriers in magnetic channels represent a combination carrier of statistically significant Hall and anomalous Hall effects, meeting conditions to simultaneously trigger both. The voltage formed by liquid and solid-state carriers should be approximately ten times that of the normal Hall effect. As shown in Figures 10e-f, magnetizing ferromagnetic materials directionally generates outward magnetic fields perpendicular to the surface, enabling detection of simultaneous Hall and anomalous Hall effects using electrodes, voltmeters, and ammeters at corresponding positions.

4. Conclusion

The innovations of this article can be summarized as follows: (1) Establishment of a technique for preparing high-concentration charged solutions using dual electrostatic feedback, employing electrostatic attraction, gravity separation, and positive feedback to effectively separate anions and cations, while electrostatic repulsion and permissive separation networks partition like-charged ions, enabling continuous single-charge species replenishment and sustained power generation; (2) Identification of evidence for charged solution existence and prediction of electrostatic boiling phenomena, enriching electrostatics and electrochemistry research; (3) Proposal of exploring voltage limits from multiple angles including force effects, charge distribution, splash prevention, interference, constrained flow, equipotential partitioning, high-pressure jetting, reflow/reseparation, and ePTFE phase-change dewatering; (4) Introduction of unique topological and physicochemical properties of charged solutions and prediction of anomalous Hall effect in equipotential body dual-state carriers; (5) Proposal of self-powered desalination technology based on dual electrostatic methods combined with wind, photovoltaic, and pumped storage to mitigate renewable energy intermittency and promote seawater for land; (6) Introduction of charged ice crystals, topological ice crystals, conductive ice crystals, and strange ice crystals along with their preparation and applications; and (7) Proposal of charged solution applications in water splitting and crystal synthesis.

This article introduces a newly established research field with extensive content requiring fine-tuned research and improvement. It is hoped that this work will inspire academic and industrial sectors while satisfying the author' s pursuit of truth. Any inadequacies are open to criticism and correction.

ACKNOWLEDGEMENTS The author gratefully acknowledges support from the Natural Science Foundation of Jiangsu Province for Young Scientists (Grant No. BK20201064).

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Supporting Information

Using alcohol lamp wick mesh with ~3 mm apertures overlaid to form the water-electricity separation conductive grid (Figure S1a), with tin foil-wrapped plastic cups serving as hollow conductive rings and electrodes, we measured 5 V with an electroscope probe (Figure S2). The low voltage results from high water flow rate, large mesh apertures, and incomplete bottom mesh coverage, allowing water leakage from both edge and central areas. Rapid flow without sufficient conductive network contact leaves droplets elevated during exit, carrying away substantial charge and preventing the upper conductive ring from attracting sufficient voltage via electrostatic attraction. Nevertheless, results demonstrate the feasibility of water-permeable power generation—the most fundamental verification of all research presented here.

Copper plates welded into barrels with ~0.3 mm aperture metal foam nickel (100 mm thick) welded at the bottom (Figure S1b) yield static voltages of 1000-5000 V when water flows, indicated by swinging suspended balls near conductive rings (Figure S2). These results demonstrate successful water-permeable power generation meeting some application requirements, though the thin nickel foam has high cost and limited charge storage capacity.

Building upon this, filling barrels with substantial ~0.03 mm aperture stainless steel braided mesh (Figure S1c) produces intense ball vibrations and static voltages of 10,000-27,000 V (Figure S2), achieving highly desirable results that drive exploration toward even higher voltage limits.

Experimental Video: https://www.bilibili.com/video/BV1RA4m157Nz/?spm_{{{id}}*{{from}}}=333.337.*
card.all.click&vd{source}=d1aa9b9c9480b62215fc589302004419

Based on the dual electrostatic water drop generator and LC resonance, charge export, storage, and emission can transmit radio waves. The tip charge continuously charges a capacitor until increasing voltage breaks down the spark gap, forming a circuit that charges an inductor coil and creates LC resonance. Continuous inductor charging/discharging generates electromagnetic waves released into surrounding space. Oscillation and electromagnetic wave frequencies can be regulated by adjusting LC circuit parameters (Figure S3). The dual electrostatic water drop generator’ s charge handling and radio wave transmission capabilities have potential wireless charging applications.

Experimental Video: https://www.bilibili.com/video/BV1oK41187XN/?spm_{{{id}}_{{from}}}=333.999

Positive and negative hydrovoltaic materials assembled with conductive networks in “concrete” construction serve as water-electricity separation zones (Figure S4m), facilitating positive feedback acceleration and strengthening electrostatic repulsion while controlling flow rates. System performance factors include ionized charge quantity, ion types, conductivity, particle size, and material content ratios.

Adsorption properties of H_2O molecules on graphene, Janus-graphene, SiO_2 (111) surface, and Al_2O_3 (1-12) surface were calculated using grand canonical Monte Carlo method at 298 K and 100 kPa (Figure S4a-l). Janus-graphene shows significant adsorption differences between sides, with oxygen-containing group sides adsorbing substantially more. SiO_2 and Al_2O_3 adsorption is less prominent, suggesting surface functionalization to enhance capacity and fixed charge formation.

The zero charge point is where solid surface potential equals zero. If surface charge state depends on solution pH, a pH value exists where surface charge is zero. As shown in Figure S4n, Al_2O_3’ s zero charge point corresponds to pH ~9 (positively charged when pH < 9, negatively when pH > 9), while SiO_2’ s corresponds to pH 2.5 (positively charged when pH < 2.5, negatively when pH > 2.5). This zero charge point division rule greatly expands selection ranges for positive/negative hydrovoltaic material combinations, facilitating efficient, cost-effective new materials and devices.

Mobile charges in aqueous solution come not only from H^+ and OH^- ionized from H_2O but also from Na^+, K^+, Cl^-, $C_3H_7COO^-$, $C_8H_{17}COO^-$, solute particles, etc. Conducting ion movement speeds differ, with H^+, OH^-, Na^+, K^+, and Cl^- responding more rapidly to electric fields than $C_3H_7COO^-$, $C_8H_{17}COO^-$, and solute particles (Figure S4o), serving as criteria for comparing material performances.

Density of states (DOS) diagrams for monolayer graphene, bilayer graphene, $FeCl_3$-intercalated bilayer graphene, and Janus graphene with epoxy groups were calculated using first-principles methods (Figure S5a). Graphene, bilayer graphene, and $FeCl_3$-bilayer graphene show intersecting valence and conduction bands with metallic properties. $FeCl_3$-bilayer graphene’ s DOS at the Fermi level is two orders of magnitude higher than graphene and bilayer graphene, indicating $FeCl_3$ intercalation enhances conductivity (proportional to Fermi-level DOS), likely due to increased carrier concentration. Figure S5b shows absorption coefficients. Visible light corresponds to 3.84\$$\times10^{\{14\}-7.7\times10}${14}\$ Hz (1.6–3.2 eV), marked with light pink bars. $FeCl_3$ intercalation negligibly affects graphene’ s absorption coefficient, even improving visible light transparency. This provides material options for non-metallic, waterproof, corrosion-resistant, transparent, conductive containers and photochemical reactions at water-electricity separation interfaces. However, incomplete exfoliation creates $FeCl_3$-bilayer graphene powder structures with various pores (Figure S5d) that form well-conductive separation networks mass-producible. Janus-graphene has a bandgap with the Fermi level near the valence band, making it a semiconductor. Figure S5c shows 2-stage $FeCl_3$-graphite intercalation compound ($FeCl_3$-GIC) prepared by molten salt method, double-layer graphene obtained by H_2O_2 exfoliation, and $FeCl_3$-bilayer graphene re-formed by $FeCl_3$ intercalation. Figure S5d shows the incompletely exfoliated powder structure. Figure S5e shows synthesis of “heterogeneous alternately intercalated graphite” using chlorate and concentrated sulfuric acid oxidation of 2-stage $FeCl_3$-GIC. Due to strong $FeCl_3$-

graphite bonding preventing acid and oxidant infiltration, the original $FeCl_3$ intercalation structure remains intact while non-intercalated carbon layers oxidize, forming oxygen-containing groups. Mild ultrasonic treatment easily peels off the oxygen-containing layer, obtaining "$FeCl_3$-dispersible-graphene."

Single-sided selective oxidation of Janus-graphene is achieved by reacting hydrogen peroxide with ferric chloride. When placed in water with the hydrophobic side up contacting air and hydrophilic side down contacting solution, Janus-graphene disperses at the gas-liquid interface, self-assembling into monolayer films (Figure S5f). Janus-graphene films can be used in electrodes and separation zones. Quenching in liquid nitrogen followed by freeze-drying can roll films into quasi-one-dimensional nanoribbons or contract them into three-dimensional granular aggregates. Janus-graphene' s asymmetry facilitates curved structure formation from planar structures during cooling (Figure S5g). With one side hydrophilic (oxygen-containing groups) and the other unoxidized, Janus-graphene offers special structures with minimal damage and strong controllability for atomic-layer-thick transparent electrodes and separation zone construction.

Container wall material, structure, conductivity, and transparency enrich charged solution applications. Waterproof, corrosion-resistant transparent conductive containers provide special conditions for photocatalytic water splitting at interfaces (Figure S6a), while crystal growth can occur on conductive copper foil surfaces, and flexible breathable waterproof films can utilize water phase changes for dewatering (Figure S6b). Based on Raoult' s law, Dalton' s law, and the Clausius-Clapeyron equation describing vapor pressure-solution concentration relationships, the hydrophobic waterproof breathable layer isolates liquid seawater and impurities while allowing only water vapor diffusion. A natural vapor pressure difference between seawater and highly water-absorbent resin drives mass transfer, enabling moisture migration from the seawater side where it vaporizes, diffuses through the membrane, and is absorbed/liquefied on the resin side. Using a semi-permeable membrane to encase water-absorbing powder creates an osmotic pressure difference promoting water molecule transport. After swelling, the water-absorbent resin increases pressure during expansion, facilitating transport. As shown in Figure S6d, the increment pressure method utilizing vapor pressure and osmotic pressure differences for in-situ potable water preparation from seawater and wastewater effectively isolates ions and impurities, suitable for maritime emergencies, wilderness travel, and industrial beverage preparation without reverse osmosis' s external high pressures or traditional decontamination procedures. Experimental results show potential for everyday life and industrial production, indicating ePTFE can remove water while retaining charge, making it viable for preparing high-concentration charged solutions.

Figure Legends

Figure 1: (a) Schematic diagram of simple preparation of charged solution, (b) Schematic diagram of ion/charge distribution in charged solution.

Figure 2: Schematic diagram of the single electrostatic method for preparing charged solutions with positive feedback mechanism.

Figure 3: (a) Schematic diagram of electrostatic repulsion principle, (b) Composition of the core part of electrostatic repulsion and voltage measurement results, (c) Voltage and phenomena induced by metal foam, (d) Voltage and phenomena induced by stainless steel braided mesh. The bottom shows four theoretical bases.

Figure 4: (a) Curve of the voltage variation over time for a charged solution existing alone and exposed to air, (b) Prediction of the phenomenon of "electrostatic boiling" and its principle.

Figure 5: (a) Schematic diagram of ice and "topological ice crystals," (b) Schematic diagram of charged ice crystal preparation, (c) Model diagram of quasi-two-dimensional ice, (d) Model diagram of charged quasi-two-dimensional ice, (e) Band structure diagram of quasi-two-dimensional ice, (f) Band structure diagram of charged quasi-two-dimensional ice.

Figure 6: (a) Probability of multiple crystal facets exposed in pure ice crystals, (b) Model diagram of the "strange ice crystal" structure formed by different valence state ferromagnetic ions freezing in ice crystals to create non-equilibrium periodic electric and magnetic fields, (c) Numerical values of band gaps for different crystal orientations, thicknesses, ions, and structures (data being supplemented).

Figure 7: (a) Schematic diagram of the instrument design for preparing high-concentration charged solutions, (b) Ice lens, (c) Schematic diagram of the alternately stacked structure of positive and negative ion layers frozen layer by layer, (d) Top view structure diagram of hexagonal ice phase, (e) Side view structure diagram of hexagonal ice phase, (f) Top view structure diagram of alternately stacked anion/cation ice layers, (g) Side view structure diagram of alternately stacked anion/cation ice layers, (h) Density of states of hexagonal ice phase and alternately stacked layers of ice containing anions and cations, (i) Real and imaginary parts of the dielectric function.

Figure 8: (a) The left half depicts the smooth surface of the original copper foil, while the right half shows a non-reflective rough surface with grown crystals. (b) SEM image of the original copper foil surface. (c) Schematic diagram of non-equilibrium ionic interface reactions. (d) SEM images of four morphologies of CuCl crystal materials. (e) TEM image, elemental surface scan, and optical property image of ultra-thin CuCl sheet-like crystals.

Figure 9: Self-powered desalination and water purification model of positive feedback dual electrostatic method and "seawater for land."

Figure 10: (a) Schematic diagram of the Hall effect, (b) Schematic diagram of the anomalous Hall effect, (c) Schematic diagram of ferromagnetic material structure with capillary channels, (d) Schematic diagram of carrier movement

inside ferromagnetic material, (e) Schematic diagram of a droplet-based hydrovoltaic generator with coexisting spontaneous magnetization of magnetic moments and Hydrovoltaic effect, (f) Schematic diagram of test setup for moving charged water droplets inside ferromagnetic materials.

Figure S1: (a)-(c) Corresponding materials and phenomena for the water and electricity separation conductive network with aperture sizes of 3, 0.3, and 0.03 mm.

Figure S2: Corresponding voltage values for the water and electricity separation conductive networks with aperture sizes of 3, 0.3, and 0.03 mm.

Figure S3: Schematic diagram of the structure and principle of the dual electrostatic water drop generator capable of emitting radio waves.

Figure S4: (a)-(d) Top views of graphene, Janus-graphene, SiO_2 (111) surface, and Al_2O_3 (1-12) surface, (e)-(h) Side views of graphene adsorbing H_2O molecules, Janus-graphene adsorbing H_2O molecules, SiO_2 surface adsorbing H_2O molecules, and Al_2O_3 surface adsorbing H_2O molecules, (i)-(l) Side views of the distribution of the center of mass of H_2O molecules on the graphene surface, Janus-graphene surface, SiO_2 surface, and Al_2O_3 surface, all at a temperature of 298 K and a fugacity of 100 kPa, (m) A conductive network for water and electricity separation containing positive and negative hydrovoltaic materials, (n) Schematic diagram of the relationship between the surface chargeability of Al_2O_3 and SiO_2 materials and the pH of the solution, (o) A table showing the migration speeds of various charged ions in the solution.

Figure S5: (a) Density of states and (b) Absorption coefficient plot of monolayer graphene, bilayer graphene, $FeCl_3$-bilayer graphene and Janus-graphene, (c) Preparation of bilayer graphene and $FeCl_3$-bilayer graphene by H_2O_2 stripping of $FeCl_3$ intercalated graphite, (d) Powder of $FeCl_3$-bilayer graphene, (e) Synthesis of Janus graphene, (f) Interface self-assembly of Janus-graphene thin film, (g) Dimensional variation of Janus-graphene.

Figure S6: (a) Schematic diagram of a transparent conductive electrode for photocatalytic water splitting, (b) Waterproof breathable membrane for phase separation of water, retaining ions and separating water, reducing volume, and increasing concentration, (c) Principle schematic diagram of in-situ preparation of drinking water from seawater and wastewater using the osmotic pressure difference and vapor pressure difference increment pressure method, (d) Diagram of glucose powder wrapped with ePTFE and semipermeable membrane for water absorption and expansion.

Figures Figure 1 Figure 2 Figure 3 Figure 4 Figure 5 Figure 6 Figure 7 Figure 8 Figure 9 Figure 10 Figure S1 Figure S2 Figure S3 Figure S4 Figure S5 Figure S6

Note: Figure translations are in progress. See original paper for figures.

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