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Water Photomolecular Evaporation Due to Light-Mediated Ortho-Para Spin Transitions

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Abstract

Recent discoveries have revealed a groundbreaking phenomenon where light alone, without any thermal input, can induce water evaporation, termed the "photomolecular effect". This study explores a novel hypothesis that this effect can be explained by ortho-para magnetic spin interactions in water molecules within the water-air interface layer. Water molecules, consisting of hydrogen and oxygen, exhibit different nuclear spin states: ortho-(triplet) and para-(singlet). The interaction of polarized light with these spin states may induce transitions between the rotational levels of ortho- and para-forms due to catalysts like triplet oxygen (O_2) in its inhomogeneous magnetic field. Resonance pumping at 532 nm (~18,797 cm^{-1}) due to the transition v_1-v_2-v_3 ~ 0-8-2 (~18,796 cm^{-1}) results in an increase in molecular energy sufficient to overcome intermolecular forces at the water surface, thereby causing evaporation. The proposed ortho-para conversion mechanism involves spin-orbit coupling and specific resonance conditions. This theory provides a quantum mechanical perspective on the photomolecular effect, potentially offering insights into natural processes such as cloud formation and climate modeling, as well as practical applications in solar desalination and industrial drying. Further experimental validation is required to confirm the role of spin interactions in light-induced water evaporation.

Keywords

Ortho-Para Spin Transition, Water Structure, Evaporation Theory, Photo Molecular Effect

1. Introduction

The evaporation of water, a fundamental process observed in nature and utilized in various industrial applications, has traditionally been understood as a heat-driven phenomenon. However, recent research from MIT has identified a surprising new mechanism whereby light alone can cause water to evaporate without water heating [1]-[7]. This discovery, known as the "photomolecular effect" challenges conventional understanding and opens up new avenues for scientific exploration and technological innovation [1].

The photomolecular effect raises significant questions about our current understanding of water's interaction with light. In traditional models, evaporation is primarily driven by thermal energy, with light playing a secondary role by providing heat. The MIT experiments suggest a direct interaction between light and the molecular structure of water, leading to evaporation even in the absence of a temperature increase. This phenomenon could have far-reaching implications for climate models, where water evaporation plays a crucial role in energy exchange processes and atmospheric dynamics. The most interesting application is to use the "photomolecular effect" as a trigger or starting step of tornado or typhoon phenomena.

It should be noted that the intriguing MIT experiments have shown (see Fig. S 20 from [2]) a high density of water vapor above the surface (water-air interface), resembling the liquid water OH band. This OH band consists of monomer spectral lines at 6550 cm^{-1} and 7500 cm^{-1} in the layer around 120 - 150 nm above the water surface. We propose that both ortho- and para-H_2O spin isomers exist within these lines. Identifying the energy of quantum levels corresponding to the pump laser line at 532 nm is the main purpose of this paper.

2. Ortho-Para Magnetic Spin Interaction Hypothesis

Water molecules (H_2O) consist of two hydrogen atoms bonded to an oxygen atom. The hydrogen nuclei (protons) have a spin of ½, resulting in two distinct spin states for the hydrogen pair:

Ortho-H_2O isomer (triplet state): Both protons have parallel spins (↑↑), leading to a total nuclear spin of 1 and magnetic properties of H_2O. The ortho-H_2O lacks a 0 rotational energy level, resulting in constant rotation of molecules, which is significant for faster evaporation from the water surface compared to para-H_2O one.

Para-H_2O isomer (singlet state): The protons have antiparallel spins (↑↓), resulting in a total nuclear spin of 0. This spin isomer is not the magnet. Some para-H_2O does not rotate according to the Boltsmann distribution of energy level population. The thermodynamic equilibrium Ortho/Para H_2O spin isomers (O/P) ratio at the room temperature is 3:1 in air.

The thermodynamic equilibrium Ortho/Para H_2O spin isomers (O/P) ratio at room temperature is 3:1 in air. In the liquid phase, the O/P ratio is 1:1, which is not thermodynamic equilibrium, as measured by the four-wave mixing technique for the first time [7]. Thus, water at room temperature is significantly overheated (or overcooled) up to 270 K (depending on the O/P or P/O ratio). Any interaction (mechanical mixing, shocking, cavitation, electromagnetic excitation by laser beam, etc.) enriches water with ortho-H_2O isomers [8]. It is known [9] [10] that the ortho-para conversion process occurs due to catalysts like triplet oxygen O_2.

These states differ in energy and magnetic properties, with the ortho-state being higher in energy due to spin-spin interactions. The proposed hypothesis suggests that polarized light can interact with these spin states, inducing transitions between ortho- and para-isomers. This interaction, mediated by spin-orbit coupling, could provide the energy necessary to overcome intermolecular forces at the water surface, leading to evaporation.

3. Quantum Mechanical Explanation and Mechanisms

3.1. Spin-Orbit Coupling

Spin-orbit coupling is a fundamental quantum mechanical interaction where the spin of a particle (in this case, a proton) interacts with its motion (orbit) around the nucleus. In the context of water molecules, this coupling can be influenced by external factors, such as polarized light, which can induce transitions between ortho- and para-spin states. The energy associated with these transitions can contribute to molecular excitation, enhancing the likelihood of evaporation.

The presence of triplet oxygen (O_2), with its unpaired electrons, can create an inhomogeneous magnetic field, further influencing the spin states of water molecules. This interaction could be crucial in facilitating the transitions between ortho and para states, providing the necessary energy to overcome the binding forces at the water surface.

When polarized light, particularly with transverse magnetic polarization, interacts with water molecules, it can induce changes in the spin states of hydrogen atoms. This interaction might facilitate transitions from para to ortho-states or vice versa, resulting in increased molecular energy.

3.2. Resonance Conditions

The efficiency of the photomolecular effect is believed to be highly dependent on resonance conditions. The specific wavelength of light (532 nm) aligns with the energy difference between certain quantum states of the water molecule, particularly in the para-H_2O isomer. This precise energy match allows for efficient energy transfer, promoting the ortho-para conversion and subsequent evaporation.

The proposed mechanism suggests that resonance pumping at 532 nm (~18,797 cm^{-1}), due to the transition v_1-v_2-v_3 ~ 0-8-2 (~18,796 cm^{-1}), results in an increase in molecular energy sufficient to overcome intermolecular forces at the water surface. This condition is particularly effective in causing water molecules to escape as vapor.

3.3. Energy Transfer

The transition between ortho and para states involves an energy change in the water molecules. This energy can be transferred to the kinetic energy of the molecules, increasing their velocity and allowing them to escape from the surface as vapor.

3.4. Angular and Polarization Dependence

The effect of light's angle and polarization on evaporation rates can be explained by the orientation of water molecules and their magnetic dipole interactions. Certain angles and polarizations may more effectively induce the ortho-para transition, enhancing evaporation.

3.5. Color Dependence

The peak in green light effectiveness might relate to specific resonance conditions for molecules excitation into the high energy level due to the energy of green photons (532 nm ~ 18,797 cm^{-1}) matches the energy difference between the first and upper energy level of para-H_2O isomer (~18,796 cm^{-1} for combined transitions: v1-v2-v3 ~ 0-8-2 of para-H_2O isomer). Then para-ortho conversion occurs in quantum mixed states due to collisions, which increase the number of ortho-H_2O isomer in high excitation states [9]. Despite water transparency to green light, this resonance could facilitate the transition and subsequent evaporation.

4. Experimental Validation

To test this hypothesis, several experimental approaches can be considered:

1) ***Magnetic Field Influence***: Investigate the effect of external magnetic fields on the evaporation rate of water under light exposure. By manipulating the magnetic field, it may be possible to alter the ortho-para ratio, providing insights into the role of spin interactions in the evaporation process. It should be mentioned that the ortho-H_2O isomer with magnetic moment precesses in the Earth magnetic field always. This isomer feature can be used in the experiments with polarized laser.

2) ***Spectroscopic Analysis***: Using spectroscopic techniques, we can tune the wavelength of the laser beam to measure the resonance response. Quite effective method is to use direct measurement magnetic response such as Nuclear Magnetic Resonance (NMR) to monitor changes in the spin states of hydrogen nuclei when exposed to polarized light. This could provide direct evidence of the proposed spin transitions.

3) ***Controlled Light Exposure***: Vary the angle, polarization, and color of light to observe corresponding changes in evaporation rates. By correlating these changes with theoretical predictions, the role of spin interactions in light-induced water evaporation can be further elucidated.

5. Practical Implications

Understanding this light-induced evaporation mechanism could have significant implications for climate science and various industrial processes. For instance, it could help explain discrepancies in cloud absorption measurements and improve models of cloud-climate interactions. Additionally, the "photomolecular effect" could be considered in dynamical models of tornado and typhoon. Observations show that both phenomena occur during the daytime but not at night.

5.1. Solar Desalination

The proposed mechanism could enhance the efficiency of solar desalination systems. Traditional methods rely on thermal energy to evaporate water, but the photomolecular effect could enable evaporation at lower energy levels, potentially reducing the cost and energy consumption of desalination processes.

5.2. Industrial Drying

In industrial drying applications, where water removal is critical, leveraging the photomolecular effect could lead to more efficient drying processes. By optimizing light exposure and harnessing the spin interactions within water molecules, industries could achieve faster drying times and reduce energy usage.

6. Conclusion

The ortho-para magnetic spin interaction theory offers a quantum mechanical explanation for the newly discovered photomolecular effect. By considering the magnetic spin states of protons in ortho-H_2O molecules and their interaction with light, this hypothesis provides a novel perspective on light-induced water evaporation. Further experimental validation is needed to fully understand the underlying mechanisms and to explore the broader implications of this effect.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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