A rapid method for the determination of stable hydrogen isotope ratios of acetic acid in vinegar

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Interview with Professor Guoqing Zhang

On the grand expanse, things are calm and still. But on the microscale, waves rise and thrill. – Zhang's own interpretation of the physical world.

Guoqing Zhang serves at the University of Science and Technology of China as a full professor and a Ph.D. advisor. He earned his bachelor's degree from the Department of Polymer Science and Engineering between 2001 and 2005 at the same institution. Subsequently, he pursued his Ph.D. at the University of Virginia's Chemistry Department in the USA from 2005 to 2010. He did his postdoctoral research at the Department of Chemistry and Chemical Biology at Harvard University during 2010-2011. In 2011, Zhang returned to the University of Science and Technology of China, where he began his independent research group. He is affiliated with the Hefei National Research Center for Physical Sciences at the Microscale. He is primarily interested in the optoelectronic properties of pure organic molecular materials. A notable focus of his work is on the spin-state modulation of electrons of organic molecules, particularly in their excited and ground states. Apart from his research, Zhang has taught General Chemistry to undergraduate students (*http://www.hfnl.ustc.edu.cn/detail?id=11295*).

Tang: *May you introduce your research interest and its future development?*

Zhang: Since becoming an independent principal investigator in 2011, our research group has been deeply invested in exploring and gaining mechanistic insights into organic molecular charge-transfer systems, with a special focus on charge-transfer-mediated room-temperature phosphorescence (RTP). The investigation of molecular RTP serves multiple purposes. Firstly, it stands as a vital spectroscopic method for examining electron spin in excited states. Secondly, there is a practical imperative to innovate metal-free RTP molecules, paving the way for the creation of energy-efficient organic light-emitting diodes. Moreover, the potential of long-lived excited states, such as charge-transfer or triplet states, beckons further exploration, as they hold promise for the development of novel organic photocatalysts and synthetic methodologies.

Tang: *What is your understanding on aggregate science?*

Zhang: The future trend in fundamental research will likely focus on characterizing physical matter that is shorter in time, more microscopic in space, and more intricate in scale, using sophisticated instrumentation. That said, the field of aggregate science is no exception. This holds even truer for organic aggregates, whose interactions display profound disorder and complexity, both energetically and spatiotemporally. The *status quo* of research on organic aggregates centers largely around chemical synthesis and relatively simple characterization. This trend has persisted for over twenty years since Prof. Ben Zhong Tang first introduced the concept of "aggregation-induced emission", or AIE. While chemical synthesis is undoubtedly the foundational pillar for studying aggregate science, we are only beginning to scratch the surface of this domain.

We've made significant progress in synthesis, and the new frontier in aggregate science is now moving towards quests for precision measurement, theoretical modeling, and understanding the novel properties of microscopic particles *en masse* . No single particle exists in complete isolation. In essence, there is only one single quantum mechanical equation encompassing all possible interactions that can describe the entire universe. In the early days of "cowboy science," we often overlooked what we deemed to be negligible interactions, basing our conclusions on experiments with these purportedly isolated systems. However, we are now beginning to recognize that even the weakest couplings must be considered, as they might hold the key to overcoming significant scientific challenges.

A prominent example of this is the microscopic origin of gravity, which seems incompatible with the laws of gravity observed on a planetary scale. While galaxies are just aggregates of massive numbers of microscopic particles like neutrons, atoms, and molecules, the same gravitational effects don't appear to manifest among these smaller entities. This inconsistency has become one of the most significant unsolved mysteries in contemporary physics. This aligns with what Prof. Ben Zhong Tang has often emphasized in his lectures: reductionism may not be the best approach for addressing issues in aggregate science. This might be why, in my opinion, physicists find themselves at an impasse.

There are numerous examples in chemistry that mirror this conundrum, such as the physical description of weak intermolecular interactions. A particular case in point is the nature of hydrogen bonding. Whether it's more rooted in covalent/charge-transfer or electrostatic interactions has been a subject of debate for over a century, with no definitive resolution in sight. Yet, we have a comprehensive understanding of the chemistry and physics of a drop of water. The missing piece clearly resides in aggregate science – how do water molecules, as quantum objects, aggregate to produce the microscopic properties of a droplet? I believe merely attributing this to the "uncertainty principle" or a "phase transition" is vague and insufficient. Modern chemistry demands more details, like how a gigantic group of water molecules coordinate their electrons and nuclei during the transition to give rise to emergent properties explainable mathematically. Otherwise, we risk remaining at a standstill.

Speaking of being stuck, I believe no field demands a grasp of aggregate science more than the life sciences. Life itself is a special form of molecular aggregates. Yet, despite possessing state-of-the-art equipment, biologists have not fully connected the dots between a wad of molecules and a rudimentary living organism, such as a bacterium. The ultimate quest in life science might be to comprehend why we are conscious entities, a question that, to this day, remains elusive. However, I dare to make a guess that a prerequisite for consciousness is memory, which runs on some type of "molecular hard drive." The act of forming memories might involve changes in the aggregation state of these drive-constructing molecules, akin to optical or magnetic hard drives. To tackle such a challenging "aggregation" issue, collaborations between physicists, chemists, biologists, and engineers will be indispensable.

The examples I've mentioned concerning molecular aggregates pertain largely to systems in the ground state. However, when these systems transition to the excited state, the complexity becomes almost unfathomable. This is because the number of potential microscopic states—and consequently, the modes of interactions—multiply exponentially. In reality, unless measured at temperatures near absolute zero, all systems under experimental conditions are in excited states. But in the context of aggregate science, such as with AIEgens, "excited systems" typically refer to electronic excited states. These states can display lifetimes that vary widely, ranging from femtoseconds to seconds—a staggering 15 orders of magnitude. Grasping this spatiotemporal intricacy demands modern chemists not only to master the art of molecule creation but also to embrace a comprehensive, holistic view offered by aggregate science.

In summary, in chemical science, we are fully capable of addressing issues concerning individual molecules or even a small group of them. The advent of supercomputers has empowered us to calculate the properties of thousands of atoms with remarkable precision. The real challenge emerges when trying to comprehend how myriad weak interactions among these microscopic entities, spanning diverse timescales, culminate in the macroscopic behaviors we observe. This presents a daunting task, primarily because our prevailing theory for the minuscule, quantum mechanics, demands a composite of numerous possible patterns. Revisiting the gravity example, how can space itself oscillate among different configurations? And if it does, in which version of space do we exist? It's pretty evident to me that a reductionist approach will only take us so far.

Aggregate science, on the other hand, circumvents our old routine of quantizing whatever macroscopic things we encounter, a typical reductionist approach. Instead, it redirects our attention to potentially solvable problems when considered from a slightly elevated perspective. For instance, a semi-classical approach that factors in quantum mechanics and varying aggregation statistics when studying colloidal particles could provide insights into some paradoxes within the field. With this in mind, I genuinely hope that more people will gravitate towards these intriguing challenges, holding onto the optimism that aggregate science may someday illuminate the answers.

Tang: *Why did you choose to pursue a career in scientific research?*

Zhang: I think being able to live a life is so precious that we can't afford not to know the physical laws governing our universe; otherwise, life seems unfulfilled. Moreover, engaging in scientific research allows one to remain distant from worldly concerns without hiding in a monastery, leading to a simpler life.

Tang: *Where do you think the greatest charm of science lies, and how did you resolve to pursue a career in scientific research?*

Zhang: The true allure of science is its ability to grant us the ability to predict the future. Why do humans experience anxiety? It boils down to a lack of security. And why this insecurity? That is if we don't know what's going to happen in the next moment. However, scientific laws will tell us how things will evolve to a very good extent, alleviating our anxieties. I decided to become a full-time scientist when I realized the enormous freedom this career offers, especially at USTC (University of Science and Technology of China) – where there's autonomy to pursue what you desire. I mean I get paid for just coming up with new ideas and testing them? How is this different from living in heaven?!

Tang: *Do you have any academic aspirations you'd like to achieve? Would you mind sharing your short-term goals and long-term vision with our readers?*

Zhang: My short-term objective is to secure funding from the National Natural Science Foundation's Outstanding Youth Program. In the long run, I aim to win a globally recognized scientific award.

Tang: *What has been the most memorable experience in your research career?*

Zhang: When I first accidentally observed the room-temperature phosphorescence of the polymer I synthesized, I excitedly showed it to my Ph.D. advisor, Professor Cassandra Fraser. Her response was, "What the heck is that?"

Tang: *Could you describe some exhilarating moments in your research career?*

Zhang: On one occasion, we identified a method for specifically marking solid tumors for surgeries using luminescent molecules. Dr. Xu from Professor Guoqiang's Bi research group exclaimed, "Professor Zhang, does this mean we'll soon afford a Boeing 777?"

Tang: *Have you encountered any bottlenecks in your research career? How did you overcome these challenges and maintain your determination?*

Zhang: For a time, I struggled to find a breakthrough in organic room-temperature phosphorescence. But now, as I delve deeper, the path becomes increasingly clear, akin to discovering a hidden utopia as described in the classical Chinese masterpiece "The Peach Blossom Spring".

Tang: *Where does the pressure in your job come from, and how do you manage it?*

Zhang: I've never felt pressured in my job, a sentiment that all my colleagues and students can attest to.

Tang: *What qualities do you hope students in your research group possess? Do you have any messages for your current and future students?*

Zhang: I hope they have a solid foundation in mathematics and physics and are adept at hands-on tasks; with these skills, they would be unbeatable. During challenging times in the lab, I hope they never doubt themselves, and believe that among the myriad of complex chemical systems, there's certainly one tailored for them.

Tang: *What do you believe is the most important quality for a scientific researcher?*

Zhang: Curiosity and perseverance are paramount, and you need both to succeed.

Tang: *If you could go back to your graduate years, is there a new career you would like to pursue?*

Zhang: If I had prior knowledge of the developments of China over the past two decades, I might have pursued a career in foreign trade. This way, I could have traveled around the globe much earlier.

Tang: *What hobbies do you have outside of your scientific work?*

Zhang: I enjoy watching movies and writing novels, and I'm currently obsessed with The Legend of Zelda: Tears of the Kingdom.

Tang: *As the Next Generation Board Member of Aggregate, What are your expectations and suggestions for the development of the journal?*

Zhang: The starting point of *Aggregate* is very high, and everyone has high hopes, believing it's worth the lifetime investment! I hope that in the future, it adheres to the highest standards, treating each manuscript impartially. It's vital to not show favoritism, even towards the journal's routine authors, including members of the editorial board like us.

Zhang's comment on his Aggregate paper entitled "Kinetic and thermodynamic control of tetraphenylethene aggregation-induced emission behaviors"[1]:

Tetraphenylethene (TPE) is a classic example of an Aggregation-Induced Emission (AIE) system. In good solvents, it doesn't display any photoluminescence. However, in poor solvents, it exhibits sky-blue fluorescence emission. During the experiment, we noticed subtle changes in TPE's AIE emission wavelength and peak maximum and spectral shape over time. By synthesizing various derivatives, we discerned this phenomenon is prevalent during AIE sample preparation. Organic molecules, when aggregating rapidly, might be locked into a kinetically metastable state that remains stable at room temperature. But this kinetic stability can transition to a thermodynamically stable aggregated state when heated or when exposed to good solvents. Depending on the molecular structure, these kinetically aggregated species and thermodynamically aggregated species display vastly different luminescent phenomena. This topic underscores that the physical properties of organic aggregates are highly sensitive to their surroundings and offers crucial theoretical insights for precision synthesis of an AIE system.

REFERENCES

X. Nie, W. Huang, D. Zhou, T. Wang, X. Wang, B. Chen, X. Zhang, G. Zhang, *Aggregate* **2022** , *3* , e165. https://doi.org/10.1002/agt2.165

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.