It's not only opposites that attract: New study shows like-charged particles can come together

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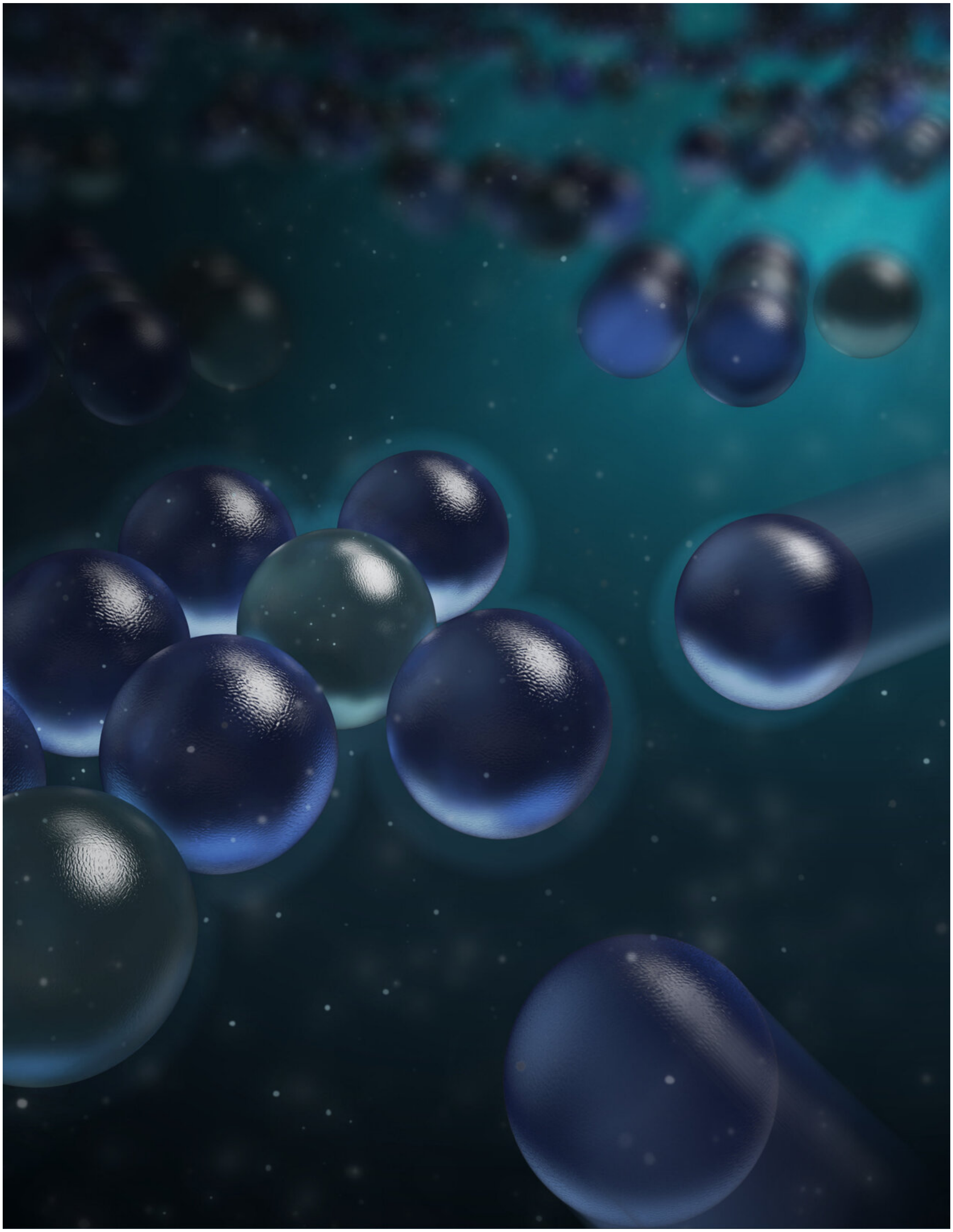

The study found that negatively charged silica microparticles suspended in water attracted each other to form hexagonally arranged clusters. Credit: Zhang Kang.

"Opposites charges attract; like charges repel" is a fundamental principle of basic physics. But a new study from Oxford University, published today in *Nature Nanotechnology*, has demonstrated that similarly charged particles in solution can in fact attract each other over long distances. Just as surprisingly, the team found that the effect is different for positively and negatively charged particles, depending on the solvent.

Besides overturning long-held beliefs, these results have immediate implications for a range of processes that involve interparticle and intermolecular interactions across various-length scales, including self-assembly, crystallization, and phase separation.

The team of researchers, based at Oxford's Department of Chemistry, found that negatively charged particles attract each other at large separations whereas positively charged particles repel, while the reverse was the case for solvents such as alcohols. These findings are surprising because they seem to contradict the central electromagnetic principle that the force between charges of the same sign is repulsive at all separations.

Using bright-field microscopy, the team tracked negatively charged silica microparticles suspended in water and found that the particles attracted each other to form hexagonally arranged clusters. Positively charged aminated silica particles, however, did not form clusters in water.

Using a theory of interparticle interactions that considers the structure of the solvent at the interface, the team established that for negatively charged particles in water there is an attractive force that outweighs electrostatic repulsion at large separations, leading to cluster formation. For positively charged particles in water, this solvent-driven interaction is always repulsive, and no clusters form.

This effect was found to be pH-dependent; the team was able to control the formation (or not) of clusters for negatively charged particles by varying the pH. No matter the pH, the positively charged particles did not form clusters.

Naturally, the team wondered whether the effect on charged particles could be switched, such that the positively charged particles would form clusters and the negatives would not. By changing the solvent to alcohols, such as ethanol, which has different interface behavior than water, this was exactly what they observed: Positively charged aminated silica particles formed hexagonal clusters, whereas negatively charged silica did not.

According to the researchers, this study implies a fundamental recalibration in understanding that will influence the way we think about processes as different as the stability of pharmaceutical and fine chemical products or the pathological malfunction associated with molecular aggregation in human disease. The new findings also provide evidence for the ability to probe properties of the interfacial electrical potential due to the solvent, such as its sign and magnitude, which were previously thought immeasurable.

Professor Madhavi Krishnan (Department of Chemistry, Oxford University), who led the study, says, "I am really very proud of my two graduate students, as well as the undergraduates, who have all worked together to move the needle on this fundamental discovery."

Sida Wang (Department of Chemistry, Oxford University), a first-author on the study, says, "I still find it fascinating to see these particles attract, even having seen this a thousand times."

More information: A charge-dependent long-ranged force drives tailored assembly of matter in solution, *Nature Nanotechnology* (2024).
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