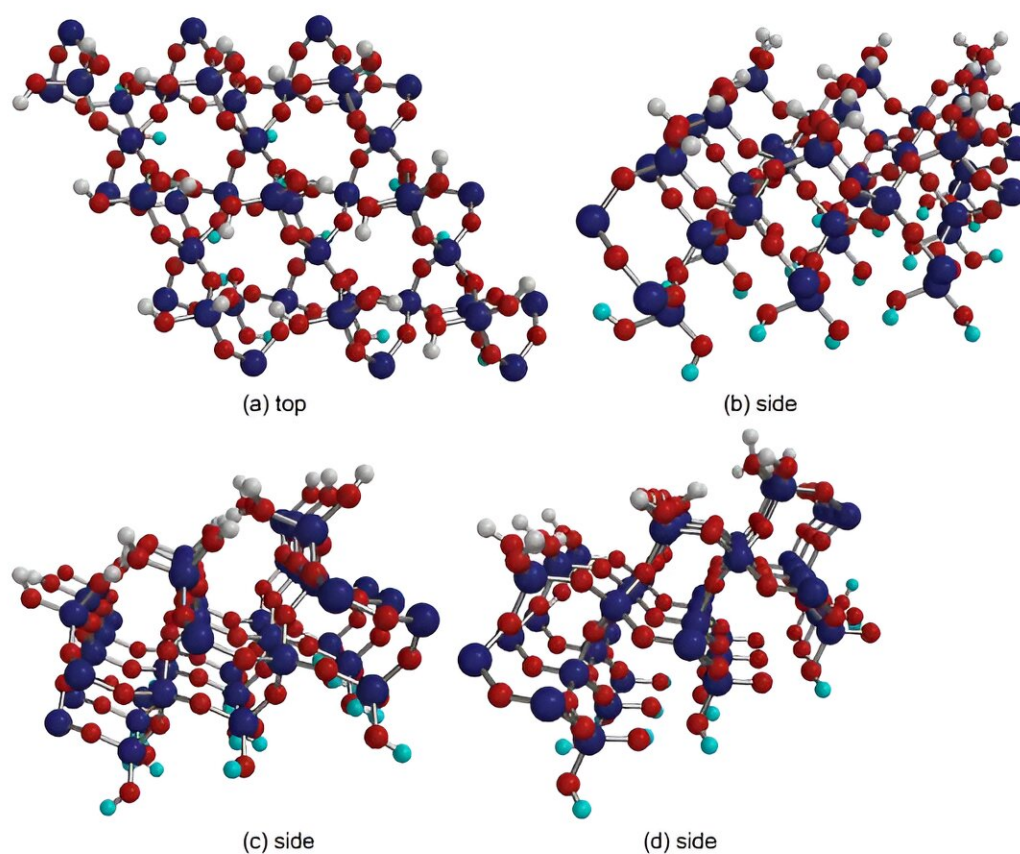


Silica particles found in food and makeup could be chemically reactive, study finds

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The $\text{Si}_{42}\text{O}_{90}\text{H}_{36}$ cluster used to model $\text{SiO}_2(001)$. (a) Top view. (b–d) Side views along different directions. Si atoms are blue. O atoms are red. H atoms are white. ^{28}H atoms are light blue-green. Credit: *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2304735120

New Stanford University research has revealed that the mineral silica, a common food additive and popular cosmetics ingredient, is not a chemically inert substance, as has long been supposed.

As described in a new study, researchers placed commercially available [silica](#) particles in a water solution with biomolecules containing compounds called thiols. These thiol-containing biomolecules are widespread in nature and in the [human body](#), for instance, in the form of glutathione, a key antioxidant found in most cells.

When exposed to silica, the thiol biomolecules underwent redox [chemical reactions](#). These reactions, in which electrons are lost, could degrade or alter the molecules' function, potentially posing [health risks](#). For instance, low levels of glutathione can lead to increased oxidative stress in the body that can damage all manner of cellular components, from membranes to DNA.

The findings highlight the need for further research into the reactivity of silica, especially given its extensive usage in everyday products.

"Silica particles are thought to be benign and inert, but our study's results indicate that silica is actually reactive," says Yangjie Li, a postdoctoral scholar in the Department of Chemistry in the Stanford School of Humanities and Sciences and lead author of the study, which published Aug. 17 in *Proceedings of the National Academy of Sciences*. "We encourage further investigation into whether silica particle exposure can deplete glutathione and other critical compounds in the body."

"Our findings sound an alarm for the continued use of silica particles," said senior author Richard Zare, the Marguerite Blake Wilbur Professor in Natural Science and a professor of chemistry in H&S. "While it's too soon to say that silica is a health risk, at minimum silica poses the potential problem of introducing unwanted chemistry, particularly in

food."

Often consumed and applied

Silica—another name for compounds of silicon and oxygen—is a colorless, odorless, tasteless material. While silica occurs naturally in foods including leafy greens, manufacturers often add tiny, sand-like particles of silica as an anticaking agent to soups and coffee creamers, for instance. Currently, the Food and Drug Administration allows foods to contain as much as 2% by weight of silica particles.

For cosmetics, including skin care products, silica serves as a bulking or absorbing agent, or as an abrasive in scrubs. In health care, silica particles have also found significant use in the delivery of drugs and for medical imaging purposes. For those applications, silica particles are manufactured to have tiny holes, or pores, into which pharmaceuticals and other substances can be slotted.

Given this scope of applications, Li and Zare sought to examine the orthodoxy of silica as a chemically inert substance. Li has a background in probing presumed properties of everyday materials. For her doctoral dissertation work, Li investigated how glass—long relied on for stably storing medicines and other important materials—can, in certain circumstances, act as a catalyst and accelerate chemical reactions.

"We've seen before that so-called inert materials may not really be inert," said Zare. "That story may be repeating itself with silica particles."

Overlooked chemistry at work

For the study, the Stanford researchers purchased commercially

available, pure silica particles, sold as a dry powder. Working with Kurt Kolasinski, a former graduate scholar of Zare and now a professor of physical chemistry at West Chester University, Li added silica to watery solutions containing one of three thiol-bearing biomolecules. The biomolecules studied were cysteine (a key amino acid), the aforementioned antioxidant glutathione, and penicillamine (a so-called heavy metal antagonist for treating Wilson's disease, a condition that occurs when too much copper accumulates in the body).

Li incubated the solutions in the dark for a day at room temperature. She obtained small samples of the solutions at half-hour, 2-hour, 4-hour, and 24-hour marks to gauge the rates of any chemical reactions that might have occurred, using an instrument called a mass spectrometer.

Over time, the biomolecules were oxidized (a loss of electrons in a chemical reaction) by incubation with silica, to the surprising tune of as much as 95% of the molecules in solution ultimately reacting in this way, while the control experiments without silica incubation showed minimal oxidation.

From a chemistry perspective, the reactive pure silica particles converted thiol-containing molecules to disulfide molecules. Spelled out in terms of their elemental compositions, the former molecules, which contain sulfur-hydrogen (S-H) bonded groups, changed to have disulfide bridges, symbolized S-S.

The reverse reaction is familiarly encountered, Zare pointed out, when curly hair is straightened by applying heat with a flat iron. The process breaks [disulfide bonds](#) in the proteins in the hair, allowing the hair to be reshaped into straight hair strands. "When people use flat irons to straighten their hair, the chemistry of what's going on there is breaking disulfides and turning them into thiols, the reverse reaction of our study," said Zare.

For the observed reactions, the Stanford researchers think that upon contact with water, silica forms so-called surface-bound silyloxy radicals (a silicon atom bound to an oxygen atom in a configuration that has an unpaired electron). When encountering the radicals, thiol biomolecules in the solution transfer hydrogen atoms (H) to the radicals. Accordingly freed of bonded H, the sulfur atoms in two thiol molecules then recombine to form the S-S disulfides.

Looking ahead, the Zare lab researchers plan to further test how varying sizes of silica particles influence chemical reaction rates. Experiments with larger biomolecules are also ongoing.

Zare and Li hope that their initial findings prompt other researchers, and potentially regulators, to characterize the chemistry of silica more thoroughly.

"Silica is a material that shows up in a lot of places, in the things we eat, in the products we put on our skin, and in medical settings," said Zare. "In light of this new study, we ought to know more about silica and its interactions with other materials."

More information: Yangjie Li et al, Silica particles convert thiol-containing molecules to disulfides, *Proceedings of the National Academy of Sciences* (2023). [DOI: 10.1073/pnas.2304735120](https://doi.org/10.1073/pnas.2304735120)

Provided by Stanford University

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