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Communication

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An Exploration of the "Sweet Nanochemistry" Synthesis for Silver and Gold Colloids

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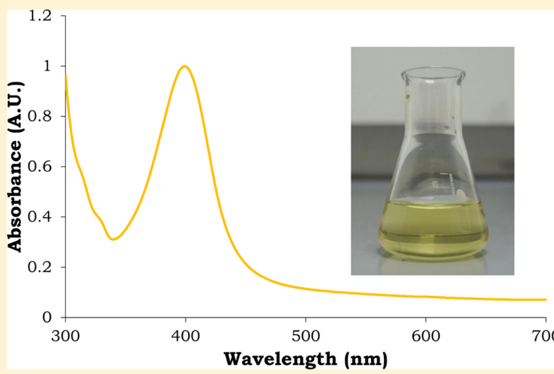
Supporting Information

ABSTRACT: We describe the "sweet nanochemistry" synthesis of starch stabilized silver and gold nanoparticles in a glucose solution rendered basic by the addition of ammonia or sodium hydroxide.



KEYWORDS: *First-Year Undergraduate/General, Second-Year Undergraduate, Inorganic Chemistry, Inquiry-Based/Discovery Learning, Colloids, Nanotechnology, UV–Vis Spectroscopy*

INVESTIGATING THE ROLE OF pH IN SYNTHESIZING SILVER NANOPARTICLES

Nanotechnology has become one of the most intriguing research topics. The synthesis of silver and gold nanoparticles is a challenging research project for chemistry students to learn more about the specific properties of nanomaterials. Laboratory experiments to synthesize silver and gold nanoparticles have been extensively described in this journal.[1,2] Green chemistry aspects in the synthesis of metal nanoparticles were introduced by Sharma et al., and honey was used in a greener preparation of gold nanoparticles by Paluri et al.[3,4] An enzymatic system using glucose oxidase to produce hydrogen peroxide in situ, simulating a glucose biosensor, can be successfully used to enlarge gold nanoparticles.[5] However, in this communication we would like to explore and extend the "sweet nanochemistry" synthesis as described in the original "sweet nanochemistry" article.[6] During a research project our students were able to prepare yellow silver colloids as described in "sweet nanochemistry". Based on this method silver colloids were synthesized by reducing silver(I) ions with glucose in a solution of starch and trisodium citrate. Cooke et al. stated that trisodium citrate was necessary although it is a mild reducing agent and that only glucose was responsible for the reduction of the silver(I) ions. As the authors suggested, we investigated the role of trisodium citrate during the synthesis of the metal nanoparticles; specific details of the experiments can be found in the Supporting Information. Consistent with Cooke et al.'s observations, without the addition of trisodium citrate we were not able to conventiently prepare yellow silver nanoparticles. However, the suggestion that pH could play an essential role in the synthesis of the metal nanoparticles provided an interesting research project for our students. First, we started the synthesis without the addition of trisodium citrate and we lowered the pH by adding nitric acid, but at low pH we were not able to synthesize silver colloids. Therefore, we investigated the "sweet nanochemistry" synthesis in base solution. The Tollens reaction introducing the use of ammonia has been described to successfully produce silver nanoparticles of different sizes.[7,8] We added the weak base ammonia to the starch and glucose solution with silver(I) ions leading to diamminesilver(I) ions. After heating this ammonia solution of starch, diamminesilver(I) ions, and glucose, we observed a yellow sol after a couple of minutes indicating the formation of silver colloids. A representative UV–vis spectrum visualizing the surface plasmon resonance for the silver colloids is shown in Figure 1 with λ_{max} around 410 nm and the full width at half-maximum (fwhm) was calculated to be 66 nm, in correspondence with Cooke et al.

The role of pH in the synthesis of silver nanoparticles has been previously investigated by adding sodium hydroxide to a glucose, starch, and silver nitrate solution.[9] Therefore, we added a small amount of sodium hydroxide to a starch and glucose solution of silver(I) ions. Instead of several minutes, the solution now immediately turned yellow indicating the formation of silver colloids. The appearance of silver colloids

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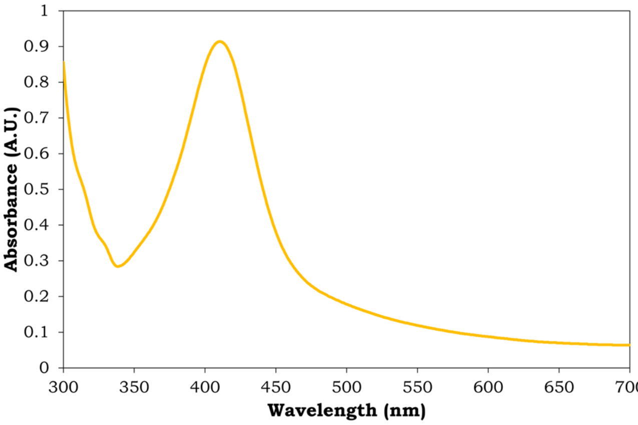

Figure 1. UV−vis spectrum of the sweet nanochemistry synthesis of silver colloids after the addition of an ammonia solution to a glucose/starch/silver nitrate solution.

was characterized using the Faraday−Tyndall effect, and the plasmon resonance was shown using UV−vis spectroscopy.

EXTENDING THE SWEET NANOCHEMISTRY SYNTHESIS TO GOLD NANOPARTICLES

Furthermore, the method described in this communication can be easily adapted for the synthesis of starch stabilized gold colloids. We added the weak base ammonia to a starch, glucose, and tetrachloroaurate(III) solution. After heating of this solution, the color changed from pink to purple into red after a couple of minutes, indicating the formation of gold colloids.[10] The corresponding UV−vis spectrum for gold colloids is shown in Figure 2. The typical surface plasmon resonance peak is observed around 520 nm, and the fwhm was calculated to be 42 nm.

Similarly to the synthesis of silver colloids, addition of sodium hydroxide to a starch, glucose, and tetrachloroaurate(III) solution turned the solution immediately red.

CONCLUSIONS

As an alternative to previously published procedures, we suggest trying the "sweet nanochemistry" synthesis without the addition of trisodium citrate, but instead in a weak base solution of ammonia or after adding a small amount of sodium hydroxide to the glucose, starch, and silver nitrate solution. These straightforward experiments confirm that it is glucose that accomplishes the reduction of silver(I) ions and that pH plays an essential role in the synthesis of starch stabilized silver nanoparticles. Moreover, this procedure can be easily adapted to the "sweet nanochemistry" synthesis of gold colloids, another experiment that is popular in chemical education curricula.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00943.

Detailed information about the experimental procedures and results (PDF, DOCX)

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Notes

The authors declare no competing financial interest.

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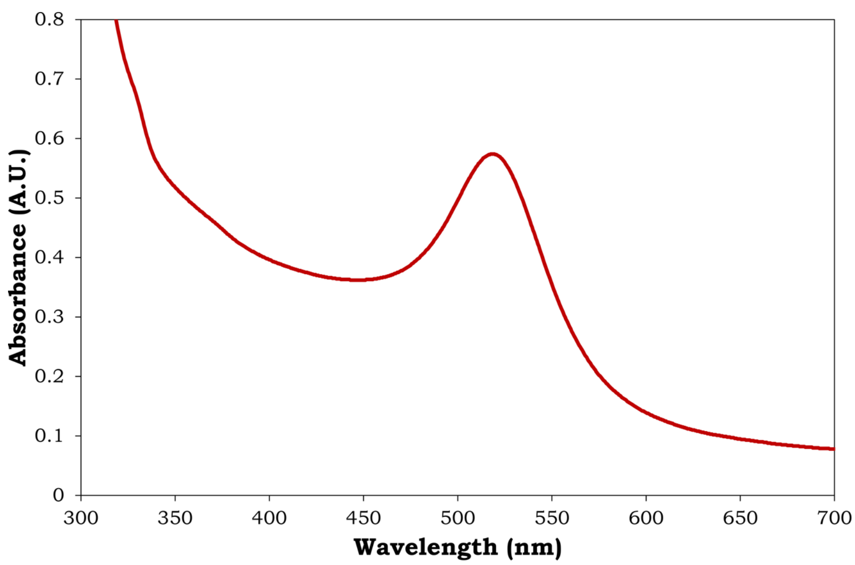

Figure 2. UV−vis spectrum of the sweet nanochemistry synthesis of gold colloids after the addition of an ammonia solution to a glucose/starch/tetrachloroaurate(III) solution.

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