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Colorimetric measurement of heavy metals in water using gold nanoparticles

Sensors utilizing plasmonic nanoparticles (NPs) operate on the principle of localized surface plasmon resonances (LSPRs), where free electrons in metals oscillate coherently in response to an electromagnetic wave. The primary method of plasmonic sensing involves detecting shifts in the plasmon resonance spectrum, which occurs when an analyte selectively binds to the metal surface, altering the local refractive index. Due to their easy fabrication, low cost, rapid readout, and broad acceptance, plasmonic sensors, especially those using gold nanoparticles, hold great potential for future advancements.

Plasmonic sensing with gold nanoparticles (AuNPs) relies on their aggregation in the presence of surface-binding bio(macro)molecules, causing a color change from red to blue due to plasmon coupling. This color shift can be easily observed without specialized equipment, and digital devices can capture it, providing detailed information through color space (RGB) analysis. In nanoparticle aggregation sensors, significant clustering occurs within minutes of analyte addition, with the color change intensifying as the particles come closer together and form larger clusters [1].

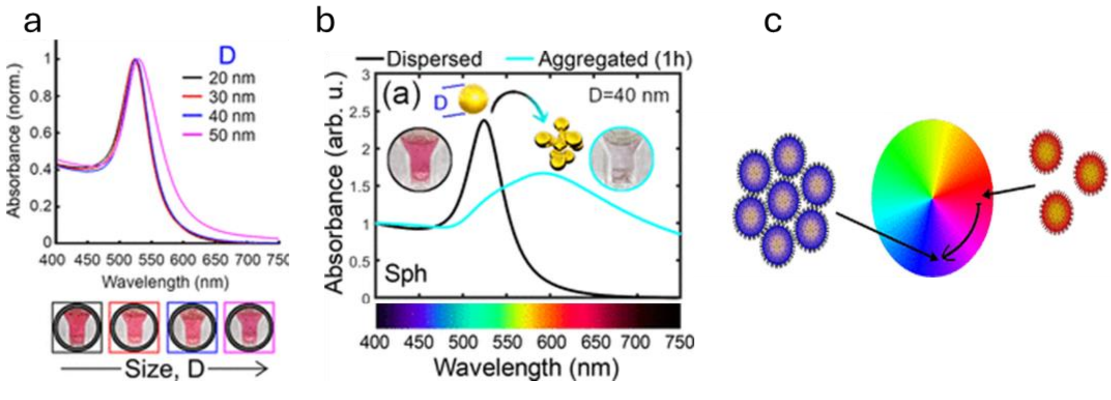

Figure 1 a) The absorbance spectra of AuNPs and photographs of the colloidal solutions. b) the spectral shift observed in colloidal sensors due to the aggregation of AuNPs. c) Aggregation-induced color transition of AuNPs [1].

Monitoring barium (Ba) concentrations in water is essential for regulatory compliance and preventing contamination in many industries. Colorimetric methods, such as the chromate method [2], are cost-effective and simple, making them ideal for on-site analysis of Ba. However, these methods have limitations, including interference from other ions, pH sensitivity, and limited ability to detect low Ba concentrations. Additionally, turbidity-based methods can suffer from interference by suspended particles and lack specificity, making them less reliable for precise barium measurements.

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AuNPs present a promising alternative. They offer enhanced sensitivity and selectivity, allowing for the detection of low Ba concentrations with faster response times. Less affected by interference, nanomaterials also have a high surface area, ensuring efficient interaction with Ba ions. Consequently, they provide greater accuracy and precision compared to traditional colorimetric methods, making them a valuable option for Ba measurement.

We synthesized functionalized AuNPs for the selective and colorimetric detection of Ba^{2+} in aqueous solutions. The synthesized AuNPs were characterized to assess particle size and dispersion quality. These modified AuNPs were then utilized to measure the Ba concentration in standard solutions containing 12.5 ppm, 25 ppm, and 50 ppm, with deionized (DI) water serving as the blank. As illustrated in Figure 2, the blank solution appeared red, while the samples containing Ba^{2+} exhibited a blue color due to the aggregation of the AuNPs. In the next phase, we refined our synthesis and measurement setup, as well as the experimental parameters, resulting in lower detection limits. However, since this method is entirely novel, further modifications and optimizations are still in investigation.

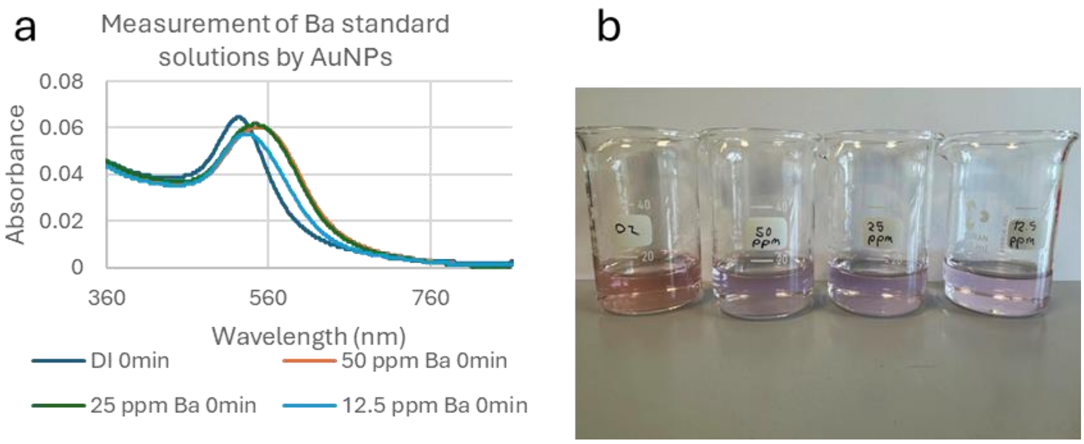

Figure 2 Colorimetric measurement of Ba by AuNPs. a) Spectra and b) Photograph of the measured Ba solutions.

References:

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2. Norwitz, George. Assay of Barium Compounds by Precipitation of Barium Chromate from Homogeneous Solution. *Anal Chem* 33, 312–313 (1961).