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Gold nanoparticles-based colorimetric sensor for cysteine detection

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Abstract

A simple, sensitive and selective colorimetric method for the detection of cysteine was demonstrated with unmodified gold nanoparticles (AuNPs) as probes. In this approach, the synthesized AuNPs solution was stabilized by the citrate anions as their repulsion protected the AuNPs from aggregation. Cysteine was added to AuNPs solution and was incubated to react for 3 min. The resulting mixture color changes dramatically from red-purple-blue because cysteine induced the nanoparticle aggregation. These processes were studied and characterized by UV–vis spectroscopy, zeta potential and dynamic light scattering. Several parameters including AuNPs size, reaction time and media pH that governed the analytical performance of the method have been studied in detail and optimized. Under the optimized experimental conditions, cysteine could be selectively detected in a concentration range from 0.1 to 0.6 ppm with a limit of detection as 0.01 ppm at a signal-to-noise ratio of 3. The sensitivity was calculated as 1.474 Abs/ppm. Some common interferents such as Na^+, Cu^{2+}, Cl^- and urea showed no interference in the determination of cysteine by using AuNPs.

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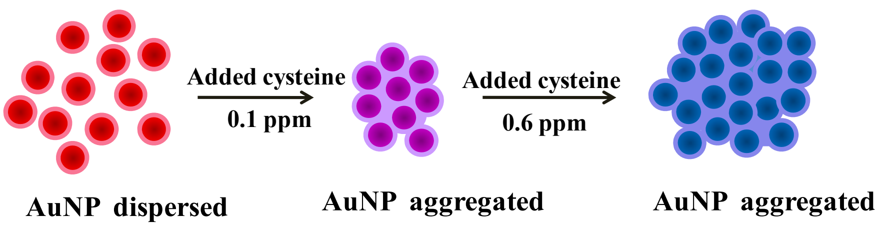
1. Introduction

In the past decades, there has been rapid growth in nanotechnology research. Nanotechnology deals with processes that take place on the nanometer scale, that is, from approximately 1 to 100 nm. In nanotechnology, the assembly of metallic nanoparticles has resulted in novel materials with interesting electronic, optical and chemical properties [1-3]. Metal nanoparticles have attracted great interests as the both chemical sensor and biosensor because of their easy biofunctionalization, high surface area and spectral properties [4]. Among these metal nanoparticles, gold nanoparticles (AuNPs) have found useful applications in chemical analysis [5-7]. In recent few years the use of AuNPs as sensing probe for the detection of important analyses base on aggregation of nanoparticles was dramatically increased.

AuNPs can exhibit unusual chemical, physical, electrical and optical properties that are not likely in bulk materials. The optical properties of AuNPs have attracted scientists because of their applications as a colorimetric probe [8-10]. AuNPs as colorimetric sensor or probe have been widely used for several analytes such as mutations [8], immunoglobulin G [11], mercury(II) ion [12], cartap [13] and melanine [14]. AuNPs provided high sensitivity for the detection because they exhibit characteristic surface plasmon resonance (SPR) absorption properties. The resonance frequency of this SPR is strongly dependent upon the size, shape, dielectric properties, and local environment of the nanoparticles [15]. In most of the cases the use of AuNPs as chemical sensing can achieved by mornitoring the changes in the color upon aggregation/dissociation processes. The color of AuNPs may range from red to purple, to blue and almost black, due to the formation of aggregates. In colloidal solutions, AuNPs are red in color because of the Mie absorption by their surface plasmon oscillation that peaks at 520 nm [16]. AuNPs have been induced to aggregate by the addition of molecule which presented of amine or thiol groups via non-covalent bonding. The aggregation of AuNPs leads to the formation of a new absorption band at longer wavelengths as a result of color change from red to purple-blue depending on their particle size [17].

Cysteine is a non-essential α-amino acid containing nonpolar sulphydryl (-SH) group that provides its participation in a variety of biochemical reactions. The lack of cysteine is responsible for many kinds of different diseases. It causes slow hair growth, depigmentation, damage of liver and muscles [18]. Therefore, the monitoring of cysteine in biological matrices is highly demanded. A number of methods have been developed for the assay of cysteine such as spectrofluorimetric [19], chemiluminescent [20], electrochemistric [21] and chromatographic methods [22]. These methods are generally laborious and time consuming. In addition, procedures require expensive and complicated instrumentation that make them unattractive to routine analysis.

Thus, this work investigated the development of method for cysteine detection with cost effective, short analysis time and no requirement of expensive instrumentation. A propose method was evaluated by using unmodified AuNPs. The cysteine presented $-NH_2$ and -SH which offered to coordinate to AuNPs and cross-link AuNPs causing aggregation. The clearly distinguish able color change facilitates a simple sensor was developed for cysteine detection. Hence, in this work we gave the demonstration of the colorimetric detection of cysteine using unmodified AuNPs as probes. The assay procedure for the colorimetric detection of the cysteine is illustrated in scheme 1.



Scheme 1. Schematic representation of the colorimetric assay for cysteine detection using AuNPs.