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Lithium dodecyl sulphate assisted synthesis of Ag nanoparticles and its exploitation as a catalyst for the removal of toxic dyes

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ABSTRACT

We established for the first time the dual significance of lithium dodecyl sulphate (LDS) as a reducing agent as well as a stabilizing agent in the synthesis of silver nanoparticles (Ag NPs). This is an eco-friendly and economical method which avoids the utilization of additional external reducing agent, external stabilizing agent, template and solvent. The size and morphology of the individual Ag NPs can be tuned by controlling the various reaction parameters, such as temperature, concentration and pH. The studies showed that with increase in concentration, not only the size but also the morphology of the Ag NPs changes (from particles to rod). The size of the Ag NPs increased with increase in temperature and pH. The prepared Ag NPs were characterised by ultraviolet–visible spectroscopy (UV–vis), transmission electron microscopy (TEM), selected area electron diffraction (SAED) and X-ray diffraction (XRD) analyses. The probable mechanism for the formation of Ag NPs is presented. The formation of Ag NPs was also studied as a function of time. The synthesised Ag NPs were used for the catalytic reduction of methylene blue and eosin dyes in aqueous media and methylene blue in micellar media. They exhibited good catalytic reduction ability towards methylene blue and eosin dyes in aqueous and micellar media. The probable mechanism for the reduction of dyes is also presented in this article.

1. Introduction

During the past two decades, nanometal particles (ranging from 1 to 100 nm) have received immense attraction due to their potential applications in the field of catalysts, electronics, pharmaceuticals, data storage and optics [1–6] as compared to the bulk materials. Although various biomass and waste materials are employed for the removal of metals, dyes and other hazardous contaminants from water [7–19]. But these processes are further modified by introducing nanostructured materials because of their vast applications instead of waste products and biomass [20–36].

Among the various NPs, the noble metal NPs, especially silver (Ag) NPs have been the main area of focus of the scientists because of their fascinating physical and chemical properties. These Ag nanoparticles have potential applications in various emerging fields, like catalysis, nanoelectronics, biomedicine, sensing, and surface-enhanced Raman scattering (SERS), in the field of water treatment, such as removal of hazardous dyes and other toxic metals from water [37–39]. In the UV–visible region, these Ag NPs exhibit a unique absorption phenomenon known as surface plasmon resonance (SPR) [40,41], where the conducting electrons in metals collectively oscillate in resonance with electromagnetic radiation. The change in position of these bands gives information of the morphology, chemical surrounding, particle type, particle size, dielectric constant and adsorbed species on the surface [42,43]. The difference of morphologies of the NPs governs their properties and applications. Therefore, in any synthesis process, the control of their sizes and shapes is an essential requirement. Several methods have been reported for the synthesis of NPs of different morphologies [44–48]. Various methods are available in the literature for their synthesis [49–55]. A directed synthesis using appropriate template offers a better control over the shape and size of nanostructures and avoids the agglomeration of NPs. The hexagonal mesoporous silica SBA-15, anodized alumina, carbon nanotubes, hydroquinone nanotubes and self-assembled calyx are utilized as hard templates [56–59]. The block co-polymers, polymers, DNA molecules, Langmuir–Blodgett (LB) films, co-polymer gels and rod-shaped micelles (inverted) have been employed as soft templates to produce Ag nanostructures [60–68]. Generally, cationic and anionic surfactant based micelles are used as a template for the growth and stabilization of the NPs in the solution. The morphology of NPs is dependent on the size and shape of the micelle utilized as a template in the reaction [69]. In this communication, we demonstrated the dual importance of amphiphilic molecule, lithium dodecyl sulphate (LDS), as a stabilizing as well as a reducing agent in the synthesis of Ag NPs. The prepared Ag NPs were utilized for the catalytic reduction

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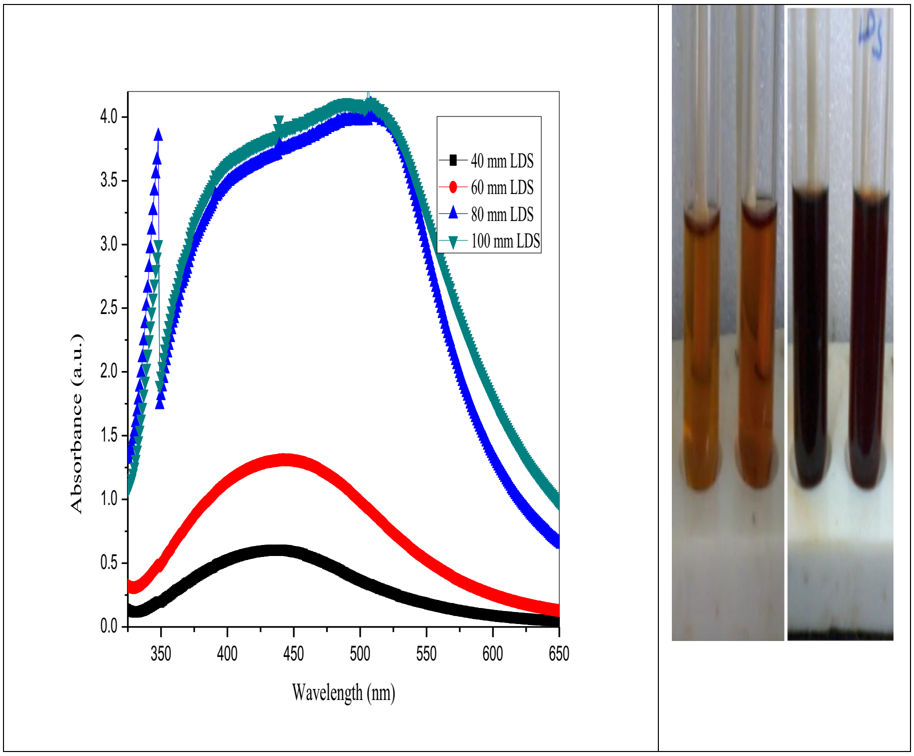

Fig. 1. UV–vis absorption spectra were recorded of synthesised Ag NPs with different concentrations of LDS (40, 60, 80, and 100 mM) solution treated to 0.1 M $AgNO_3$ solution. The colours of the solution are shown in the inset after 5 days in increasing order of concentration from left to right.

of methylene blue (MB) and eosin (EO) dyes in aqueous medium and methylene blue in micellar media. In the reported method, the distinct use of reducing agents, like $NaBH_4$, hydrazine and glucose with stabilizing agents, like sodium dodecyl sulphate (SDS), cetyl trimethyl ammonium bromide (CTAB) and Triton X-100 can be eliminated. The LDS can function both as a reducing as well as a stabilizing agent in the synthesis of Ag NPs. The present synthesis process and catalytic reactions are simple, reproducible and robust.

2. Materials and methods

2.1. Materials

Silver nitrate, lithium dodecyl sulphate, sodium borohydride, sodium dodecyl sulphate, n-dodecyl dimethyl ethyl ammonium bromide, methylene blue and eosin of analytical grade were purchased from Sigma-Aldrich Chemicals and used without any further purification.

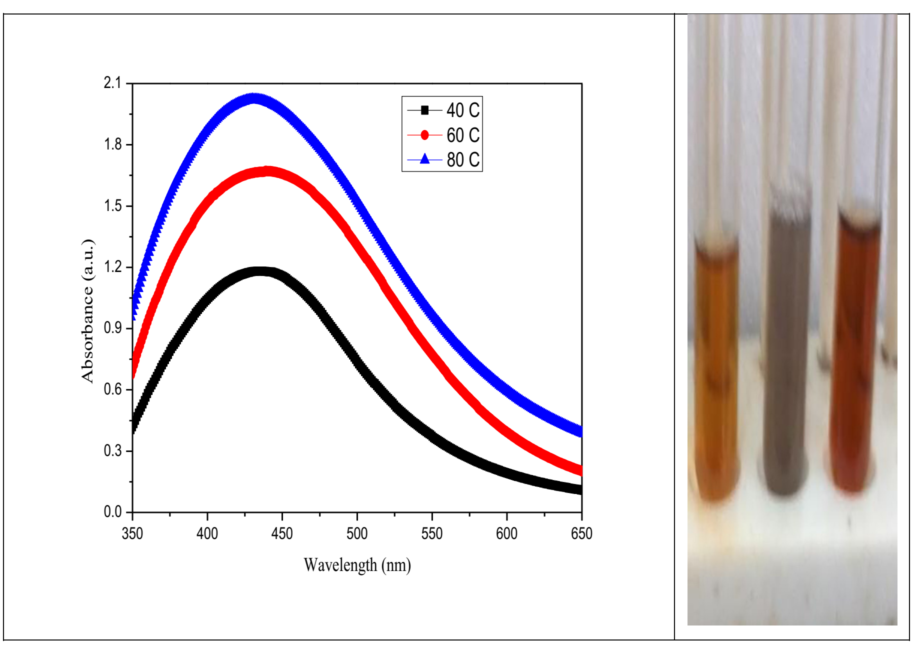

Fig. 2. UV–vis absorption spectra were recorded for Ag NPs at different temperatures (40, 60, 80 °C) when 10 mL of 0.1 M silver nitrate solution was treated to 10 mL of 60 mM LDS solution. The colours of the solution are shown in the inset after 5 days in increasing order of temperature from left to right.

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