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The preparation of poly(vinyl phosphonic acid) hydrogels as new functional materials for in situ metal nanoparticle preparation

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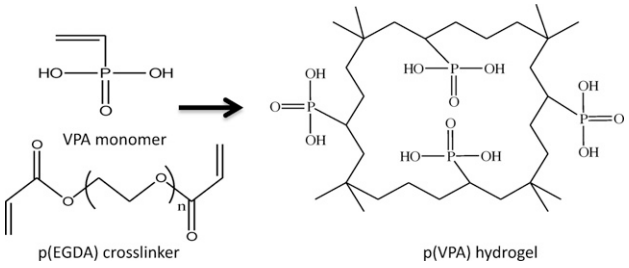
HIGHLIGHTS

- A new p(vinyl phosphonic acid) hydrogel.
- Soft template and reactor metal catalyst preparation.
- Hydrogel–metal nanoparticle composites hydrogen generation.

GRAPHICAL ABSTRACT



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ABSTRACT

Bulk poly(vinyl phosphonic acid) (p(VPA)) hydrogels were synthesized via a photo polymerization technique using polyethylene glycol diacrylate with different molecular weights as crosslinker. The prepared hydrogel was also used as template for in situ metal nanoparticle preparations of Co, Ni and Cu, by loading the corresponding metal ions from aqueous solution into the p(VPA) hydrogel networks and then reducing the metal ions with sodium boron hydride ($NaBH_4$) within the hydrogel matrices. The amount of metal in hydrogel composites was determined by atomic absorption spectroscopy (AAS) and thermogravimetric analysis (TGA) measurements. Moreover, p(VPA)–M (M: Co, Ni, Cu, etc) were used as a soft reactor for the generation of hydrogen by hydrolysis of $NaBH_4$,and in the reduction of 4-nitrophenol (4-NP) to 4-aminophenol (4-AP). P(VPA)–Co composite demonstrated the best catalytic performance and its activation energy was calculated as 23.01 kJ mol^{-1} which is comparable and mostly better than similar work in the literature.

1. Introduction

The three-dimensional networks of crosslinked hydrophilic polymers hold a significant amount of water [1]. Most of the time in a super absorbent hydrogel the weight percent of polymer in a swollen hydrogel is >1 [2]. Hydrogels can be prepared with different functional groups containing monomers such as $-SO_3H$, $-COOH$, $-NH_2$, and $-OH$ [3]. The functional groups that are attached onto the polymeric networks can render different abilities for versatile applications, such as tissue engineering, drug delivery systems [4–6], water purification [3,7,8], and sensors [9], etc. Recently, hydrogels with different functional groups have been reported as template materials for different metal nanoparticle synthesis in situ and these metal nanoparticle-containing composite hydrogels were used in catalysis of various reactions [10,11].

In the past decades, metal nanoparticle preparation methods in different templates have been extensively investigated [12–15]. Many catalysts, such as Ni, Co, Cu, Pt, Ru nanoparticles [16–18], Ni–Ru nanocomposite [18], ruthenium (III) acetylacetonate [19], Ni–B [20], and Co–B [21,22] have been prepared and used in the hydrolysis of $NaBH_4$ [23–25] and in the reduction of 4-NP to 4-AP [26,27].

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