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Cooperative effect of gold nanoparticles with CUS aluminium from nanoalumina support in the catalysis of an electron transfer reaction

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ABSTRACT

In this paper, firstly mesoporous gamma and alpha-alumina with nanorod morphology, exhibiting high surface area (629.44 $m^2\,g^{-1}$), large pore volume (2.25 $cm^3\,g^{-1}$) and pore size (140.3 Å) have been synthesised by a non-surfactant-templating sol–gel method. Then, new nanocatalysts, i.e. Au-NAl350, Au-NAl550, Au-NAl750, and Au-NAl1100 were prepared by deposition of gold nanoparticles on the various synthesised nanostructured alumina supports with different physicochemical properties; surface area (20.56–629.44 $m^2\,g^{-1}$), pore volume (0.63–2.25 $cm^3\,g^{-1}$) and pore size (73.88–143.76 Å). Textural, morphological and structural characterisations of both nanoalumina supports and nanogold/nanoalumina catalysts were done by nitrogen physisorption, XRD, ^{27}Al MAS NMR, TEM and FTIR study of low temperature CO-adsorption. The effect of physiochemical properties of the nanoalumina supports on the structure and catalytic activity of nanogold active phase were studied in the catalytic reduction of ferricyanide to ferrocyanide by thiosulphate under three reaction temperature; 20, 40 and 60 °C. It was found that the Au-NAl550 nanocatalyst with large surface area (579 $m^2\,g^{-1}$), pore volume (2.13 $cm^3\,g^{-1}$) and pore size (141.05 Å) has the highest catalytic activity. The characterisation results showed that Au nanoparticles highly and uniformly dispersed on the high surface area nanoalumina support. The metallic character of the gold nanoparticles, acidity and activity of catalyst were determined by structure, acidity and texture of the nanoalumina support. It was confirmed that the reduction reaction is totally controlled by the surface properties of catalyst.

1. Introduction

Gold supported catalysts are at present applied to catalyse many reactions of both industrial and environmental importance. The remarkable catalytic performance of supported gold was first reported for the reaction of CO oxidation at low temperature by Haruta et al. [1]. Since then, gold has been tested as catalyst in various other reactions, which involve electron transfer [2–6].

The support plays a crucial role for the catalyst reaches the best performance. Firstly, diffusion of reactants can be determined by the support [7,8]. Secondly, the support may influence the surface properties of gold particles because of the gold-support interactions [9,10]. Thirdly, the support can drive the hydrophilic character of catalyst. The performance of supported catalysts, including of the redox catalysts such as supported-gold ones is significantly depending on the physicochemical properties (surface area, pore diameter, acidity) of their support. Actually, often the physicochemical properties of the support drive the dispersion and oxidation state of metal. Thus gold has been supported on titania, silica, mixed oxides, zeolites, alumina, and boehmite, among others [11–15]. Boehmite and alumina comprise an interesting material for catalysts and catalyst supports applications in various chemical processes, mostly because of their low production costs. Boehmite (aluminium oxyhydroxide, γ-AlOOH) is the main precursor used to obtain aluminas (transition alumina γ, θ, and α-Al_2O_3). Of course, the support is selected keeping in mind the reaction to be catalysed. In these sense, the reduction reaction of ferricyanide to ferrocyanide by thiosulphate in aqueous solution has been by the first time catalysed by colloidal gold [16].

$$[Fe(CN)_6]^{3-} + (S_2O_3)^{2-} \rightarrow [Fe(CN)_6]^{4-} + 1/2\,(S_4O_6)^{2-} \quad \text{(I)}$$

It was shown that this reaction, which is taken as a model of an electron transfer reaction, is catalysed by other noble metals

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