Hydrothermal synthesis of basic catalysts from waste container glass

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Soda-lime-silica glass containers form a large proportion of the municipal waste-stream in every developed nation. The full recycling potential of waste container glass is frustrated by a number of political, aesthetic and technical obstacles. Commonly, poor collection infrastructure and colour mismatch limit the respective supply and demand for coloured waste glass that can be effectively recycled as new container glass.

Various projects have been carried out to 'upcycle' surplus soda-lime-silica glass into potential value-added materials such as ion-exchangers, lightweight aggregates and ceramics.[1-4] In this study, waste green container glass cullet has been evaluated as a feedstock material for the hydrothermal synthesis of the basic mineral phases, tobermorite ($Ca_5Si_6O_{16}(OH)_2.4H_2O$) and lithium metasilicate (Li_2SiO_3).

A mixed product of tobermorite with minor proportions of calcium hydroxide and calcium carbonate was obtained by hydrothermal synthesis from waste green container glass in 4 M sodium hydroxide solution at 125 °C. Lithium metasilicate with minor quantities of calcium carbonate, lithium carbonate and calcium hydroxide was prepared similarly in 4 M lithium hydroxide solution. The reaction products were characterised by powder X-ray diffraction, Fourier transform infrared spectroscopy and scanning electron microscopy.

The Knoevenagel condensation is an important reaction in the chemical and pharmaceutical industries to generate new carbon-carbon bonds. It involves the nucleophilic addition of an active hydrogen compound to an aldehyde or ketone in the presence of a basic catalyst.[5] This reaction is generally carried out in solution under basic homogeneous catalysis which presents problems associated with the separation of the product and the disposal of the caustic waste liquor. Accordingly, environmentally benign solid basic catalysts have been proposed as a superior alternative to the traditional homogeneous catalysis.

The potential ability of the tobermorite and lithium metasilicate products to catalyse the Knoevenagel condensation was tested on the reaction of benzaldehyde and ethyl cyanoacetate at 80 °C to produce ethyl trans-α-cyanocinnamate. The ethyl trans-α-cyanocinnamate product was confirmed by gas chromatography with mass spectrometry, and the reaction, in the presence and absence of the catalyst, was monitored by gas chromatography. Both tobermorite and lithium metasilicate products were found to successfully catalyse the Knoevenagel synthesis of ethyl trans-α-cyanocinnamate. These findings indicate that these waste-derived materials are promising basic heterogeneous catalysts for organic synthesis.

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