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Alkene epoxidation with urea–hydrogen peroxide complex and PS–DVB supported phthalic anhydride

Chiara Ghiron,[a] Lorenzo Nannetti[b] and Maurizio Taddei[b,*]

[a]*Sienabiotech srl, Via Fiorentina 2, 53100 Siena, Italy*
[b]*Dipartimento Farmaco Chimico Tecnologico, Università degli Studi di Siena, Via A. Moro, 53100 Siena, Italy*

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Abstract—A new PS–DVB supported phthalic anhydride and UHP (urea–hydrogen peroxide complex) have been used for metal-free alkene epoxidation reactions. The resin was prepared by MW mediated 'PEGylation' of Merrifield resin followed by esterification with trimellitic anhydride chloride. Epoxidation of several alkenes was carried out with this resin and UHP.

The use of polymer-supported reagents and scavengers is a powerful technique for expedited synthesis and purification.[1] Polymer-supported reagents and scavengers can selectively remove excess reagents and by-products by simple filtration rather than liquid–liquid extraction and chromatographic purification. In addition, polymer-supported reagents offer further advantages that include reaction of active intermediates by 'catch-and-release', selectivity and immobilization of toxic intermediates. In order to broaden the range of reactions capable of being carried out using such polymer-assisted techniques, new polymer-supported reagents are continually being developed.[2]

The epoxidation of olefins is a very important reaction in organic synthesis and few methods that rely on the aid of polymer-supported reagents are available.[3] Apart from the use of different supported metal catalysts with different peroxide sources,[4] there have been several reports regarding the linkage of different ketones to various insoluble supports and their use in dioxirane-mediated epoxidations.[5] Moreover recently a PEG-ketone reagent was found to be an effective homogeneous catalyst for dioxirane-mediated epoxidation.[6]

Following our interest in development and use of new supported reagents,[7] we focused our attention on the preparation of a polymer-supported peroxyacid to carry out a direct epoxidation of an alkene in solution. This kind of reagent would have the advantages of a supported reagent together with the safer handling of the peroxyacid.

Inspired by magnesium monoperoxyphthalate, considered an alternative reagent for many reactions conventionally carried out with MCPA,[8] we tried to prepare a peroxyphthalic compound supported on insoluble polystyrene–divinylbenzene (PS–DVB). Reaction of trimellitic anhydride chloride (commercially available) with a OH or NH_2 terminal resin would link a phthalic anhydride moiety to the support for the transformation into the required peroxyacid using H_2O_2. As the last step would require an aqueous environment,[9] we decided to insert a polyethylene glycol spacer on the PS–DVB resin.

Thus Merrifield resin was submitted to 'PEGylation' using PEG with molecular weight 200, under microwave irradiation, to give the OH terminal product **2**.[10] The reaction was monitored by FT-IR (OH stretching at $3100\ cm^{-1}$) and by a colorimetric test.[11] Reaction with trimellitic anhydride chloride in DCM and triethylamine gave the supported anhydride **3**, which was characterized through FT-IR and a negative colorimetric test for free OH.[12] This resin was treated with H_2O_2 (30% in H_2O). After filtration and wash with MeOH and DCM, we obtained a resin (**4**) that gave a positive test for acids[10] and a positive test for the presence of peroxides[13] (Scheme 1).

This resin was initially used to carry out the epoxidation of 1-octene but without any appreciable results.

Keywords: Supported reagents; Epoxidation; Peroxyacid.

* Corresponding author. Tel.: +39 057 723 4280; fax: +39 057 723 4333; e-mail: taddei.m@unisi.it

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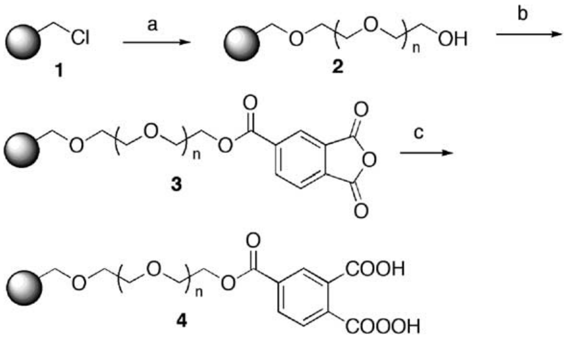


Scheme 1. Reagents and conditions: (a) PEG(200), NaOH, MW, 170 °C, 2 min. (b) Trimellitic anhydride chloride, DCM, Et$_3$N, rt, 2 h. (c) H_2O_2/H_2O 30%, MeOH, rt, 6 h.

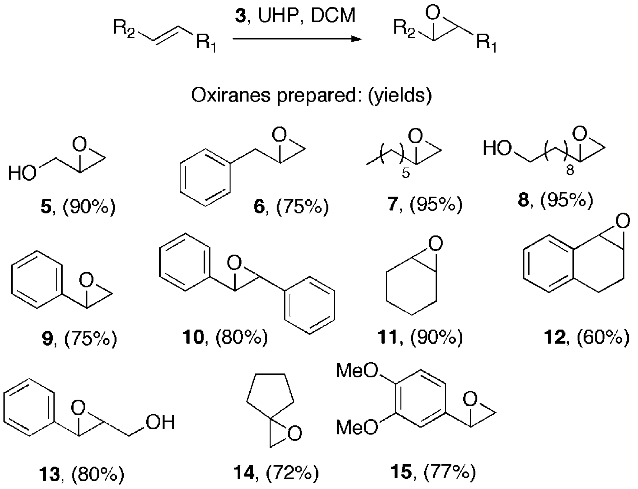
Different reaction conditions were employed but the epoxide was obtained in modest yields. The presence of unreacted alkene was detected even when a large excess of the resin was employed. Such poor reactivity was attributed to a low peracid content in the resin, as we were not able to accurately determine the loading through iodimetric titration due to the low amount of iodine produced.

We then explored alternative conditions to form the supported peroxyacid, which could be successfully prepared in situ by treatment of the supported phthalic anhydride with urea–hydrogen peroxide complex (UHP).[14]

The reaction of 1-octene with resin **3** in the presence of UHP in DCM at room temperature gave a complete conversion to the corresponding oxirane, which was isolated pure by ^{1}H NMR after filtration and evaporation of the solvent.[15] It is to be noted that control experiments using UHP as the only oxidizing agent did not lead to the formation of the desired epoxides.

The epoxidation of a variety of alkenes was therefore examined following this procedure and epoxides **5–15** were obtained in good yields. The reactions were monitored using standard TLC or GLC techniques. When the presence of starting material was observed after 12 h at room temperature, resin **3** was added (portions of 1 equiv every 6 h) until a complete conversion was achieved. The yields listed in Scheme 2 represent pure isolated products. In most cases, the epoxide was the sole product formed and the lower yields are the result of product loss during the work-up.

In summary, we have developed a system for alkene epoxidation reactions based on PS–DVB supported phthalic anhydride and UHP. Resin **3** and UHP, both insoluble in DCM, allow epoxidation to be carried out in a parallel fashion. Since purification is limited to filtration, solvent change and evaporation, the method should be a useful new tool in the synthetic chemistry toolbox.



Scheme 2.

Further applications of the peroxyacid resin are currently under investigation in our laboratories, as well as the use of a simple PD-DVB resin without PEG linker and will be reported in another communication.

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Supplementary data

IR spectra (registered as diffuse reflectance infrared fourier transform spectroscopy) of resin **2** and **3**. Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.tetlet.2005.01.074.

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15. Benzyloxirane **6**, general procedure. A mixture of UHP (0.25 g, 0.79 mmol, H_2O_2 contents 30% w/w) and resin **3** (0.44 g, 0.26 mmol of a resin loading 0.6 mmol/g) in dry DCM (2 mL) were stirred (using a vortex system) at room temperature for 15 min. Allylbenzene (21 mg, 0.176 mmol) was added and the mixture stirred at room temperature overnight. After filtration to remove the solid, the solvent was evaporated. The crude was treated with dry Et_2O, stirred for 10 min and then filtered on a short cartridge filled with silica or celite in order to remove completely possible traces of UHP still present in solution. The solvent was evaporated to give 17.6 mg (75% yield) of benzyloxirane **6** that resulted pure by ^1H NMR analysis.