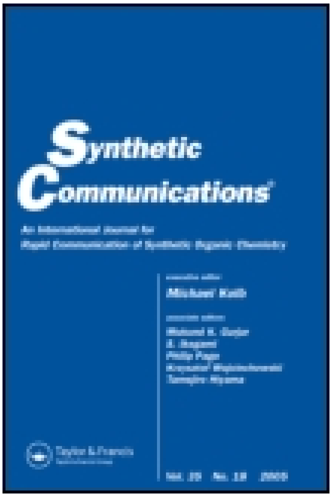

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Green Alkoxyiodination of Cyclohexene Mediated by Natural Clay

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Abstract: The reaction of cyclohexene with iodine and alcohols (ethanol, isopropanol, and *t*-butanol) at room temperature is effectively mediated by clays to produce the corresponding *trans*-*β*-alkoxy-iodocyclohexane.

Keywords: Clay, coiodination, green chemistry

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INTRODUCTION

The successful application of heterogeneous catalysis in organic reactions has been one of the most fruitful areas of green chemistry. Clay minerals are silicate of aluminium with layered structures that present a wide use in organic synthesis and exhibit specific features such as high versatility, gain in yield and/or selectivity, low cost, and so forth.[1-3]

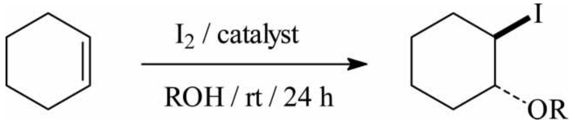
β-Iodoethers are useful intermediates in synthetic organic chemistry[4,5] and are used in radiodiagnosis.[6] Several methodologies are known for their preparation and, among them, the coiodination (iodination in the presence of a nucleophilic solvent) of alkenes with alcohols mediated by metal salts is well documented in the literature.[7]

Recently we published the hydroxyiodination (coiodination with water) of several alkenes mediated by clay minerals as an efficient route for the preparation of iodohydrins.[8] Continuing our interest in the cohalogenation of alkenes,[9-12] we communicate here the results of the reaction of cyclohexene with I_2/alcohols in the presence of clays and compare the results with traditional metal salt-mediated reactions.

RESULTS

The results of the reactions of cyclohexene with I_2 and alcohols (ethanol, isopropanol, and *t*-butanol) in the presence of diverse catalysts at room temperature for 24 h are summarized in Table 1. The catalysts studied were clays (a natural smectite Brazilian F-101 and the commercial montmorillonite K-10) and metal salts (Cu^{2+} and Fe^{3+}). In all the reactions, the corresponding *trans*-β-alkoxy-iodocyclohexane was formed as the unique organic product, which was characterized by comparison of its spectral data with those previously reported.[7,13,14] No diiodo compounds were detected in the crude products by the analytical techniques employed (high-resolution gas

Table 1. Yields of *trans*-β-alkoxy-iodocyclohexanes



	Catalyst				
R	None	F-101	K-10	$Cu(OAc)_2$	$Fe_2(SO_4)_3$
Et	27%	90%	70%	92%	89%
i-Pr	23%	90%	71%	58%	63%
t-Bu	17%	72%	50%	50%	55%

chromatography, ^{1}H and ^{13}C NMR) and although alcohols without further purification were employed, no iodohydrin arising from small amounts of water in the solvents was detected either.

All the catalysts used led to the same product and in the absence of any catalyst the yield was very poor. The reactions mediated by $Cu(OAc)_2$ and $Fe_2(SO_4)_3$ afforded the β-iodoethers in nearly the same yields. The best results were obtained with the natural smectite Brazilian clay F-101. This clay proved superior to commercial montmorillonite clay K-10 and this difference could be explained in terms of the higher Fe content of the former (10.11% vs. 3.10%),[15] which is known to catalyze coiodination reactions.[9,16]

These results clearly show the great advantage of using a clay to perform the reaction as the yields are higher, it is not toxic, the workup is easy (only a filtration of the catalyst at the end of the reaction), and there is no metal iodide residue as in the cases of metal salt–promoted reactions.

In summary, the preparation of *trans*-β-alkoxy-iodocyclohexanes from the reaction of cyclohexene with I_2 and alcohols is effective with promotion by clays and metal salts. However, considering the environmental issues that require the substitution of toxic catalysts by more friendly solid catalysts and the advantages of heterogeneous catalysis in terms of ease of workup, the utilization of clays is a better choice and consistent with green chemistry philosophy.[17]

EXPERIMENTAL

General

All chemicals were used without further purification. K-10 was purchased from Aldrich and F-101 was donated by Bentonit do Brasil (Brazil). ^{1}H and ^{13}C NMR were acquired on a Bruker AC-200 (200 and 50 MHz, respectively) spectrometer in $CDCl_3$ solutions with TMS as internal standard. Analyses by HRGC were performed on a HP-5890-II gas chromatograph with flame ionization detector (FID) by using a 28-m (length), 0.25-mm (ID), and 0.50-μm (phase thickness) RTX-5 silica capillary column and He (flow rate $50\,cm\,s^{-1}$) as carrier gas (split 1 : 10). Mass spectra were obtained on a Hewlett-Packard HP 5896-A HRGC-MS using electron impact (70 eV). IR spectrum were recorded on a Perkin Elmer 1600 FT-IR or on a Nicolet 740 FT-IR spectrometers (NaCl film).

Typical Procedure for Coiodination of Cyclohexene with Alcohols Mediated by Clays

To a stirred suspension of cyclohexene (5 mmol) and the clay (0.2 g) in the appropriate alcohol (15 mL) was added iodine (10 mmol) in small portions at room temperature. After 24 h, the clay was filtered off, Et_2O (10 mL) was added, and the organic layer was washed with a saturated solution of $Na_2S_2O_3$ (3 × 5 mL). The organic extract was dried (anhydrous Na_2SO_4) and filtered through a small column of SiO_2. The solvent was evaporated on a rotatory evaporator and then concentrated under reduced pressure (2 Torr) and in a 50°C bath to give the pure product as a colorless or light orange oil. The purity of the *trans*-2-alkoxy-iodocyclohexenes (>99%) was checked by comparison of the analytical data with that previously reported[7,13,14] as well as by coinjection in HRGC in different conditions that showed only one peak.

***trans*-1-Etoxy-2-iodocyclohexane.** Bp 235°C (Lit.[13] 95–96°C/8 Torr, corrected[18] for 760 Torr: ca. 239°C). δ_H 1.24 (t, 3H, *J* 7.00 Hz), 1.30–1.61 (m, 4H), 1.7–2.2 (m, 3H), 2.37–2.48 (m, 1H), 3.32 (m, 1H), 3.60 (m, 2H), 4.04 (m, 1H, *J* 8.9 Hz) ppm. δ_C 15.8, 23.9, 27.4, 31.6, 36.2, 38.1, 65.0, 82.0 ppm. *m/z* 254, 127, 81 (100%), 57.

***trans*-1-Isopropoxy-2-iodocyclohexane.** Bp 254°C (Lit.[13] 65–66°C/1 Torr, corrected[18] for 760 Torr: ca. 250°C). δ_H 1.16 (d, 3H, *J* 6.15 Hz), 1.23 (d, 3H, *J* 6.15 Hz), 1.28–1.57 (m, 4H), 1.79–2.14 (m, 4H), 3.38 (m, 1H), 3.78 (m, 1H), 4.02 (m, 1H, *J* 8.9 Hz) ppm. δ_C 22.8, 23.4, 24.0, 27.4, 33.2, 37.2, 38.4, 71.5, 80.7 ppm. ν_{max} 2970, 2934, 2858, 1447, 1377, 1366, 1166, 1117, 1087, 661 cm^{-1}. *m/z* 268, 225, 141, 98, 81 (100%).

***trans*-1-*t*-Butoxy-2-iodocyclohexane**. Bp not determined (decomposes during determination of bp). δ_H 1.18 (s, 9H), 1.30–1.60 (m, 4H), 1.70–2.10 (m, 4H), 3.60 (m, 1H), 4.10 (m, 1H, *J* 8.0 Hz) ppm. δ_C 23.9, 27.4, 29.4, 31.2, 36.6, 38.7, 67.1, 82.7 ppm. *m/z* 282, 267 (100%), 209, 155, 81.

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