Supplementary Material

Hydrotalcite catalysis for the synthesis of new chiral building blocks

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Abstract

We describe the use of hydrotalcites for the synthesis of two chiral building blocks in a simple way. It has been achieved the synthesis of these compounds, that implies a regioselective Baeyer-Villiger reaction in a very selective way with ulterior opening and lactonization. This methodology can be considered green for the use of hydrogen peroxide as the only oxidant and hydrotalcites as the catalyst, and no residues produced apart from water. The procedure is very adequate for using in large scale, so increase the value of the obtained compounds. The conditions are very excellent for not stable compounds as they are very mild.

Keywords: Hydrotalcites, natural products, terpenes, hydrogen peroxide, carvone

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1. Experimental

1.1 - Material and methods

Unless otherwise stated, all chemicals were purchased as the highest purity commercially available and were used without further purification. IR spectra were recorded on a BOMEM 100 FT-IR or an AVATAR 370 FT-IR Thermo Nicolet spectrophotometers. ^1H and ^{13}C NMR spectra were performed in CDCl_3 and referenced to the residual peak of CHCl_3 at δ 7.26 ppm and δ 77.0 ppm, for ^1H and ^{13}C , respectively, using Varian 200 VX and Bruker DRX 400 instruments. Chemical shifts are reported in δ ppm and coupling constants (J) are given in hertz. MS were performed at a VG-TS 250 spectrometer at 70 eV ionising voltage. Mass spectra are presented as m/z (% rel int.). HRMS were recorded on a VG Platform (Fisons) spectrometer using chemical ionisation (ammonia as gas) or Fast Atom Bombardment (FAB) technique. For some of the samples, QSTAR XL spectrometer was employed for electrospray ionization (ESI). Optical rotations were determined on a Perkin-Elmer 241 polarimeter in 1 dm cells. THF were distilled from sodium, and dichloromethane was distilled from calcium hydride under argon atmosphere. Element chemical analyses were carried out by ICP-OES in a YOBIN IVON ULTIMA II equipment at Servicio General de Análisis Químico Aplicado (Universidad de Salamanca, Spain). The powder X-ray diffraction (PXRD) patterns were recorded in a Siemens D-500 diffractometer ($2^\circ/\text{min}$) equipped with DIFFRACT-AT software and a DACO-MP microprocessor, a copper ($\lambda=1.5405 \text{ \AA}$) anode and a graphite filter. The FT-IR spectra of the catalyst was recorded in the $4000\text{--}450 \text{ cm}^{-1}$ range in a Perkin-Elmer Spectrum-One by the KBr pellet method.

1.2 - Hydrotalcite preparation and characterization

The solids were prepared by the coprecipitation method. A solution of $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ and $\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ with a Mg/Al molar ratio of 4 was added to an

aqueous solution of Na_2CO_3 at pH 10. This pH was fixed and maintained at this value by dropwise addition of 1 M NaOH. The slurry was magnetically stirred for 8 h at room temperature, then centrifuged, washed until absence of nitrates and dried at room temperature.

Element chemical analysis data for Mg and Al are given in Table S1; this table also contains the calculated formulae for the sample. As it can be observed from these data, the hydrotalcite obtained has a Mg/Al molar ratio (3.99) close to that of the initial mixed solution.

Table S1. Element chemical analysis and formula of the synthesized hydrotalcite.

	%Mg ²⁺	%Al ³⁺	Formula
HT	21,46	6,03	Mg _{0.798} Al _{0.202} (OH) ₂ (CO ₃) _{0.101} nH ₂ O

Figure S1 shows the PXRD pattern of the synthesised hydrotalcite. The position, shape, broadness, symmetry and other properties of the signals recorded agree with those reported in the literature for the hydrotalcite-like structure.⁸ The maxima recorded at low diffraction angles correspond to diffraction by the basal planes, and are ascribed to diffraction by planes (003), (006), and (009), respectively, from lower to higher diffraction angle. The spacing for planes (003) and (110) were 7.95 and 1.54 Å, respectively. The spacing of the (003) maximum corresponds to one third of lattice parameter c and the spacing of the diffraction due to planes (110) is one half of lattice parameter a . The calculated lattice parameters c and a are 23.85 and 3.08 Å, respectively. These values are typical of a Mg-Al hydrotalcite.^{7a}

Figure S1.-PXRD of the hydrotalcite

The presence of carbonate in the interlayer was confirmed by FT-IR spectroscopy, Figure S2. The FT-IR spectrum of the solid obtained present bands due to the H_2O stretching and bending modes, and the bands due to the CO_3^{2-} , thus confirming that the interlayer anion is the carbonate. The restricted interlayer space gives rise to a distortion

of the carbonate anion, as it can be concluded from the presence of the band due to the symmetric mode ν_1 , which is inactive in a D_{3h} symmetry.

Figure S2.-FT-IR spectrum of the hydrotalcite

2. IR spectrum of 8,9-epoxycarvone 2

^1H NMR spectrum of 8,9-epoxycarvone 2

¹³C NMR spectrum of 8,9-epoxycarvone 2

GC-MS of 8,9-epoxycarvone 2

RODILLA.D18 * M-4
MaxE3 SumE5
RI 98495 30640

3. IR spectrum of 1,6;8,9-diepoxy-carvone 4

¹H NMR spectrum of 1,6;8,9-epoxycarvone 4

¹³C NMR spectrum of 1,6;8,9-epoxycarvone, 4

HSQC correlation of 1,6;8,9-epoxycarvone 4

HMBC correlation 1,6;8,9-epoxycarvone 4

GC-MS of 1,6;8,9-epoxycarvone 4

RODILLA.D19 * M-5
 MaxE3 SumE4
 RI 24235 47372

2009 (21:44) 26799 12% RODILLA.D19 * M-5
 RODILLA.D19

4. IR spectrum of 8,9-epoxycarvone-1,2-olide **6**

¹H NMR spectrum of 8,9-epoxycarvone-1,2-olide 6

¹³C NMR spectrum of 8,9-epoxycarvone-1,2-olide 6

HSQC correlation of 8,9-epoxycarvone-1,2-olide 6

HMBC correlation of 8,9-epoxycarvone-1,2-olide 6

5. IR spectrum of (4*R*,5*S*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3*H*)-one, 7

¹H NMR spectrum of (4*R*,5*S*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3*H*)-one, 7

¹³C NMR spectrum of (4*R*,5*S*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3*H*)-one, 7

HSQC correlation of (4*R*,5*S*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)tetrahydrofuran-2(3*H*)-one, 7

HMBC correlation of (4*R*,5*S*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)tetrahydrofuran-2(3*H*)-one, 7

COSY of (4*R*,5*S*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)tetrahydrofuran-2(3*H*)-one, 7

NOESY of (4*R*,5*S*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)tetrahydrofuran-2(3*H*)-one, 7

ROESY of (4*R*,5*S*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3*H*)-one, 7

6. IR spectrum of (4*R*,5*R*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3*H*)-one 8

¹H NMR spectrum of (4R,5R)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3H)-one 8

¹³C NMR spectrum of (4R,5R)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3H)-one 8

HSQC correlation of (4*R*,5*R*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3*H*)-one 8

HMBC correlation of (4*R*,5*R*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3*H*)-one 8

COSY of (4*R*,5*R*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3*H*)-one 8

NOESY of (4*R*,5*R*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3*H*)-one 8

ROESY of (4*R*,5*R*)-5-(hydroxymethyl)-5-methyl-4-(3-oxobutyl)dihydrofuran-2(3*H*)-one 8

Stereochemistry determination of 7 and 8

The stereochemistry for compound **7**, was based in the existence of spatial interaction between the hydrogen H-4 that appears poorly defined at 2.21 ppm, with the Me-1'' ; this situate this methyl and hydrogen H-4 on the same side. This interaction are observed in the spectrum of ROESY. The ROESY spectrum for compound **8**, shows that the signal for H-4 located at 2.58 ppm has no spatial interaction with Me-1''. This together with the data observed for **7** indicate that Me-1'' and h4 are in trans.

7. IR spectrum of 8,9-dihydroxycarvone **9**

¹H NMR spectrum of 8,9-dihydroxycarvone **9**

¹³C NMR spectrum of 8,9-dihydroxycarvone 9

GC-MS of 8,9-dihydroxycarvone 9

RODILLA2.D13 * C-18
MaxE2 SumE4
RI 87742 11740

8. IR spectrum of 1,6;8,9-diepoxy-carvone-1,2-olide 10.

¹H NMR spectrum of 1,6;8,9-diepoxy-carvone-1,2-olide 10.

^{13}C NMR spectrum of 1,6;8,9-diepoxy-carvone-1,2-olide 10.

HSQC correlation of 1,6;8,9-diepoxy-carvone-1,2-olide 10.

HMBC correlation of 1,6;8,9-diepoxy-carvone-1,2-olide 10.

COSY of 1,6;8,9-diepoxy-carvone-1,2-olide 10