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# Experimental Studies of Lewis Acid Catalyzed Additions of Long Chained Alcohols to Activated 1,4-Benzoquinone

Osmo E.O. Hormi*, Anu M. Moilanen

University of Oulu, Department of Chemistry, Linnanmaa, PB 333, 90571 Oulu-Finland

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***Abstract:*** Lewis acid promoted additions of long chained alcohols to 2-carbomethoxy-1,4-benzoquinone (**1**) have been examined by using various LAs; $AlCl_3$, $TiCl_4$, $MgBr_2$ and $MgCl_2$. It has been found that the bidentate Lewis acid $MgCl_2$, having ability to coordinate to both carbonyl oxygens (chelate control) of 2-carbomethoxy-1,4-benzoquinone (**1**), produced the addition product almost quantitatively at mild conditions. The $MgCl_2$ catalyzed additions of alcohols have been utilized in the synthesis of rare 2-alkoxyhydroquinones (**7a-e**). The reactions between quinone **1**, alcohol and $AlCl_3$ or $TiCl_4$ have also been investigated by using NMR spectroscopy.



## INTRODUCTION

Very recently great attention has been focused on Lewis acid (LA) catalyzed reactions and their mechanistic details.[1] Among the LA reactions, those involving the formation of complexes between organic molecules and LAs are important since these complexes play a fundamental role in organic and bioorganic chemistry. Of special interest to the organic chemist is the possibility of devising a LA able to enhance of the reactivity of carbonyl compounds by coordination to the (Lewis) basic carbonyl oxygens.[2]

In our preliminary studies we tried to apply the synthesis of Farina *et al.*,[3] who had successfully added alcohols to the β-carbon of 2-acetyl-1,4-benzoquinone (BQ), on a reaction of 2-carbomethoxy-1,4-BQ (**1**) and long chained alcohols. Unfortunately, when we refluxed a mixture of 1-octadecanol and 2-carbomethoxy-1,4-BQ (**1**) for two weeks in toluene under a nitrogen atmosphere in the absence of catalyst we could not find any signs of the desired addition product in the reaction mixture (t.l.c analysis). However many other previous studies have revealed that quinones activated by acceptor groups can react with heteroatom nucleophiles mainly into the 3-position only in the presence of Lewis or Brönsted acids.[4] Our own interest focused then on various LAs and their ability to catalyze nucleophilic conjugate addition of long chained alcohols to activated 1,4-benzoquinone. We record in this paper the results of studies which indicate that the nature of LA and solvent have dramatic effects on the product distribution obtained in the experiments described herein.

The final goal of our research is to find a set of conditions acceptable for the preparation of 2-alkoxyhydroquinones used as compatibilizers in the blends of aliphatic and liquid crystalline polymers (LCP),[5] which have been one of the most intensively investigated research areas in LCP chemistry in recent years.

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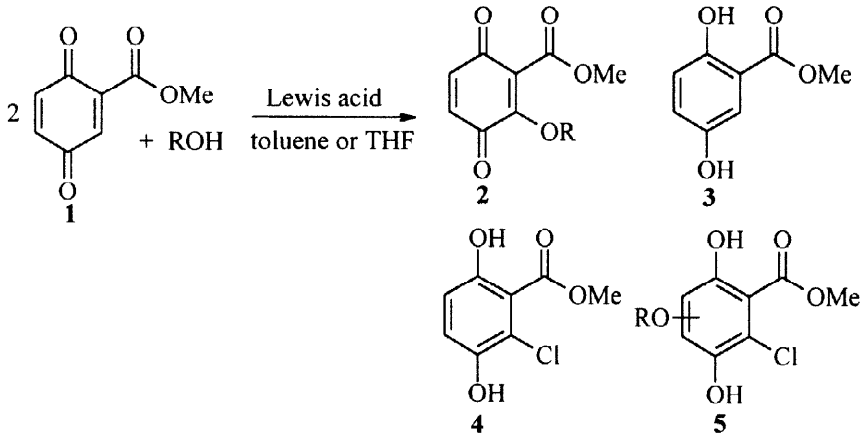
## RESULTS

In our case 2-carbomethoxy-1,4-BQ (**1**) was chosen as the starting material, partly because it is easily prepared from commercially available materials[6] and most importantly the methyl ester group can be removed later by decarbomethoxylation.[7] Furthermore, 3-position of the quinone **1** posesses then strong electrophilic character and may easily be attacked by some anionic species.[8,9]

Many previous investigations have shown that results observed in LA catalyzed reactions are a sensitive function of substrates, conditions and catalyst used, therefore detailed experimental studies are usually necessary. It is also clear that 2-carbomethoxy-1,4-BQ (**1**) needs a detailed investigation, because of its multifunctional (two α,β-double bonds,[10] one 1,3-diketo system, two carbonyl groups and one ester group) chemical nature.

Interest in the possibility of enhancing the reaction between 2-carbomethoxy-1,4-BQ (**1**) and alcohols led us to investigate the use of the range of Lewis acid catalysts ($AlCl_3$, $TiCl_4$, $MgBr_2$, $MgCl_2$). We performed LA catalysed reactions in a molar ratio 2:1:1 of quinone, alcohol and catalyst, because previous studies in the literature have indicated that excess of quinone is needed for an efficient addition of nucleophiles to quinone. The great importance of the molar ratio of quinone and alcohol was also noticed later in our work. The reaction involves an initial addition of alcohol to the activated quinone with formation of alkoxyhydroquinone which is then oxidized by another mole of the starting quinone to alkoxyquinone.[11]

The products obtained are summarized in scheme 1. and the overall results are described in the following text. It can be observed that depending on the LA and the solvent used, the reaction gives either addition product **2**, reduced starting material **3**, chlorinated hydroquinone (HQ) **4** or compound which contains both alkoxy and halogen moiety **5**.




**Scheme 1.**

At the outset we hoped that the formation of a 1:1 complex would enhance the reactivity of 2-carbomethoxy-1,4-BQ (**1**) enough and started the experimentation with commonly used strong LA, $AlCl_3$.[12] This is a typical monodentate catalyst and has ability to form 1:1 complex with carbonyl compounds. The reaction activated by $AlCl_3$ in toluene, the final reaction mixture contained 43 % of the addition product **2**. We reasoned that the modest reactivity enhancement of $AlCl_3$ is the result of that Al has only one empty p-orbital to interact with one of the carbonyl oxygens and the nonchelated transition state can not activate the β-carbon enough towards our nucleophile. In THF the main product was surprisingly the chlorinated HQ **4**. The formation of product **4** in the THF can be rationalized by NMR measurements of the mixture of alcohol, THF and $AlCl_3$ in a molar ratio of 1:1:1 in d-benzene. The experiment revealed that both alcohol and THF formed a complex simultaneously with $AlCl_3$ which means that monodentate $AlCl_3$ have to release one HCl. This liberated HCl can then add to quinone **1** to give the chlorinated product **4**.[13]

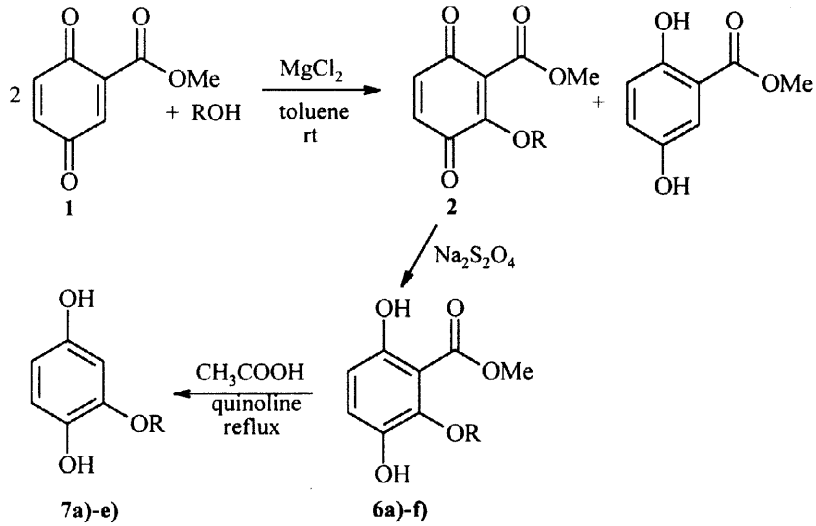
Because the activation of our starting material towards our weak nucleophile with monodentate LA was poor, our attention was then turned to the task of obtaining a better reactivity via a chelation controlled transition state. First, we tested a widely used chelate forming LA, $TiCl_4$, which has ability to form 1:2 complexes, 1:1 chelated adducts or even 1:1 dimeric complexes with carbonyl compounds.[2,14] $TiCl_4$ reaction did not produce the desired addition product **2**, and it was observed, surprisingly, that the final mixture consisted mainly of the chlorinated HQ **4**, the reduced starting material **3** and also the product **5**. It is interesting to note that the overall yield of the chlorinated HQ **4** was about 60 % of the theoretical yield based on the calculation that one mole of quinone produces one mole of the chlorinated HQ **4**. Apparently, one $TiCl_4$ can deliver two chlorides to two quinones. A plausible rationalization of the result is presented in the note.[15] In an attempt to contribute to the knowledge of a plausible reaction mechanism we carried out an NMR spectroscopic investigation (200 MHz, d-benzene) directly on mixtures containing $TiCl_4$ and the other starting materials. A NMR spectrum of a sample of quinone **1** and $TiCl_4$ in the molar ratio 2:1 proved that one bidentate Ti compound forms complex with two quinone **1** molecules because all the signals of free uncomplexed quinone disappeared. Finally we made a measurement of the mixture of quinone **1**, alcohol and $TiCl_4$ in the molar ratio of 2:1:1. The signals of complexed quinone **1** and uncomplexed alcohol and uncomplexed THF in the spectrum proved that $TiCl_4$ forms more preferably complex with quinone **1** than with alcohol or THF and activates quinone towards nucleophilic addition.

Because the reactions to obtain addition products from quinone **1** and alcohol with $AlCl_3$ and $TiCl_4$ as catalysts were not succesful enough, our next attempt was to use a weaker chelate forming catalyst, $MgBr_2$, which has been used in many chelate controlled syntheses.[16] The reaction produced the desired product **2**, but only in 26 % yield and the residue contained the reduced starting material **3** and polar, so far unidentified, byproducts.[17] So far it is not clear why $MgBr_2$ did not produce the product **2**, but one possible cause might be that, in THF, quinone **1** formed insoluble precipitates upon complexation with $MgBr_2$ and therefore could not efficiently react with the alcohol.

Having failed to obtain good yields of the desired addition product **2** with above mentioned LAs, we finally tested anhydrous $MgCl_2$, which is also a bidentate Lewis acid like $TiCl_4$ and $MgBr_2$ and is able to form chelate with Lewis bases with two empty p-type orbitals of the metal. As we can see from the table 1., the excellent yields in both toluene and THF show that $MgCl_2$ is the perfect catalyst to our synthesis. We believe that $MgCl_2$ initially coordinates to the carbonyl oxygens and forms a six-membered chelation ring intermediate. This is followed by a nucleophilic attack of alcohol to the chelated quinone **1**.

We also tested the reaction between the quinone **1** and alcohol by using different amounts of $MgCl_2$ and found that molar ratios 1:1 and 1:0.01 between quinone **1** and $MgCl_2$ produced the desired addition product **2** in good yields. Apparently, the ratio quinone **1**:$MgCl_2$ is not of crucial importance to the outcome of the addition. In this context we also tested the effect of varying molar ratios quinone **1** to alcohol. When we treated 2 moles of quinone **1** with one mole of alcohol, the alcohol was consumed quantitatively to give one alkoxyquinone **2** and one hydroquinone **3**. When we used one mole of quinone **1** with one mole of alcohol the crude reaction mixture comprised of only 30 % yield of the addition product **2** and the rest of the mixture contained reduced starting material **3** and unreacted alcohol. A plausible rationalization of the catalytic process is given in the note.[18] In a proton NMR spectrum (200 MHz, d-benzene) of 2-carbomethoxy-1,4-BQ (**1**) and $MgCl_2$ there were no signals from soluble $MgCl_2$-quinone complexies, which means that the catalysis has to be heterogeneous and $MgCl_2$ is present as a distinct phase and the reaction proceeds then at the surface of the catalyst.

From the results it was obvious that the choice of Lewis acid and solvent proved crucial to the success of the addition reaction. Catalysis by $MgCl_2$ in toluene was generally satisfactory and 2-alkoxy-3-carbomethoxy-1,4-BQs (**2**) were obtained in excellent yields.




ROH = a) 1-octadecanol, b) 1-dodecanol, c) 1-octanol, d) 1-hexanol, e) 1-butanol
f) benzyl alcohol[19]

**Scheme 2.**

Finally, we tested the applicability of the $MgCl_2$ catalysis on the addition of long chained alcohols to 2-carbomethoxy-1,4-BQ (**1**) and produced a series of 2-alkoxyHQs (**7**) by using the synthetic route shown in scheme 2. These reactions can also be successfully accomplished in a larger scale synthesis.

## CONCLUSION

$MgCl_2$ proves to be an effective activating agent for regioselective monoaddition of long chained alcohols to activated quinone. In general, this reaction may be performed under very mild conditions and it offers a simple and straightforward route for larger scale production of 2-alkoxyhydroquinones (**7**).

## EXPERIMENTAL SECTION

Melting points are reported uncorrected. $^1H$ NMR spectra were recorded on a Bruker AM 200 MHz spectrometer in $CDCl_3$ and d-acetone. Infrared spectra were performed as KBr pellets and recorded on a Bruker IFS 66. Mass spectra were determined by the EI mode using Kratos MS 80 FF spectrometer. Column chromatography was carried out on silica gel 60 (70-230 mesh, Merck). Thin layer chromatography was performed on 0,25 mm precoated silica gel 60 $F_{524}$ (Merck) and viewed by UV light/ $I_2$. The yields are not optimized.

**General Procedure for the Lewis Acid Promoted Addition of 1-Octadecanol to 2-Carbomethoxy-1,4-BQ (Scheme 1.).** The reactions were carried out at room temperature, under $N_2$ atmosphere. 2-carbomethoxy-1,4-BQ (**1**) and 1-octadecanol were dissolved in toluene or THF and the Lewis acid catalyst was added. The mixture was stirred until the starting quinone had been consumed completely (t.l.c., eluent: 10 % EtOAc/$CH_2Cl_2$, $R_f$(**1**) = 0.84, $R_f$(**3**) = 0.71). The final reaction mixture was extracted with diluted hydrochloric acid and $Et_2O$. Organic layer was dried and evaporated. Products were separated by column chromatography.

**Spectroscopic Data of Products 3, 4, 5:**
**Methyl 2,5-dihydroxybenzoate (3).** $^1H$ NMR (200 MHz, d-acetone): δ 3.93 (s, 3H), 6.84 (d, 1H, J = 9.1 Hz), 7.08 (dd, 1H, J = 9.1, 3.2 Hz), 7.28 (d, 1H, J = 3.2 Hz), 8.15 (s, 1H), 10.20 (s, 1H); m/z (%) + EI: M+ 168 (37), 136 (100) HRMS, EI calcd. for $C_8H_6O_4$ 168.042, found 168.040.
**Methyl 2-chloro-3,6-dihydroxybenzoate (4).** $^1H$ NMR (200 MHz, d-acetone): δ 3.89 (s, 3H), 6.79 (d, 1H, J = 9.0 Hz), 7.00 (d, 1H, J = 9.0 Hz), 8.41 (s, 1H), 8.99 (s, 1H); m/z (%) + EI: M+ 202 (30), 170 (100), 142 (32) ; HRMS, EI calcd. for $C_8H_7O_4Cl$ 202.003, found 202.004.
**Methyl 2-chloro-(4 or 5)-octadecanyloxy 3,6-dihydroxybenzoate (5).** $^1H$ NMR (200 MHz, d-$CDCl_3$): δ 0.89 (t, 3H), 1.27 (m, 30 H), 1.79 (m, 2H), 3.87 (t, 3H), 4.03 (s, 3H), 5.45 (s, 1H), 7.28 (s, 1H), 11.10 (s, 1H); m/z (%) + EI: M+ 470 (5), 218 (62), 186 (100); HRMS, EI calcd. for $C_{26}H_{43}O_5Cl$ 470.280, found 470.280.

**General Procedure for the Addition of Alcohols to 2-Carbomethoxy-1,4-BQ (1) in the Presence of $MgCl_2$.** A mixture of 2-carbomethoxy-1,4-BQ (**1**), ROH and anhydrous $MgCl_2$ (molar ratio 2:1:1) in toluene was stirred at room temperature overnight under a nitrogen atmosphere. At the completion of the reaction two spots were visible on t.l.c., the addition product (upper spot) and the reduced starting quinone.
The mixture was extracted with diluted hydrochloric acid and $Et_2O$. Organic layer was dried and evaporated. The addition product was isolated by crystallization from methanol (**2a,b**) or the residue was chromatographed on silica gel (**2c-f**).

**2-Carbomethoxy-3-octadecanyloxy-1,4-BQ (2a).** A mixture of (**1**) (64.05 g, 0.39 mol), 52.18 g (0.19 mol) of 1-octadecanol and 18.33 g (0.19 mol) of $MgCl_2$ in 1000 ml of toluene.

Isolation from methanol gave **2a** (75.36 g, 0.174 mol) in a 90 % yield). $R_f$ = 0.64 (eluent: 25% EtOAc/hexane), mp. 55 °C. IR(KBr): 2820, 1735, 1680, 1642, 1600, 1470, 1340, 1240 $cm^{-1}$, $^1H$ NMR (200 MHz $CDCl_3$): δ 0.88 (t, 3H), 1.26 (m, 30H), 1.72 (m, 2H), 3,90 (s, 3H), 4.28 (t, 2H), 6.71 (s, 2H). m/z (%) + EI: M+ 434 (8), 184 (92), 152 (100); HRMS, EI calcd. for $C_{26}H_{42}O_5$ 434.303, found 434.301. Only 2-carbomethoxy-3-octadecanyloxy-1,4-BQ **(2a)** was isolated and analyzed. Otherwise t.l.c. (eluent: 25 % EtOAc/hexane) indicated so clearly the formation of addition products, that we had no need to analyse the quinone intermediates. After separation the addition products **(2a-f)** were reduced immediately to the corresponding HQs **(6a-f)** by using $Na_2S_2O_4$.

**2-Carbomethoxy-3-octadecanyloxyHQ (6a).** 2-carbomethoxy-3-octadecanyloxy-1,4-BQ **(2a)** was dissolved in $CH_2Cl_2$ and 1000 ml of saturated $Na_2S_2O_4/H_2O$ was added. The mixture was stirred for 30 min at room temperature, until the yellow color of the quinone had disappeared. Organic layer was dried and evaporated to a 95-100 % yield of **6a**. $R_f$ = 0.65 (eluent: 25% EtOAc/hexane), mp. 61 °C. IR(KBr): 3380, 2890, 2840, 2820, 1645, 1595, 1455, 1215 $cm^{-1}$; $^1H$ NMR (200 MHz, d-acetone): δ 0.88 (t, 3H), 1.29 (m, 30H), 1.78 (m, 2H), 3,94 (s, 3H), 3.95 (t, 2H), 6.57 (d, 1H, J = 8.9 Hz), 7.02 (d, 1H, J = 8.9 Hz); m/z (%) + EI: M+ 436 (10), 184 (100), 152 (79); HRMS, EI calcd. for $C_{26}H_{44}O_5$ 436.319 found 436.316.

**2-Carbomethoxy-3-dodecanyloxyHQ (6b).** A mixture of **(1)** (6.00 g, 0.036 mol), 3.35 g (0.018 mol) of 1-dodecanol and 1.71 g (0.018 mol) of $MgCl_2$ in 150 ml of toluene proceeded 2-carbomethoxy-3-dodecanyloxy-1,4-BQ **(2b)**. Isolation from methanol gave **2b** (5.38 g, 0.015 mol) in a 85 % yield.
2-carbomethoxy-3-dodecanyloxy-1,4-BQ **(2b)** from the previous step was dissolved in $CH_2Cl_2$ and 250 ml of saturated $Na_2S_2O_4/H_2O$ was added. The mixture was stirred for 15 min at room temperature, until the yellow color of the quinone had disappeared. Organic layer was dried and evaporated to a 95-100 % yield of **6b**. $R_f$ = 0.61 (eluent: 25% EtOAc/hexane), mp. 51 °C. IR(KBr): 3400, 2900, 2840, 2820, 1650, 1600, 1440, 1330 $cm^{-1}$; $^1H$ NMR (200 MHz, d-acetone): δ 0.87 (t, 3H), 1.29 (m, 18H), 1.77 (m, 2H), 3.94 (s, 3H), 3.95 (t, 2H), 6.58 (d, 1H, J = 9.1 Hz), 7.02 (d, 1H, J = 9.1 Hz), 7.58 (s, 1H), 9.93 (s, 1H); m/z (%) + EI: M+ 352 (10), 184 (71), 152 (100); HRMS, EI calcd. for $C_{20}H_{32}O_5$ 352.225, found 352.222.

**2-Carbomethoxy-3-octanyloxyHQ (6c).** A mixture of **(1)** (8.12 g, 0.049 mol), 3.25 g (0.025 mol) of 1-octanol and 2.38 g (0.025 mol) of $MgCl_2$ in 200 ml of toluene proceeded 2-carbomethoxy-3-octanyloxy-1,4-BQ **(2c)**. Flash chromatography on silica gel (eluent: 25 % EtOAc/hexane) afforded **2c** (5.90 g, 0.020 mol) in a 82 % yield.
2-carbomethoxy-3-octanyloxy-1,4-BQ **(2c)** from the previous step was dissolved in $CH_2Cl_2$ and 250 ml of saturated $Na_2S_2O_4/H_2O$ was added. The mixture was stirred for 15 min at room temperature, until the yellow color of the quinone had disappeared. Organic layer was dried and evaporated to a 95-100 % yield of **6c**. $R_f$ = 0.59 (eluent: 25% EtOAc/hexane), mp. 50 °C. IR(KBr): 3410, 2900, 2830, 1650, 1600, 1430, 1330, 1215, 830 $cm^{-1}$; $^1H$ NMR (200 MHz, d-acetone): δ 0.88 (t, 3H), 1.31 (m, 10H), 1.76 (m, 2H), 3.94 (s, 3H), 3.95 (t, 2H), 6.57 (d, 1H, J = 8.9 Hz), 7.02 (d, 1H, J = 9.1 Hz), 7.59 (s, 1H), 9.92 (s, 1H); m/z (%) + EI: M+ 296 (11), 184 (31), 152 (100); HRMS, EI calcd. for $C_{16}H_{24}O_5$ 296.162, found 296.158.

**2-Carbomethoxy-3-hexanyloxyHQ (6d).** A mixture of **(1)** (5.93 g, 0.036 mol), 1.83 g (0.018 mol) of 1-hexanol and 1.70 g (0.018 mol) of $MgCl_2$ in 150 ml of toluene proceeded 2-carbomethoxy-3-hexanyloxy-1,4-BQ **(2d)**. Flash chromatography on silica gel (eluent: 25 % EtOAc/hexane) afforded **2d** (3.80 g, 0.014 mol) in a 80 % yield.
2-carbomethoxy-3-hexanyloxy-1,4-BQ **(2d)** from the previous step was dissolved in $CH_2Cl_2$ and 200 ml of saturated $Na_2S_2O_4/H_2O$ was added. The mixture was stirred for 15 min at room temperature, until the yellow color of the quinone had disappeared. Organic layer was dried and evaporated to a 95-100 % yield of **6d**. $R_f$ = 0.52 (eluent: 25% EtOAc/hexane), mp. 57 °C IR(KBr): 3420, 2940, 2910, 2860, 2840, 1660, 1590, 1450, 1420, 1200 $cm^{-1}$; $^1H$ NMR (200 MHz, d-acetone): δ 0.89 (t, 3H), 1.27-1.47 (m, 6H), 1.75 (m, 2H), 3.95 (s, 3H), 3.95 (t, 2H), 6.57 (d, 1H, J = 9.0 Hz), 7.01 (d, 1H, J = 9.0 Hz); m/z (%) + EI: M+ 268 (24), 184 (23), 152 (100); HRMS, EI calcd. for $C_{14}H_{20}O_5$ 268.131, found 268.134.

**2-Carbomethoxy-3-butoxyHQ (6e).** A mixture of **(1)** (7.82 g, 0.047 mol), 1.78 g (0.024 mol) of 1-butanol and 2.28 g (0.024 mol) of $MgCl_2$ in 200 ml of toluene proceeded 2-carbomethoxy-3-butoxy-1,4-BQ **(2e)**. Flash chromatography on silica gel (eluent: 40 % EtOAc/hexane) afforded **2e** (4.48 g, 0.019 mol) in a 80 % yield. 2-carbomethoxy-3-butoxy-1,4-BQ **(2e)** from the previous step was dissolved in $CH_2Cl_2$ and 200 ml of saturated $Na_2S_2O_4/H_2O$ was added. The mixture was stirred for 15 min at room temperature, until the yellow color of the quinone had disappeared. Organic layer was dried and evaporated to a 95-100 % yield of **6e**. $R_f$ = 0.48 (eluent: 25% EtOAc/hexane). IR(KBr): 3570, 3380, 2940, 2920, 2870, 1670, 1430, 1220, 750 $cm^{-1}$; $^1H$ NMR (200 MHz, $CDCl_3$): δ 0.99 (t, 3H), 1.49 (m, 2H), 1.78 (m, 2H), 3.87 (t, 2H), 3.99 (s, 3H), 5.46 (s, 1H), 6.70 (d, 1H, J = 9.1 Hz), 7.12 (d, 1H, J = 9.1 Hz), 10.59 (s, 1H); m/z (%) + EI: M+ 240 (17), 184 (16), 152 (100); HRMS, EI calcd. for $C_{12}H_{16}O_5$ 240.100, found 240.100.

**2-Carbomethoxy-3-benzyloxyHQ (6f).** A mixture of **(1)** (7.80 g, 0.047 mol), 2.59 g (0.024 mol) of benzyl alcohol and 2.28 g (0.024 mol) of $MgCl_2$ in 200 ml of toluene proceeded 2-carbomethoxy-3-benzyloxy-1,4-BQ **(2f)**. Flash chromatography on silica gel (eluent: $CH_2Cl_2$) afforded **2f** (5.11 g, 0.019 mol) in a 80 % yield. 2-carbomethoxy-3-benzyloxy-1,4-BQ **(2f)** from the previous step was dissolved in $CH_2Cl_2$ and 250 ml of saturated $Na_2S_2O_4/H_2O$ was added. The mixture was stirred for 15 min at room temperature, until the yellow color of the quinone had disappeared. Organic layer was dried and evaporated to a 95-100 % yield of **6f**. $R_f$ = 0.40 (eluent: 25% EtOAc/hexane), mp. 95 °C. IR(KBr): 3300, 2920, 1650, 1595, 1430 $cm^{-1}$; $^1H$ NMR (200 MHz, d-acetone): δ 3.84 (s, 3H), 5.03 (s, 2H), 6.63 (d, 1H, J = 9.2 Hz), 7.09 (d, 1H, J = 8.9 Hz), 7.32-7.52 (m, 5H), 7.88 (s, 1H), 10.01 (s, 1H); m/z (%) + EI: M+ 274 (7), 183 (17), 151(23), 91 (100); HRMS, EI calcd. For $C_{15}H_{14}O_5$ 274.084 found 274.079.

**General Procedure for the Decarbomethoxylation of 2-Carbomethoxy-3-alkoxyHQs (7a-e).** A mixture of 2-carbomethoxy-3-alkoxyHQ (~5-10 mmol) and freshly distilled quinoline was stirred vigorously under nitrogen atmosphere. 1-2 ml of acetic acid ( 99.8 % ) was added with syringe. After 4-5 hours refluxing the TLC indicated complete reaction. The reaction mixture was cooled and extracted several times with 5 M HCl and $Et_2O$. The ether layer was dried and evaporated. The product was isolated from hexane.

**2-OctadecanyloxyHQ (7a). 6a** (50 g, 0.11 mol) and 180 ml of quinoline with 10 ml $CH_3COOH$ gave a 91 % yield of **7a** (39 g, 0.10 mol). $R_f$ = 0.49 (eluent: 25% EtOAc/hexane), mp. 109 °C. IR(KBr): 3270, 2900, 2830, 1610, 1460, 1165 $cm^{-1}$; $^1H$ NMR (200 MHz, d-acetone): δ 0.87 (t, 3H), 1.28 (m, 30H), 1.75 (m, 2H), 3.96 (t, 2H), 6.26 (dd, 1H, J = 8.4, 2.7 Hz), 6.46 (d, 1H, J = 2.6 Hz), 6.62 (d, 1H, J = 8.4 Hz); m/z (%) + EI: M+ 378 (29), 126 (100); HRMS, EI calcd. for $C_{24}H_{42}O_3$ 378.313 found 378.316.

**2-DodecanyloxyHQ (7b). 6b** (2.99 g, 8.49 mmol) and 15 ml of quinoline with 2 ml $CH_3COOH$ gave a 72 % yield of **7b** (1.80 g, 6.12 mmol). $R_f$ = 0.46 (eluent: 25% EtOAc/hexane), mp. 100 °C. IR(KBr): 3280, 2900, 2830, 1600, 1450, 1160 $cm^{-1}$; $^1H$ NMR (200 MHz, d-acetone): δ 0.88 (t, 3H), 1.29 (m, 18H), 1.76 (m, 2H), 3.97 (t, 2H), 6.27 (dd, 1H, J = 8.5, 2.6 Hz), 6.46 (d, 1H, J = 2.6 Hz), 6.63 (d, 1H, J = 8.3 Hz); m/z (%) + EI: M+ 294 (9), 126 (100); HRMS, EI calcd. for $C_{18}H_{30}O_3$ 294.219 found 294.219.

**2-OctanyloxyHQ (7c). 6c** (3.09 g, 10.44 mmol) and 15 ml of quinoline with 2 ml $CH_3COOH$ gave a 68 % yield of **7c** (1.69 g, 7.10 mmol). $R_f$ = 0.40 (eluent: 25% EtOAc/hexane), mp. 88 °C. IR(KBr): 3270, 2900, 2830, 1600, 1450, 1160 $cm^{-1}$; $^1H$ NMR (200 MHz, d-acetone): δ 0.87 (t, 3H), 1.30 (m, 10H), 1.74 (m, 2H), 3.96 (t, 2H), 6.26 (dd, 1H, J = 8.5, 2.5 Hz), 6.45 (d, 1H, J = 2.8 Hz), 6.63 (d, 1H, J = 8.5 Hz); m/z (%) + EI: M+ 238 (16), 126 (100); HRMS, EI calcd. for $C_{14}H_{22}O_3$ 238.157 found 238.156.

**2-HexanyloxyHQ (7d). 6d** (2.5 g, 9.33 mmol) and 15 ml of quinoline with 2 ml $CH_3COOH$ gave a 70 % yield of **7d** (1.37 g, 6.53 mmol). $R_f$ = 0.36 (eluent: 25% EtOAc/hexane), mp. 83 °C. IR(KBr): 3280, 2930, 2830, 1610, 1450, 1160 $cm^{-1}$; $^1H$ NMR (200 MHz, d-acetone): δ 0.90 (t, 3H), 1.33-1.47 (m, 6H), 1.75 (m, 2H), 3.96 (t, 2H), 6.26 (dd, 1H, J = 8.5, 2.7 Hz), 6.47 (d, 1H, J = 2.7 Hz), 6.63 (d, 1H, J = 8.5 Hz); m/z (%) + EI: M+ 210 (33), 126 (100); HRMS, EI calcd. for $C_{12}H_{18}O_3$ 210.126 found 210.127.

**2-ButoxyHQ (7e). 6e** (1.0 g, 4.17 mmol) and 5 ml of quinoline with 1 ml $CH_3COOH$ gave a 65 % yield of **7e** (0.49 g, 2.71 mmol). $R_f$ = 0.30 (eluent: 25% EtOAc/hexane), mp. 79-80 °C. IR(KBr): 3260, 2930, 2840, 1600, 1450, 1160 $cm^{-1}$; $^1H$ NMR (200 MHz, $CDCl_3$): δ 0.98 (t, 3H), 1.49 (m, 2H), 1.79 (m, 2H), 3.99 (t, 2H), 6.31 (dd, 1H, J = 8.7, 2.8 Hz), 6.44 (d, 1H, J = 2.8 Hz), 6.77 (d, 1H, J = 8.7 Hz); m/z (%) + EI: M+ 182 (29), 126 (100); HRMS, EI calcd. for $C_{10}H_{14}O_3$ 182.094 found 182.092.

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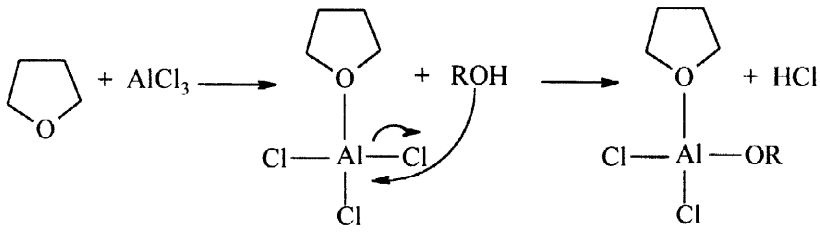
## REFERENCES AND NOTES

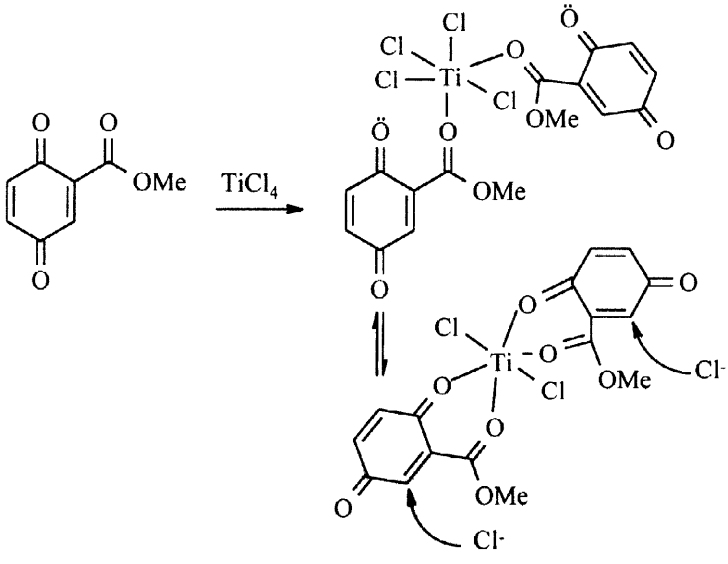

1. a) Harden, R. C.; Hodgkinson, T. J.; McKillop, A.; Prowse, W. G.; Urquhart, W. J. *Tetrahedron* **1997**, *53*, 21. b) Martín, R.; Pascual, O.; Romea, P.; Rovira, R.; Urpí, F.; Vilarrasa, J. *Tetrahedron Lett.* **1997**, *38*, 1633. c) Engler, T. A.; Meduna, S. P.; LaTessa, K. O.; Chai, W. *J. Org. Chem.* **1996**, *61*, 8598. d) Engler, T. A.; Chai, W.; LaTessa, K. O. *J. Org. Chem.* **1996**, *61*, 9297. e) Engler, T. A.; Ali, M. H.; Takusagawa, F. *J. Org. Chem.* **1996**, *61*, 8456. f) Lipshutz, B. H.; James, B.; Vance, S. Carrico, I. *Tetrahedron Lett.* **1997**, *38*, 753. g) DiMare, M. *J. Org. Chem.* **1996**, *61*, 8378. h) Casarrubios, L.; Pérez, J. A.; Brookhart, M.; Templeton, J. L. *J. Org. Chem.* **1996**, *61*, 8358. i) Kita, Y.; Kitagaki, S.; Yoshida, Y.; Mihara, S.; Fang, D-F.; Fujioka, H. *Tetrahedron Lett.* **1997**, *38*, 1061. j) Sato, M.; Aoyagi, S.; Yago, S.; Kibayashi, C. *Tetrahedron Lett.* **1996**, *37*, 9063. k) Jain, N. F.; Takenaka, N.; Panek, J. S. *J. Am. Chem. Soc.* **1996**, *118*, 12475. l) Hu, Q-S.; Vitharana, D.; Zheng, X-F.; Wu, C.; Kwan, C. M. S.; Pu, L. *J. Org. Chem.* **1996**, *61*, 8370. m) Mujica, M. T.; Afonso, M. M.; Galindo, A.; Palenzuela A. J. *Tetrahedron* **1996**, *52*, 2167. n) Yamabe, S.; Dai, T.; Minato, T. *J. Am. Chem Soc.* **1995**, *117*, 10994 and references therein
2. a) Santelli, M., Pons, J-M., *Lewis Acids and Selectivity in Organic Synthesis*; CRC Press, New York, 1996. b) Shambayati, S.; Schreiber, S.L. Lewis Acid Carbonyl Complexation in *Comprehensive Organic Synthesis*; Trost, B. M., Ed.; Pergamon Press, Oxford, 1991, 283. c) Denmark, S. E.; Almstead, N. G. *J. Am. Chem Soc.* **1993**, *115*, 3133 and references therein
3. Farina, F.; Valderrama, J. *Synthesis* **1971**, 315
4. a) De Labbey, A.; Baudry, A.; Bauer, D.; Bore, P. **Eur. Pat.Appl. EP 376,776**. b) Baudry, A.; Junino, A.; Richard, H. **Eur. Pat.Appl. EP 460,996**. c) Farina, F.; Valderrama, J. *An. Quim.* **1974**, *70*(3), 258. d) Inoue, Y.; Morita, T.; Kitajima, H. *Nippon Kagaku Kaishi* **1996**, *2*, 160. e) Cassis, R.; Fernandez, M.; Tapia, R.; Valderrama, V. A. *Synth.Commun.* **1987**, *17*(9), 1077. f) Müller, P.; Venakis. T.; Eugster, C. H. *Helv. Chim. Acta* **1979**, *62*, 2350. g) Farina, F.; Valderrama, J. *An. Quim.* **1976**, *72*(11-12), 902. h) Fumagalli, S. E.; Eugster, C. H. *Helv. Chim. Acta* **1971**, *54*, 959. i) Engler, T. A.; Combrink, K. D.; Tagusakawa, F. *J. Chem. Soc., Chem. Commun.* **1989**, 1573. j) Engler, T. A.; Letavic, M. A.; Combrink, K. D.; Tagusakawa, F. *J. Org. Chem.* **1990**, *55*, 5810. k) Engler, T. A.; Reddy, J. P.; Combrink, K. D.; Vander Velde, D. *J. Org. Chem.* **1990**, *55*, 1248. l) Uno, H. *J. Org. Chem.* **1986**, *51*, 350.
5. The manuscript is in progress.
6. a) Prager, B., Jacobson, D., Schmidt, P., Stern, D. *Beilstein Handbuch der Organichen Chemie*, vierte auflage, Band X, Verlag von Julius Springer, Berlin, 1927, 386. b) Ulrich, H., Richter, R. in *Methoden der Organichen Chemie (Houben Weyl)*, Grundmann, C.(ed), Georg Thieme, Stuttgart, 1977, vol.VII / 3a pp. 44-46 and references therein
7. Aranda, G., Fetizon, M. *Synthesis* **1975**, 330-332
8. Rozeboom, M.D., Tegmo-Larsson, I-M., Houk, K. N. *J. Org. Chem.* **1981**, *46*, 2338-2345
9. Naruta, Y; Uno, H.; Maruyama, K. *Tetrahedron Lett.* **1981**, *22*, 5221
10. a) Our starting material belong to the group of α,β-unsaturated carbonyl compound, so a good reference was the work of J. Cabral et al., who tested hard, borderline and also weak LAs for the Michael addition of amines to α,β-unsaturated carbonyl compounds. They tried to find a suitable LA, which could lower the LUMO energy and enhance the LUMO coefficient of the β-carbon. They found that the best catalyst

for the Michael addition was $FeCl_3$. Cabral, J.; Laszlo, P.; Mahé, L. *Tetrahedron Lett.* **1989**, *30*, 3969. b) Childs, R. F.; Mulholland, D. L.; Nixon, A. *Can. J. Chem.* **1982**, *60*, 801

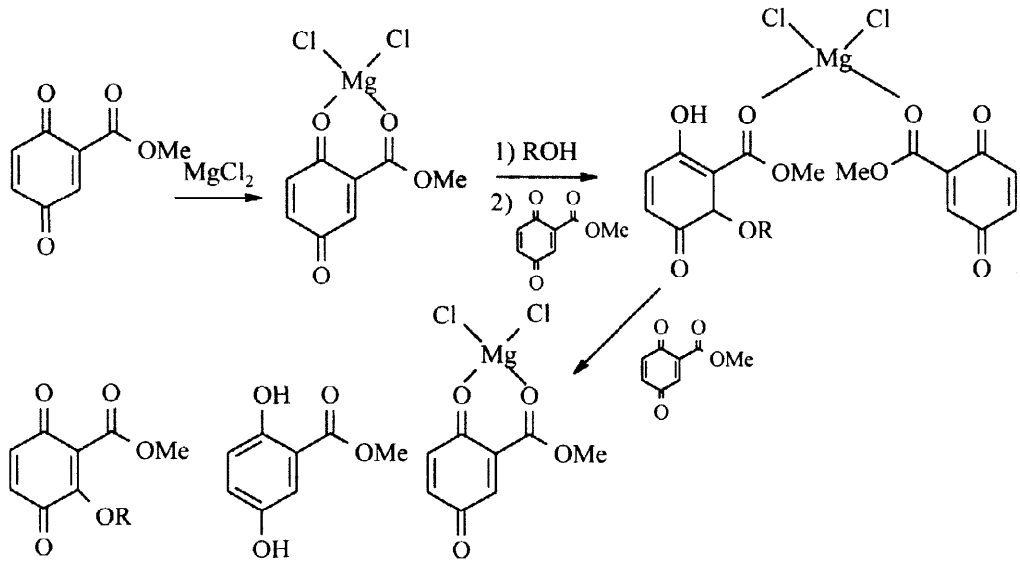
11. a) Kuturev, A. A.; Moskva, V. V. *Russian Chemical Reviews* **1991**, *60*(1), 72. b) Hormi, O. E. O.; Moilanen A. M. PCT /FI96/00047
12. We used two distinct approaches to select the suitable LAs to the experiments. In one of the approaches, because the donor atoms of carbomethoxyquinones are hard Lewis base oxygen atoms, we thought that tighter and more stable complexes are formed between carbonyl oxygens and hard LAs. a) Laszlo, P.; Teston, M. *J. Am. Chem Soc.* **1990**, *112*, 8750. b) Carlson, R.; Lundstedt, T.; Nordahl, Å; Prochazka, M. *Acta Chem. Scand.* **1986**, *B 40*, 522. c) Braddock, D. C.; Brown, J. M.; Guiry, P. J. *J. Chem. Soc., Chem. Commun.* **1993**, 1244) On the other hand, as mentioned earlier enhancement of reactivity of the carbonyl groups can be achieved through a nonchelated or a chelated intermediate. A suitable example in this connection is the investigation of Chen *et al.*, d) Chen, X.; Hortelano, E. R.; Eliel, E. L.; Frye, S. V. *J. Am. Chem Soc.* **1992**, *114*, 1778, who compared the transition state energies of LAs and alkoxy ketones in chelated and nonchelated 1:1 complexes. They showed that complexation enhances the reactivity of the ketone and, furthermore, the chelated intermediate lowers the the transition state energy further and, thus, increases the reaction rate. The chelation restricts also bond rotation and increases stereoselectivity. Their results gave us a hint of promise on that a bidentate chelating metal could further diminished LUMO energy of the β-carbon and give an additional activation towards oxygen nucleophiles.
13.




14. a) Keck, G. E.; Castellino, S. *J. Am. Chem Soc.* **1986**, *108*, 3847, b) PhD thesis, Letavic, M. A. University of Kansas, 1992, Diss. Abstr. Int. B. **1993**, *54*(4), 1969 c) PhD thesis, Reddy, J. P. M. University of Kansas, 1991, Diss. Abstr. Int. B **1993**, *54*(1), 252
15.



16. a) Mulzer, J; Pointner, A.; Straβer, R; Hoyer, K.; Nagel, U. *Tetrahedron Lett.* **1995**, *36*, 3679. b) Wang, S.; Howe, G. P.; Mahal, R. S.; Procter, G. *Tetrahedron Lett.* **1992**, *33*, 3351. c) Keck, G. E.; Dougherty, S. M.; Savin, K. A. *J. Am. Chem Soc.* **1995**, *117*, 6210. d) Keck, G. E.; Savin, K. A.; Cressman, E. N. K.; Abbott, D. E. *J. Org. Chem* **1994**, *59*, 7889
17. Unidentified polar addition products, which remained on the baseline in t.l.c. analysis.
18.




Having shown that long chain alcohols add readily to $MgCl_2$ activated 2-carbomethoxy-1,4-BQ (**1**), we were also interested to know whether $MgCl_2$ can be used as a catalyst in the reaction between inactivated quinone and long chained alcohols. We found that the catalyst did work also in this case, but only in 10 % yield. (Hormi, O. E. O.; Moilanen, A. M. unpublished results)

19. When the decarbomethoxylation was carried out with 2-carbomethoxy-3-benzyloxyHQ (**6f**) using the same reaction conditions, only tarry material was produced.