The Synthesis of Ventiloquinone F and Isoventiloquinone F as Racemates

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Racemic ventiloquinone F and isoventiloquinone F have been synthesized utilizing an initial Stobbe condensation, followed by mercury(II)-mediated ring closure and catalytic hydrogenolysis as key steps in the synthetic protocol.

Introduction

Interest in the family of ventiloquinones may be attributed to the pioneering work by Thomson et al.[1] who described the isolation and structural elucidation of primarily isofuranonapthoquinones found in the extracts of the root bark of the Indian plants *ventilago madderaspatana* and *V. calyculata*. Following on this seminal work Thomson et al.[2] extended their investigations and described eleven new ventiloquinones isolated from the same plants but in this case their work concerned mainly (1*R*,3*S*)-1,3-dimethylnaphtho[2,3-*c*]pyran-5,10- and 6,9-quinones. Additionally ventiloquinones L, M, N and O were isolated form *V. goughii*[3] while ventiloquinones G, L, and M were reported to be found in the root bark of Fijian *V. vitiensis*.[4] While the Thomson group was able to assign structures to most of the ventiloquinones based on spectral analyses, a few ambiguities still remain viz., ventiloquinones A and J.[2] A more comprehensive review on the isolation and structural elucidation of naturally occurring pyranonaphthoquinones has also appeared recently.[5]

Brimble et al.[6] recently published a fairly comprehensive review on the synthesis of pyranonaphthoquinone antibiotics. However and more specifically, Brassard et al.[7] described some early protocols developed for the synthesis of ventilagone **1** and ventiloquinone H **2** employing Diels–Alder chemistry. This was followed by the work of Giles et al.[8] who described their work on the syntheses of ventiloquinones E (**3**), G (**4**) and the regioisomer **5** of ventiloquinone J (**6**) (Figure 1). We have recently developed unambiguous syntheses for ventiloquinone J and isoventiloquinone J as their racemates, thus confirming the structure of ventiloquinone J to be **6**.[9] Different synthetic approaches were additionally described for the synthesis of ventiloquinone E (**3**) and ventilagone (**1**) by Cameron et al.[10,11] Further modified approaches towards the syntheses of ventiloquinones C, D, E (**3**) and G (**4**) were described by Brassard et al.[12]

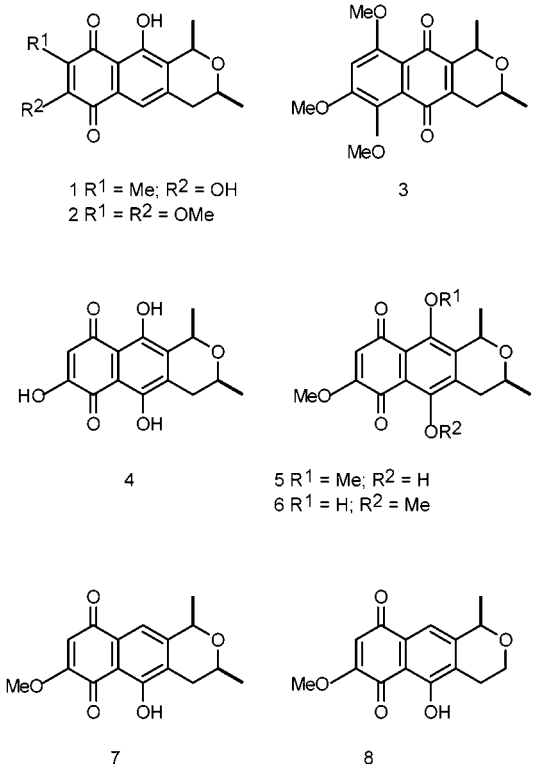

Figure 1. Examples of naphthophyranquinones

Since our group has a strong interest in naphtho[2,3-*c*]pyran-6,9-quinones and their evaluation as antibiotic and antifungal agents, we needed as part of our programme to synthesize both ventiloquinone F (**7**) and its C3 epimer iso-

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ventiloquinone F (**8**) for comparative evaluations. This paper describes their syntheses.

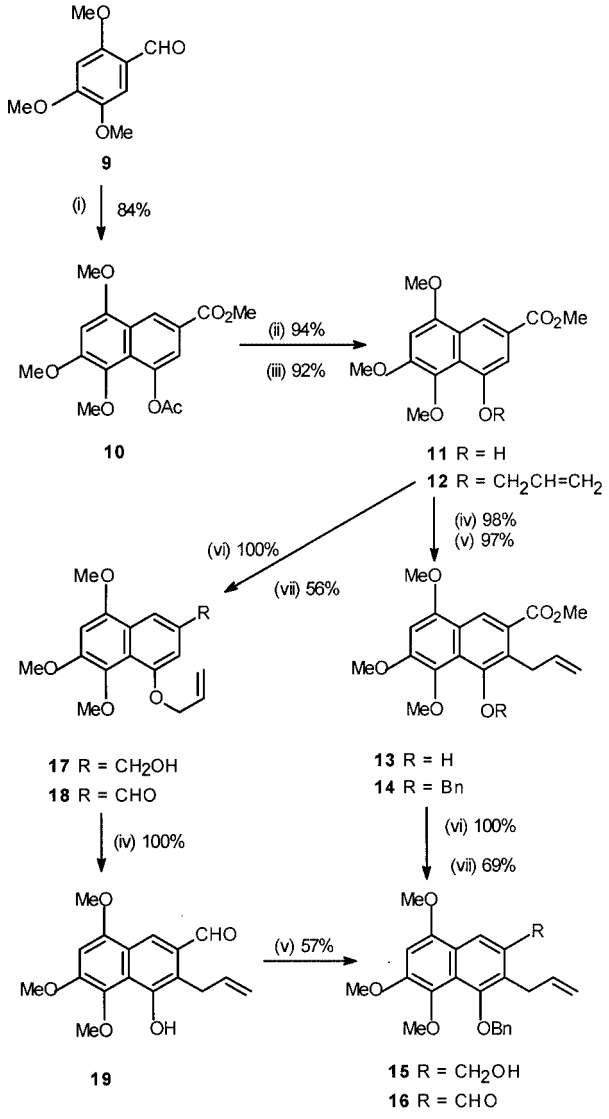
The naphthalene oxygenation pattern of ventiloquinone F (**7**) directed our approach to Stobbe methodology and despite some elegant work by Sargent et al.[13] on the use of phosphoranes[14] and McCombie et al.[15] on the use of triphenylphosphane[15] as alternative methods, our experience[16] and some others[17,18] in this most classic of reactions, favoured the former approach.

Thus the trimethoxybenzaldehyde **9**[19] was reacted under typical Stobbe conditions with dimethyl succinate to afford, after cyclisation, the desired methyl naphthoate **10** in an overall yield of 84% for the two steps. Chemoselective hydrolysis of the naphthyl acetate ester **10** with 1% ($^{w}/_{v}$) methanolic potassium hydroxide produced the expected naphthol **11** (94%) with the H-bonded 4-OH appearing as a D_2O exchangeable signal at δ = 9.70 ppm in the ^{1}H NMR spectrum. Allylation of the latter phenolic group to afford **12** was effected in 92% yield by treatment with allyl bromide and potassium carbonate in boiling acetone under vigorous stirring[20] (Scheme 1).

Naphthaldehyde **16** was pivotal to the synthetic scheme envisaged and since at least two routes to it were feasible using the same reaction conditions but in a different sequence, the more efficient route had to be discovered. Consequently pyrolysis of naphthyl ether **12** at 180 °C under nitrogen afforded phenol **13** in 98% as demonstrated by the fact that only two one-proton singlets were evident in the ^{1}H NMR spectrum, viz., at δ = 6.58 and 8.24 ppm for 7-H and 1-H respectively. Benzylation of the phenol **13** using benzyl bromide and potassium carbonate in boiling acetone with vigorous stirring afforded the desired benzyl ether **14** in 97% yield. We found that the most convenient route for the large scale transformation of the naphthyl ester **14** into the corresponding aldehyde **16** was to first reduce the former compound to the naphthyl alcohol **15** with lithium aluminium hydride (LAH) in THF at 50 °C in essentially quantitative yield followed by oxidation, employing activated manganese dioxide in boiling benzene,[21] to produce the desired aldehyde **16** in 69% yield.

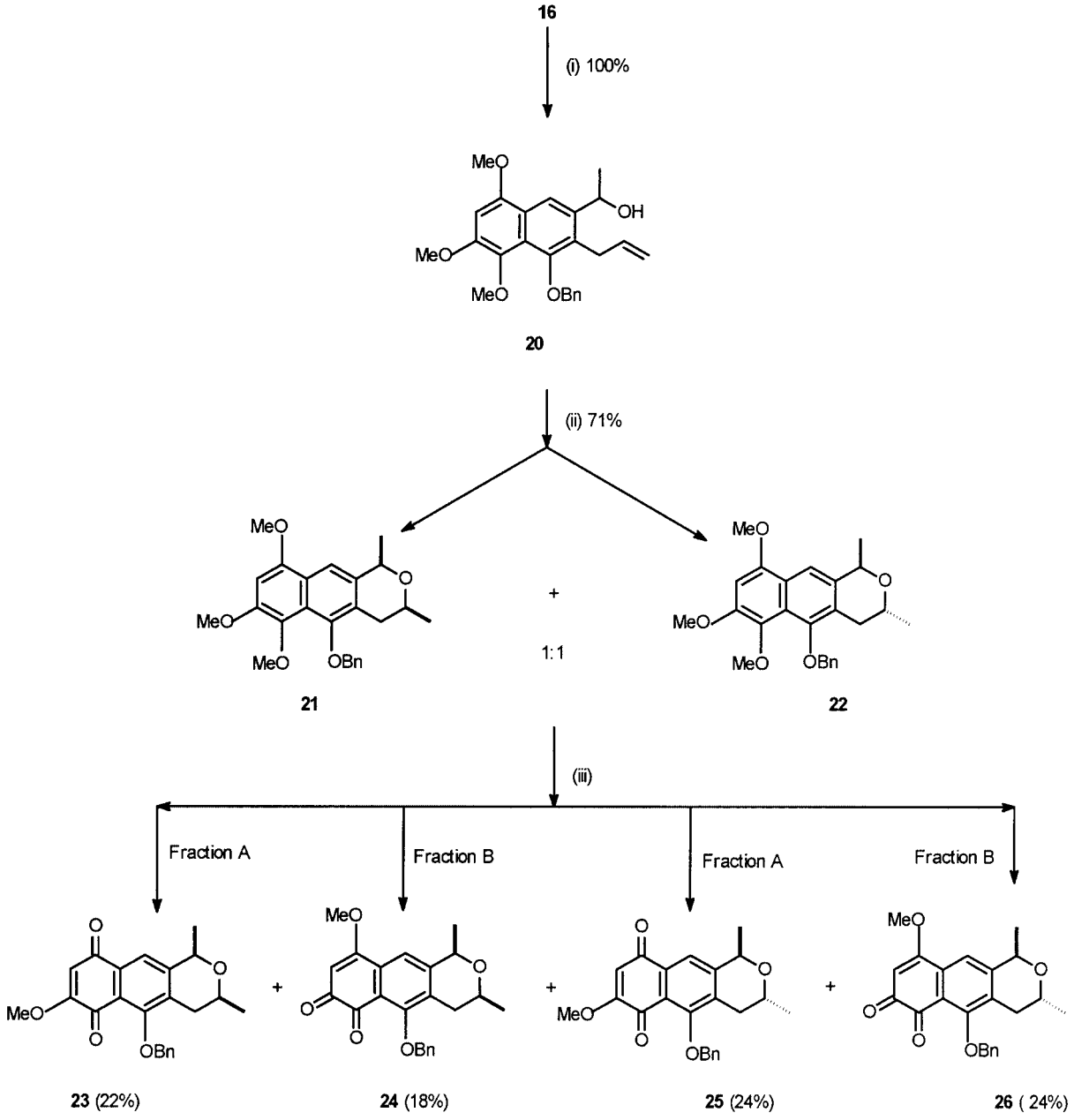
In the alternative synthetic sequence followed, methyl naphthoate **12** was reduced (LAH/THF) to the corresponding naphthyl alcohol **17** (100%) followed by oxidation (MnO_2/benzene) to afford aldehyde **18** (57%) which was subsequently pyrolysed to phenol **19** (100%), benzylation of which ($BnBr/K_2CO_3$) produced the same aldehyde **16** (57%). The overall yield for the conversion sequence **12** → **17** → **18** → **19** → **16** was 32% while that of **12** → **13** → **14** → **15** → **16** was 66% and thus the latter sequence was favoured.

With quantities of aldehyde **16** in hand, treatment with freshly prepared methylmagnesium iodide afforded alcohol **20** in quantitative yield. This was followed by intramolecular acetoxymercuration[22] followed by demercuration using sodium borohydride[23] which afforded an inseparable mixture of the naphthopyrans **21** and **22** in an overall yield of 71% and in a 1:1 ratio (Scheme 2). Oxidation of this latter mixture with cerium(IV) ammonium nitrate in aqueous



Scheme 1. Reagents and conditions: (i) dimethyl malonate/KO*t*Bu/*tert*-butyl alcohol reflux then NaOAc/Ac_2O reflux; (ii) 1% KOH/MeOH; (iii) allyl bromide/K_2CO_3/acetone/reflux; (iv) 180 °C/N_2; (v) $BnBr/K_2CO_3$/acetone/reflux; (vi) LAH/THF; (vii) MnO_2/benzene/reflux

acetonitrile afforded two major fractions viz., a faster moving yellow Fraction A (46%) and a slower moving reddish Fraction B (42%). Both fractions were separately resubjected to careful chromatographic separation. In this way Fraction A yielded the two individual naphthopyran-6,9-quinones **23** (22%) and **25** (24%). Assignment of structure **23** to the first naphthopyran-6,9-quinone to elute is based inter alia on the following one-proton signals for the pyran ring in the ^{1}H NMR spectrum; a ddd at δ = 2.42 ppm with J = 17.6 Hz for geminal coupling between the diastereotopic 4′-H's, J = 11.0 Hz for coupling between 4-H_{ax} and 3-H_{ax}, and J = 1.8 Hz representing coupling between 4-H_{ax} and 1-H_{ax} and is assigned to pseudoaxial 4-H; a ddd at δ = 2.90 ppm with a similar J = 17.6 Hz representing coupling between 4-H_{eq} and 4-H_{ax}, J = 3.0 Hz for coupling between 4-H_{eq} and 3-H_{ax}, J = 1.0 Hz representing coupling between 4-H_{eq} and 1-H_{ax} and is assigned to pseudoequa-



Scheme 2. Reagents and conditions: (i) MeMgBr/diethyl ether; (ii) $Hg(OAc)_2$/THF/H_2O/NaOH/$NaBH_4$; (iii) cerium(IV) ammonium nitrate/H_2O/CH_3CN

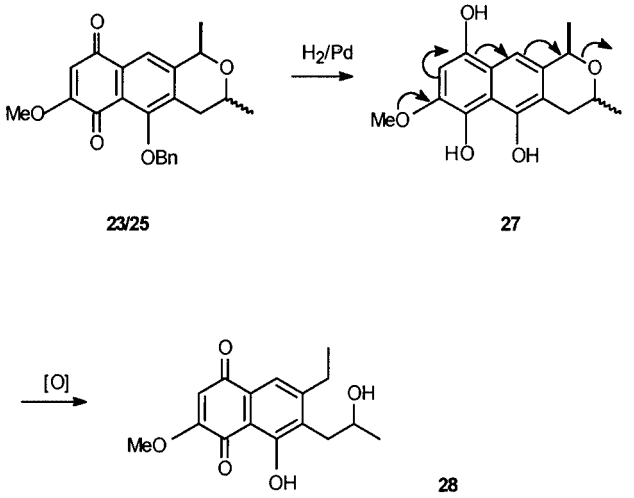
torial 4-H; a multiplet at $\delta = 3.68$ ppm assigned to 3-H_{ax}; a ddq at $\delta = 4.85$ ppm with $J = 6.6$ Hz representing coupling of 1-H_{ax} to the C1−CH_3, $J = 1.8$ Hz representing coupling between 1-H_{ax} and 4-H_{ax}, $J = 1.0$ Hz representing coupling between 1-H_{ax} and 4-H_{eq} and is assigned to the pseudoaxial 1-H.[8,24] The second naphthopyran-6,9-quinone to elute was assigned the structure **25** based on obvious similarities in the ^{1}H NMR spectrum to quinone **23** with a major difference being in the position of the signal due to 3-H_{ax}which appeared as a multiplet at $\delta = 3.95$ ppm that allowed assignment of a *trans*-1,3-dimethyl structure.[8,24]

Fraction B afforded the two individual naphthopyran-6,7-quinones **24** (18%) and **26** (24%). Assignment of the *cis* structure **24** to the first 6,7-quinone to elute was based on the comparative one-proton signals of its ^{1}H NMR spectrum to quinone **23**. The second of the 6,7-quinones to elute was assigned the structure **26** based on arguments discussed earlier.

The UV spectra of 6,9-quinones **23** and **25** displayed $\lambda_{max.}$ values at 251, 286 and 359 nm compared to those of the 6,7-quinones **24** and **26** which displayed $\lambda_{max.}$ values of 251, 288 and 372 nm. Differences in the IR spectra were also noted in that the 6,9-quinones **23** and **25** had ν bands at 1648 and 1690 cm^{-1} compared to the 6,7-diones **24** and **26** that had ν bands at 1660 and 1709 cm^{-1} as expected.[26] The alternative oxidative demethylation protocol of Rapoport[27] when applied to the mixture of naphthopyrans **21** and **22** in the hope of reducing the undesired formation of

6,7-diones **24** and **26** failed to effect this, with all four quinones being produced, but in much lower yields.

For convenience, the mixture of naphthopyran-6,9-quinones **23** and **25** was subjected to catalytic hydrogenolysis. Chromatographic purification of the crude product gave the expected mixture of quinones **7** and **8** (43%) followed by a third major fraction **28** (40%), arising from the additional hydrogenolysis of the C1/O2 benzylic bond The assignment was supported by a high resolution mass spectrum. The hydroxy group was confirmed by a broad band at 3402 cm^{-1} in the IR spectrum while a strong band at 1661 cm^{-1} confirmed the 1,4-dione configuration.[26] The typical signals in the ^1H NMR spectrum for the pyran ring protons were replaced by the following: A three-proton triplet at δ = 1.25 ppm (J = 7.8 Hz) and a two-proton doublet of quadruplets at δ = 2.80 ppm (J = 7.6, 7.8 Hz) which is assigned to the CH_3CH_2 side chain at C6. A three-proton doublet at δ = 1.32 ppm (J = 6.2 Hz) was coupled to a one-proton multiplet at δ = 4.15 ppm which in turn was coupled to a two-proton doublet at δ = 2.93 ppm (J = 6.6 Hz) and is assigned to the $CH_3CH(OH)CH_2$ side chain at C7. Two dimensional COSY spectroscopy confirmed each of the connectivities in the ethyl and 2-hydroxypropyl side chains. In addition, two one-proton D_2O exchangeable signals appeared at δ = 1.90 ppm for the C2′−OH of the 2′-hydroxypropyl side chain at C7 and the other at δ = 12.32 ppm for the strongly H-bonded 8-OH group. A possible mechanism for the over reduction is illustrated in Scheme 3 demonstrating the influence of the electron-donating ability of the C7−OCH_3 group after the initial hydrogenation to form quinol **27**.



Scheme 3. Suggested mechanism for the formation of alcohol **28** derived from pyrans **23/25**

However, by stopping the reduction of the mixture of **21** and **22** after 2 mol equivalents of H_2 were absorbed, ventiloquinone F (**7**) and isoventiloquinone F (**8**) were produced in yields of 44% and 46% respectively following chromatography. As expected, the m.p. for the *rac*-ventiloquinone F (**7**) (197−199 °C) was lower than that of the chirally pure molecule (213 °C)[2] and the ^1H NMR spectrum was identical to that published.[2] As anticipated, the ^1H NMR spectra for quinones **7** and **8** were similar and the signals for the proton 3-H_{ax} proved to be diagnostic viz., for quinone **7** it appeared as a ddq at δ = 3.75 ppm while for quinone **8** it appeared as an multiplet at δ = 4.05 ppm.[8,25]

Catalytic hydrogenolysis of the 6,7-quinone **26** only occurred when a trace amount of concentrated aqueous hydrogen chloride was added to the mixture in ethyl acetate. Again after two mol equivalents of H_2 had been absorbed, the reaction was stopped to initially afford an unstable amorphous yellow clay from which a yellow crystalline molecule was isolated with difficulty and to which structure **29** (Figure 2) has been assigned based inter alia on a high resolution mass spectrum. A strong broad peak at 3550 cm^{-1} in addition to a strong absorption at 1667 cm^{-1} in the IR spectrum supported the presence of the hydroxy and quinonoid systems while $\lambda_{max.}$ values of 258, 281 and 355 nm in the UV spectrum indicated the 6,9- rather than the 6,7-quinone isomer.[26] The absence of the methoxy signal together with the retention of the benzyl group signals in the ^1H NMR spectrum further supported the assigned structure.

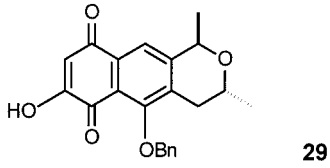


Figure 2. Hydrogenolysis product of **26**

Thus an efficient protocol has been developed for the synthesis of *rac*-ventiloquinone F (**7**) and its diastereoisomer, *rac*-isoventiloquinone F (**8**).

Experimental Section

General Remarks: ^1H and ^{13}C NMR spectra were recorded with a Varian 200 MHz spectrometer at 20 °C in $CDCl_3$ and J values are given in Hz ($CHCl_3$ at δ = 7.26 ppm and $CDCl_3$ at δ = 77.1 ppm as internal standards respectively). Infrared spectra were measured as KBr discs with a Perkin−Elmer FT-IR 1000 PC spectrometer. Ultraviolet spectra were recorded in ethyl alcohol with a GBC 920 spectrometer. Mass spectra were recorded with a VG 70E MS spectrometer. Melting points are uncorrected and were measured with a Fischer−John melting point apparatus. Elemental analysis was performed with a Carlo Erba 1500 NA analyzer. Preparative column chromatography was carried out on dry-packed columns using Silica Gel 60 (particle size 0.063−0.02 nm). The term "residue obtained upon workup" refers to the drying of the extract over magnesium sulfate, filtration and evaporation of solvent. Hexane refers to that fraction of b.p. 65−70 °C.

Methyl 4-Acetoxy-5,6,8-trimethoxy-2-naphthoate (10): The 2,4,5-trimethoxybenzaldehyde (**9**)[19] (8.0 g, 40.8 mmol) and dimethyl succinate (8.0 g, 54.8 mmol) were dissolved in hot (55 °C) dry *tert*-butyl alcohol (80 mL). This hot solution was added dropwise over 20 min to a rapidly stirred solution of KO*t*Bu [from potassium (2 g,

53.1 mmol) in *tert*-butyl alcohol (50 mL)], under reflux and nitrogen. Stirring and heating were continued for 2 h after which the cooled solution was poured into water (600 mL), acidified (litmus) with 5 M HCl and extracted with diethyl ether. The ethereal solution was extracted with saturated aqueous sodium hydrogen carbonate and the combined alkaline extracts were then acidified (litmus) with 5 M HCl and then extracted with diethyl ether. The residue obtained upon workup (12.1 g, 96% of the itaconic acid) was heated with stirring under reflux in acetic anhydride (100 mL) containing sodium acetate (4.8 g, 58.8 mmol) under nitrogen for 6 h. The cooled mixture was then poured onto ice/water (800 mL) and vigorously stirred to produce the naphthoate **10** (11.4 g, 84%) as yellow crystals, m.p. 130−132 °C (from ethanol). IR: $\tilde{\nu}$ = 1690 and 1705 cm^{-1} (s, C=O). ^1H NMR: δ = 2.38 (s, 3 H, OCOCH_3), 3.82 (s, 3 H, CO_2CH_3), 3.95, 4.00 and 4.02 (each s, each 3 H, OCH_3), 6.70 (s, 1 H, 7-H), 7.67 (d, ^3J = 1.8 Hz, 1 H, 3-H), 8.85 (d, ^3J = 1.8 Hz, 1 H, 1-H) ppm. ^{13}C NMR: δ = 20.8, 52.3, 56.1, 56.9, 62.0, 95.8, 120.4, 122.1, 124.1, 124.5, 124.9, 135.6, 145.2, 152.5, 154.3, 166.6, 169.9 ppm. $C_{17}H_{18}O_7$ (334.3): calcd. C 61.08, H 5.39; found C 61.26, H 5.45.

Methyl 4-Hydroxy-5,6,8-trimethoxy-2-naphthoate (11): A solution of the naphthyl ester **10** (5 g, 15.02 mmol) in methanolic potassium hydroxide (150 mL of a 1% w/v solution) was stirred under gentle reflux for 15 min. The cooled mixture was poured into water (600 mL) and acidified (litmus) with 5 M HCl solution followed by extraction with dichloromethane. The residue obtained upon workup afforded the naphthol **11** (4.14 g, 94%) as white crystals, m.p. 156−157 °C (from ethanol). IR: $\tilde{\nu}$ = 3280 (O-H), 1705 cm^{-1} (C=O). ^1H NMR: δ = 3.94 (s, 3 H, CO_2CH_3), 4.02 (s, 9 H, 3 × OCH_3), 6.64 (s, 1 H, 7-H), 7.43 (d, ^3J = 1.4 Hz, 1 H, 3-H), 8.42 (d, ^3J = 1.4, 1-H), 9.70 (s, 1 H, D_2O exchangeable, 4-OH) ppm. ^{13}C NMR: δ = 52.2, 56.0, 57.1, 62.3, 95.5, 97.6, 110.5, 116.7, 120.7, 122.0, 126.4, 149.5, 153.4, 154.4, 167.3 ppm. $C_{15}H_{16}O_6$ (292.3): calcd. C 61.64, H 5.47; found C 61.34, H 5.86.

Methyl 5,6,8-Trimethoxy-4-(prop-2′-enyloxy)-2-naphthoate (12): To a solution of the naphthol **11** (4.14 g, 14.20 mmol) in acetone (150 mL) containing potassium carbonate (9.9 g, 71.1 mmol) was added allyl bromide (8.6 g, 71.1 mmol) and the resulting mixture was vigorously stirred and heated under reflux under nitrogen for 12 h. The cooled mixture was filtered and the solvents evaporated to afford the naphthoate **12** (4.6 g, 92%) as light brown needles, m.p. 130−132 °C (from hexane/EtOAc). IR: $\tilde{\nu}$ = 1715 cm^{-1} (C=O). ^1H NMR: δ = 3.82 (s, 3 H, CO_2CH_3), 3.95 (s, 3 H, OCH_3), 4.01 (s, 6 H, 2 × OCH_3), 4.71 (dt, ^3J = 5.0, ^4J = 1.2 Hz, 2 H, 1′-H), 5.33 (dt, ^3J = 10.6, ^4J = 1.4 Hz, 1 H, *cis* 3′-H), 5.60 (dt, ^3J = 17.2, ^4J = 1.4 Hz, 1 H, *trans* 3′-H), 6.21 (m, 1 H, 2′-H), 6.72 (s, 1 H, 7-H), 7.41 (d, ^3J = 1.4 Hz, 1 H, 3-H), and 8.57 (d, ^3J = 1.4 Hz, 1 H, 1-H) ppm. ^{13}C NMR: δ = 52.2, 56.0, 57.4, 62.1, 70.5, 96.3, 107.8, 117.7, 118.8, 120.6, 122.4, 124.8, 133.3, 137.9, 152.4, 153.6, 154.7, 167.5 ppm. $C_{18}H_{20}O_6$ (332.4): calcd. C 65.06, H 6.02; found C 65.25, H 6.38.

Methyl 4-Hydroxy-5,6,8-trimethoxy-3-(prop-2′-enyl)-2-naphthoate (13): Pyrolysis of the naphthoate **12** (2.34 g, 7.04 mmol) at 180 °C under N_2 for 2 h afforded the naphthoate **13** (2.29 g; 98%) as light brown crystals, m.p. 94−96 °C (from hexane/EtOAc). IR: $\tilde{\nu}$ = 3270 (OH), 1705 cm^{-1} (C=O). ^1H NMR: δ = 3.87 (dt, ^3J = 5.8, ^4J = 1.5 Hz, 2 H, 1′-H), 3.90 (s, 3 H, CO_2CH_3), 3.98 (s, 3 H, OCH_3), 4.00 (s, 6 H, 2 × OCH_3), 4.97 (dt, ^3J = 11.1, ^4J = 1.5 Hz, 1 H, *cis* 3′-H), 5.04 (dt, ^3J = 18.0, ^4J = 1.5 Hz, 1 H, *trans* 3′-H), 6.11 (m, 1 H, 2′-H), 6.58 (s, 1 H, 7-H), 8.24 (s, 1 H, 1-H), 10.08 (s, 1 H, D_2O exchangeable, 4-OH) ppm. ^{13}C NMR: δ = 30.2, 52.0, 55.9, 57.2, 62.9, 95.0, 114.4, 116.7, 119.6, 120.2, 121.3, 127.5, 136.1, 137.4, 149.3, 151.1, 153.9, 168.5 ppm. $C_{18}H_{20}O_6$ (332.4): calcd. C 65.06, H 6.02; found C 65.19, H 6.10.

Methyl 4-Benzyloxy-5,6,8-trimethoxy-3-(prop-2′-enyl)-2-naphthoate (14): A solution of naphthoate **13** (2.29 g, 6.90 mmol) in acetone (110 mL) containing potassium carbonate (2.77 g, 20.04 mmol) was treated with benzyl bromide (3.43 g, 20.05 mmol) and the resulting mixture was vigorously stirred under reflux under N_2 for 24 h. The cooled mixture was filtered and the residue obtained upon workup was chromatographed with EtOAc/hexane (2:3) as eluent to yield the naphthoate **14** (2.89 g, 97%) as off-white crystals, m.p. 94−95 °C (from hexane/EtOAc). IR: $\tilde{\nu}$ = 1705 cm^{-1} (C=O). ^1H NMR: δ = 3.72 (s, 3 H, CO_2CH_3), 3.91, 4.03 (each s, each 3 H, OCH_3), 4.04 (sharp m, 5 H, OCH_3 and 1′-H), 4.88 (dt, ^3J = 10.8, ^4J = 1.8 Hz, 1 H, *cis* 3′-H), 4.94 (s, 2 H, CH_2Ph), 5.00 (dt, ^3J = 17.0, ^4J = 1.8 Hz, 1 H, *trans* 3′-H), 6.08 (m, 1 H, 2′-H), 6.71 (s, 1 H, 7-H), 7.44 (m, 5 H, Ph), 8.61 (s, 1 H, 1-H) ppm. ^{13}C NMR: δ = 30.5, 52.1, 56.0, 57.0, 62.5, 77.0, 94.9, 114.9, 120.9, 122.5, 125.8, 126.6, 127.8, 128.3 (× 2), 128.4 (× 2), 131.0, 136.1, 138.1, 138.2, 151.9, 152.2, 153.8, 168.4 ppm. $C_{25}H_{26}O_6$ (422.5): calcd. C 71.09, H 6.16; found C 71.47, H 6.05.

4-Benzyloxy-2-hydroxymethyl-5,6,8-trimethoxy-3-(prop-2′-enyl)-naphthalene (15): To a slurry of lithium aluminium hydride (LAH) (140 mg, 3.55 mmol) in THF (10 mL) under N_2 at 25 °C was added a solution of the naphthoate **14** (1.0 g, 2.4 mmol) in THF (15 mL) dropwise. The reaction mixture was then heated to 50 °C and maintained at this temperature for 30 min after which the cooled mixture was carefully treated with saturated ammonium chloride (15 drops) followed by water (30 mL) and finally extracted with dichloromethane. The residue obtained upon workup was chromatographed with EtOAc/hexane (2:3) as eluent to afford the alcohol **15** (930 mg, 100%) as a thick colourless oil IR (film: $\tilde{\nu}$ = 3450 cm^{-1} (OH). ^1H NMR: δ = 3.37 (s, 3 H, OCH_3), 3.77 (dt, ^3J = 5.2, ^4J = 1.8 Hz, 2 H, 1′-H), 4.01, 4.03 (each s, each 3 H, OCH_3), 4.81 (s, 2 H, C3−CH_2OH), 4.87 (dt, ^3J = 18.0, ^4J = 1.8 Hz, 1 H, *trans* 3′-H), 4.96 (s, 2 H, CH_2Ph), 5.05 (dt, ^3J = 11.0, ^4J = 1.8 Hz, 1 H, *cis* 3′-H), 6.13 (m, 1 H, 2′-H), 6.70 (s, 1 H, 7-H), 7.42 (m, 6 H, 1-D_2O exchangeable proton, Ph and C2−CH_2OH), 8.07 (s, 1 H, 1-H) ppm. ^{13}C NMR: δ = 25.7, 30.2, 56.0, 57.2, 62.4, 77.0, 95.1, 115.4, 118.0, 123.6, 127.1, 127.7, 128.3, 128.4 (× 2), 128.6, 129.8, 135.9, 138.1, 138.2, 150.2, 151.8, 152.8 ppm. $C_{24}H_{26}O_5$ (394.5): calcd. C 73.10, H 6.60; found 73.40, H 6.90.

4-Benzyloxy-5,6,8-trimethoxy-3-(prop-2′-enyl)naphthalene-2-carbaldehyde (16): To a solution of alcohol **15** (2.57 g, 6.52 mmol) in benzene (100 mL) was added activated manganese dioxide (15 g) and the mixture was stirred under reflux under N_2 for 18 h. The cooled mixture was filtered and the residue obtained after removal of solvent was chromatographed with EtOAc/hexane (3:7) as eluent to give the aldehyde **16** (1.76 g, 69%) as yellow crystals, m.p. 109−110 °C (from EtOAc/hexane): $\tilde{\nu}$ = 1681 cm^{-1} (C=O). ^1H NMR: δ = 3.72 (s, 3 H, OCH_3), 4.06 (s, 6 H, 2 × OCH_3), 4.09 (dt, ^3J = 6.0, ^4J = 1.8 Hz, 2 H, 1′-H), 4.91 (dt, ^3J = 17.6, ^4J = 1.8 Hz, 1 H, *trans* 3′-H), 4.96 (s, 2 H, CH_2Ph), 5.03 (dt, ^3J = 10.2, ^4J = 1.8 Hz, 1 H, *cis* 3′-H), 6.14 (m, 1 H, 2′-H), 6.73 (s, 1 H, 7-H), 7.43 (m, 5 H, Ph), 8.60 (s, 1 H, 1-H), 10.18 (s, 1 H, C2−C*H*O) ppm. ^{13}C NMR: δ = 29.2, 56.1, 56.9, 62.5, 77.1, 94.8, 115.5, 121.0, 126.7, 127.1 (× 2), 128.3 (× 2), 128.4 (× 2), 130.5, 130.6, 136.3, 138.0 (× 2), 151.9, 153.8, 154.6, 192.3 ppm. $C_{24}H_{24}O_5$ (392.4): calcd. C 73.47, H 6.12; found C 73.78, H 6.41.

2-Hydroxymethyl-5,6,8-trimethoxy-4-prop-2′-enyloxynaphthalene (17): To a slurry of LAH (170 mg, 4.5 mmol) in THF (10 mL) was added a solution of naphthoate **12** (1.0 g, 3.0 mmol) in THF

(25 mL) dropwise at 25 °C. A similar protocol described earlier afforded alcohol **17** (920 mg, 100%) as white crystals, m.p. 89−91 °C (from hexane − EtOAc). IR: $\tilde{\nu}$ = 3453 cm^{-1} (OH). ^1H NMR: δ = 3.82, 3.98, 3.99 (each s, each 3 H, OCH_3), 4.66 (dt, ^3J = 5.2, ^4J = 1.4 Hz, 2 H, 1′-H), 4.76 (s, 2 H, C2−CH_2OH), 5.32 (dt, ^3J = 10.6, ^4J = 1.4, 1 H, *cis* 3′-H), 5.57 (dt, ^3J = 17.2, ^4J = 1.4 Hz, 1 H, *trans* 3′-H), 6.20 (m, 1 H, 2′-H), 6.69 (s, 1 H, 7-H), 6.91 (d, ^3J = 1.2 Hz, 1 H, 3-H), 7.26 (s, 1 H, D_2O exchangeable, C2−CH_2O*H*), 7.75 (d, ^3J = 1.2 Hz, 1 H, 1-H) ppm. ^{13}C NMR: δ = 56.0, 57.8, 62.1, 65.9, 70.6, 96.8, 108.7, 113.0, 117.5, 121.6, 123.5, 133.6, 136.2, 138.4, 150.0, 152.3, 155.2 ppm. $C_{17}H_{20}O_5$ (304.3): calcd. C 67.11, H 6.56; found C 67.40, H 6.91.

5,6,8-Trimethoxy-4-(prop-2′-enyloxy)naphthalene-2-carbaldehyde (18): The alcohol **17** (900 mg, 2.96 mmol) was oxidized with activated manganese dioxide (5 g) as described earlier to afford the aldehyde **18** (500 mg, 56%) as yellow needles, m.p. 105−106 °C (from hexane/EtOAc). IR: $\tilde{\nu}$ = 1675 cm^{-1} (C=O). ^1H NMR: δ = 3.82, 4.03, 4.04 (each s, each 3 H, OCH_3), 4.72 (dt, ^3J = 3.6, ^4J = 1.6 Hz, 2 H, 1′-H), 5.34 (dt ^3J = 10.6, ^4J = 1.6 Hz, 1 H, *cis* 3′-H), 5.60 (dt, ^3J = 17.2, ^4J = 1.6 Hz, 1 H, *trans* 3′-H), 6.20 (m, 1 H, 2′-H), 6.75 (s, 1 H, 7-H), 7.26 (d, ^3J = 1.4 Hz, 1 H, 3-H), 8.31 (d, ^3J = 1.4 Hz, 1 H, 1-H), 9.99 (s, 1 H, C2−C*H*O) ppm. ^{13}C NMR: δ = 56.1, 57.2, 62.2, 70.2, 96.3, 102.9, 117.8, 122.0, 124.3, 125.2, 132.2, 133.0, 138.4, 153.6, 153.8, 155.5, 192.0 ppm. $C_{17}H_{18}O_5$(302.3): calcd. C 67.55, H 5.96; found C 67.75, H 5.86.

Alternative Route: Aldehyde **18** (840 mg, 2.78 mmol) was pyrolysed at 180 °C as described earlier for 2 h. The crude phenol **19** was not isolated but immediately benzylated as described before to yield the same aldehyde **16** (620 mg, 57%) with identical physical properties after chromatographic purification.

4-Benzyloxy-2-(1′′-hydroxyethyl)-5,6,8-trimethoxy-3-(prop-2′-enyl)-naphthalene (20): To a freshly prepared solution of methylmagnesium iodide [Mg (88 mg, 3.64 mmol) and methyl iodide (516 mg, 3.64 mmol) in diethyl ether (20 mL)] was added the naphthaldehyde **16** (475 mg, 1.21 mmol) in diethyl ether (25 mL) dropwise. After an additional 1 h of stirring at 25 °C, saturated aqueous ammonium chloride was added dropwise to quench the reaction followed by water (100 mL). The mixture was extracted with diethyl ether and the residue obtained upon workup was chromatographed with EtOAc/hexane (1:3) as eluent to afford the alcohol **20** (493 mg, 100%) as a clear thick oil. IR (film): $\tilde{\nu}$ = 3440 cm^{-1} (OH). ^1H NMR: δ = 1.57 (d, ^3J = 6.6 Hz, 3 H, C2−CHCH_3), 1.83 (s, 1 H, D_2O exchangeable, C2−CH(O*H*)CH_3], 3.70 (dt, ^3J = 5.6, ^4J = 1.8 Hz, 2 H, 1′-H), 3.73 (s, 3 H, OCH_3), 4.02 (s, 6 H, 2 × OCH_3), 4.87 (dt, ^3J = 17.8, ^4J = 1.8 Hz, 1 H, *trans* 3′-H), 4.96 (s, 2 H, CH_2Ph), 5.06 (dt, ^3J = 10.2, ^4J = 1.8 Hz, 1 H, *cis* 3′-H), 5.21 (q, ^3J = 6.6, 1′′-H), 6.15 (m, 1 H, 2′-H), 6.69 (s, 1 H, 7-H), 7.47 (m, 5 H, Ph), 8.25 (s, 1 H, 1-H) ppm. ^{13}C NMR: δ = 24.7, 29.9, 55.9, 57.3, 62.4, 66.8, 76.9, 95.0, 114.9, 115.4, 122.5, 123.3, 127.7, 128.6 (× 4), 128.9, 136.4, 138.2, 138.3, 141.0, 150.1, 151.4, 152.8 ppm. $C_{25}H_{27}O_5$ (407.5): calcd. C 73.71, H 6.63; found C 74.52; H 6.93.

***rac*-(1*R*,3*S*)-(5-Benzyloxy-3,4-dihydro-6,7,9-trimethoxy-1,3-dimethyl-1*H*-naphtho[2,3-*c*]pyran (21) and its (1*R*,3*R*) Diastereoisomer 22:** To a solution of the naphthyl alcohol **20** (640 mg, 1.57 mmol) in THF (35 mL) and water (25 mL) was added mercury(II) acetate (500 mg; 1.57 mmol) and the resulting mixture was stirred at 20 °C for 1 h after which aqueous sodium hydroxide (12 mL of a 5 M solution) was added and stirring maintained for an additional 1 h at 20 °C. An additional aliquot of sodium hydroxide (12 mL of a 5 M solution) was added together with sodium borohydride (1541 mg, 40.8 mmol) and the resulting reaction mixture was stirred for 1 h after which water (120 mL) was added and the aqueous solution extracted with EtOAc. The residue obtained upon workup was chromatographed with EtOAc/hexane (3:7) as eluent to yield an inseparable mixture of the naphthopyrans **21** and **22** (456 mg, 71%) as white cubes, m.p. 91−93 °C (from hexane). IR: $\tilde{\nu}$ = 1640 cm^{-1} (C=C). ^1H NMR: δ = 1.35 (d, ^3J = 6.4 Hz, 3 H, C3−CH_3), 1.40 (d, ^3J = 6.4 Hz, 3 H, C3−CH_3), 1.62 (d, ^3J = 6.2 Hz, 3 H, C1−CH_3), 1.69 (d, ^3J = 6.2 Hz, 3 H, C1−CH_3), 2.60 (dd, ^2J = 16.8, ^3J = 10.0 Hz, 1 H, 4-H_{ax}), 2.66 (dd, ^2J = 16.8, ^3J = 10.0 Hz, 1 H, 4-H_{ax}), 3.16 (dd, ^2J = 16.8, ^3J = 3.0 Hz, 1 H, 4-H_{eq}), 3.18 (dd, ^2J = 16.8, ^3J = 3.0 Hz, 1 H, 4-H_{eq}), 3.77 (s, 6 H, OCH_3), 3.80 (m, 1 H, *cis* 3-H), 4.00 and 4.02 (each s, each 6 H, OCH_3), 4.05 (m, 1 H, *trans* 3-H), 4.99 (m, 4 H, CH_2Ph), 5.20 (q, ^3J = 6.2 Hz, 2 H, 1-H), 6.67 (s, 2 H, 8-H), 7.50 (m, 10 H, Ph), 7.74 (s, 1 H, 10-H), 7.80 (s, 1 H, 10-H) ppm. $C_{25}H_{28}O_5$ (408.5): calcd. C 73.53, H 6.86; found C 72.21, H 7.06.

***rac*-(1*R*,3*S*)-5-Benzyloxy-3,4-dihydro-7-methoxy-1,3-dimethyl-1*H*-naphtho[2,3-*c*]pyran-6,9-dione (23) and its (1*R*,3*R*) Diastereoisomer 25 and *rac*-(1*R*,3*S*)-5-benzyloxy-3,4-dihydro-9-methoxy-1,3-dimethyl-1*H*-naphtho[2,3,-*c*]pyran-6,7-dione (24) and its (1*R*,3*R*) Diastereoisomer 26:** To a stirred solution of the pyrans **21** and **22** (450 mg, 1.10 mmol) in acetronile (80 mL) and water (25 mL) was added a solution of cerium(IV) ammonium nitrate (1220 mg, 2.22 mmol) in water (20 mL) dropwise over 8 min. After an additional stirring (10 min), water (800 mL) was added and the aqueous solution was extracted with dichloromethane. The residue obtained upon workup was chromatographed with EtOAc/hexane (2:3) as eluent to afford two major fractions viz., a faster moving one, Fraction A (192 mg, 46% comprising quinones **23** and **25**) and a slower moving one, Fraction B (171 mg, 42% comprising quinones **24** and **26**). Each fraction was again subjected to chromatographic separation on a long column (1.0 m × 15 mm ID) using EtOAc/hexane (1:4) as eluent to afford the following:

Fraction A: The first isomer to elute was identified as the quinone **23** (92 mg, 22%), as yellow fluffy crystals, m.p. 191−193 °C (from 2-propanol). IR: $\tilde{\nu}$ = 1648 and 1688 cm^{-1} (C=O). ^1H NMR: δ = 1.33 (d, ^3J = 6.2 Hz, 3 H, C3−CH_3), 1.61 (d, ^3J = 6.6 Hz, 3 H, C1−CH_3), 2.42 (ddd, ^2J = 17.6, ^3J = 11.0, ^5J = 1.8 Hz, 1 H, pseudoaxial 4-H), 2.90 (ddd, ^2J = 17.6, ^3J = 3.0, ^5J = 1.0 Hz, 1 H, pseudoequatorial 4-H), 3.68 (m, 1 H, 3-H), 3.90 (s, 3 H, OCH_3), 4.85 (ddq, ^3J = 6.6, ^5J = 1.8, ^5J = 1.0 Hz, 1 H, 1-H), 4.88 (d, ^2J = 10.2 Hz, 1 H, CH_2Ph), 5.02 (d, ^2J = 10.2 Hz, 1 H, CH_2Ph), 6.13 (s, 1 H, 8-H), 7.45 (m, 5 H, Ph), 7.73 (s, 1 H, 10-H) ppm. ^{13}C NMR: δ = 21.4, 21.8, 31.7, 59.6, 70.2, 73.2, 75.7, 108.6, 119.1, 121.3, 128.5, 128.6, 128.8 (× 3), 131.9, 136.5, 136.9, 148.2, 157.0, 161.0, 178.9, 184.6 ppm. $C_{23}H_{22}O_5$ (378.1): calcd. C 73.02, H 5.82; found C 73.26, H 6.10.

The second isomer to elute was identified as the quinone **25** (98 mg, 24%), as yellow crystals, m.p. 208−210 °C (from 2-propanol). IR: $\tilde{\nu}$ = 1649 and 1690 cm^{-1} (C=O). UV (ethanol): $\lambda_{max.}$ (ε) = 251 (4.82), 286 (4.08), 359 nm (3.55). ^1H NMR: δ = 1.28 (d, ^3J = 6.2 Hz, 3 H, C3−CH_3), 1.56 (d, ^3J = 7.0 Hz, 3 H, C1−CH_3), 2.37 (ddd, ^2J = 17.6, ^3J = 9.4, ^5J = 1.0 Hz, 1 H, pseudoaxial 4-H), 2.90 (dd, ^2J = 17.6, ^3J = 3.8 Hz, 1 H, pseudoequatorial 4-H), 3.91 (s, 3 H, OCH_3), 3.95 (m, 1 H, 3-H), 4.90 (d, ^2J = 10.4 Hz, 1 H, CH_2Ph), 4.95 (dq, ^3J = 7.0, ^5J = 1.0 Hz, 1 H, 1-H), 5.00 (d, ^2J = 10.4 Hz, 1 H, CH_2Ph), 6.13 (s, 1 H, 8-H), 7.49 (m, 5 H, Ph), 7.66 (s, 1 H, 10-H) ppm. ^{13}C NMR: δ = 21.0, 21.5, 30.9, 59.6, 63.6, 70.7, 75.9, 108.6, 119.1, 119.9, 128.5, 128.7, 128.8 (× 3), 131.8, 135.8, 136.9, 148.0, 157.3, 161.0, 178.9, 184.6 ppm. $C_{23}H_{22}O_5$ (378.1): calcd. C 73.02, H 5.82; found C 73.25, H 6.13. HR MS ($C_{23}H_{22}O_5$): calcd. 378.1467; found 378.1471.

Fraction B: The first isomer to elute was identified as the quinone **24** (73 mg, 18%) as bright yellow crystals, m.p. 191−193 °C (from 2-propanol). IR: $\tilde{\nu}$ = 1660 and 1709 cm^{-1} (C=O). ^1H NMR: δ = 1.33 (d, ^3J = 6.2 Hz, 3 H, C3−CH_3), 1.59 (d, ^3J = 6.6 Hz, 3 H, C1−CH_3), 2.38 (ddd, ^2J = 17.4, ^3J = 9.8, ^5J = 1.5 Hz, 1 H, pseudoaxial 4-H), 2.85 (ddd, ^2J = 17.4, ^3J = 3.2, ^5J = 1.5 Hz, 1 H, pseudoequatorial 4-H), 3.68 (m, 1 H, 3-H), 3.99 (s, 3 H, OCH_3), 4.86 (tq, ^3J = 6.6, ^5J = 1.5 Hz, 1 H, 1-H), 4.87 (d, ^2J = 10.2 Hz, 1 H, CH_2Ph), 5.00 (d, ^2J = 10.2 Hz, 1 H, CH_2Ph), 5.96 (s, 1 H, 8-H), 7.20 (m, 3 H, 3′-, 4′- and 5′-H of aryl ring), 7.46 (s, 1 H, 10 H), 7.60 (m, 2 H, 2′- and 6′-H of aryl ring) ppm. ^{13}C NMR: δ = 21.2, 21.6, 30.6, 56.9, 63.7, 70.8, 76.1, 102.8, 117.4, 118.1, 128.5, 128.6, 129.0 (× 2), 131.1, 133.7, 134.4, 136.8, 148.5, 148.8, 160.0, 178.9, 179.9 ppm. $C_{23}H_{22}O_5$ (378.1): calcd. C 73.02, H, 5.82; found C 73.36, H 6.10.

The second isomer to elute was identified as the quinone **26** (98 mg, 24%) as bright yellow crystals, m.p. 208−210 °C (from 2-propanol): IR: $\tilde{\nu}$ = 1660 and 1709 cm^{-1} (C=O). UV (ethanol): $\lambda_{max.}$ (ε) = 260 (4.35), 288 (3.90), 372 nm (3.50). ^1H NMR: δ = 1.28 (d, ^3J = 5.8 Hz, 3 H, C3−CH_3), 1.56 (d, ^3J = 7.0 Hz, 3 H, C1−CH_3), 2.33 (ddd, ^2J = 17.2, ^3J = 9.6, ^5J = 1.0 Hz, 1 H, pseudoaxial 4-H), 2.86 (dd, ^2J = 17.2, ^3J = 3.2 Hz, 1 H, pseudoequatorial 4-H), 3.95 (m, 1 H, 3-H), 4.00 (s, 3 H, OCH_3), 4.89 (d, ^2J = 10.4 Hz, 1 H, CH_2Ph), 5.01 (d, ^2J = 10.4 Hz, 1 H, CH_2Ph), 5.02 (dq, ^3J = 7.0, ^5J = 1.0 Hz, 1 H, 1-H), 5.97 (s, 1 H, 8-H), 7.39 (m, 3 H, 3′, 4′,5′-H of aryl ring), 7.40 (s, 1 H, 10-H), 7.55 (m, 2 H, 2′,6′-H of aryl ring) ppm. ^{13}C NMR: δ = 21.2, 21.6, 30.6, 56.9, 63.6, 70.7, 76.0, 102.6, 117.4, 118.1, 128.5, 128.6, 129.0 (× 2), 131.1, 133.6, 134.4, 136.8, 148.4, 148.7, 159.7, 178.8, 179.8. HR MS ($C_{23}H_{22}O_5$): calcd. 378.1467; found 378.1476.

3-Ethyl-1-hydroxy-2-(2′-hydroxypropyl)-7-methoxy-5,8-naphthoquinone (28): A mixture of the quinones **23** and **25** (192 mg, 0.51 mmol) in ethyl acetate (30 mL) containing palladium catalyst (10% on C, 40 mg) was hydrogenated for 24 h and the residue obtained after filtration of catalyst and removal of solvent was chromatographed with EtOAc/hexane (1:1) as eluent to yield a mixture of the quinone **7** and **8** (63 mg, 43%; see later). Further elution afforded the ring-opened naphthoquinone **28** (59 mg, 40%) as yellow crystals, m.p. 142−144 °C (from EtOAc). IR: $\tilde{\nu}$ = 3402 (OH), 1661 cm^{-1} (C=O). UV (ethanol): $\lambda_{max.}$ (ε) = 251 (4.05), 296 (4.07), 423 nm (3.63). ^1H NMR: δ = 1.25 (t, ^3J = 7.8 Hz, 3 H, CH_2CH_3), 1.32 (d, ^3J = 6.2 Hz, 3 H, $CH_2CH(OH)CH_3$], 1.90 (s, D_2O exchangeable, 1 H, $CH_2CH(OH)CH_3$], 2.80 (dq, ^2J = 7.8, ^3J = 7.6 Hz, 2 H, CH_2CH_3), 2.93 [d, ^3J = 6.6 Hz, 2 H, $CH_2CH(OH)CH_3$], 3.90 (s, 3 H, OCH_3), 4.15 [m, 1 H, $CH_2CH(OH)CH_3$], 6.09 (s, 1 H, 6-H), 7.51 (s, 1 H, 4-H), 12.32 (s, D_2O exchangeable, 1 H, 1-OH) ppm. ^{13}C NMR: δ = 14.0, 23.4, 26.4, 34.7, 56.0, 67.5, 109.8, 111.4, 119.2, 129.3, 131.7, 153.3, 159.7, 160.4, 183.5, 184.2 ppm. $C_{16}H_{18}O_5$ (290.1): calcd. C 66.20, H 6.25; found C 66.40, H 6.35. HR MS ($C_{16}H_{18}O_5$): calcd. 290.1154; found 290.1163.

***rac*-(1*R*,3*S*)-3,4-Dihydro-5-hydroxy-7-methoxy-1,3-dimethyl-1*H*-naphtho[2,3-*c*]pyran- 6,9-dione (7) (Ventiloquinone F) and the *rac*-(1*R*,3*R*) Diastereoisomer 8 (Isoventiloquinone F):** A mixture of the quinones **23** and **25** (362 mg, 0.96 mmol) in EtOAc (30 mL) containing palladium catalyst (10% on C, 40 mg) was hydrogenated at 20 °C until 2 mol equivalents of H_2 had been adsorbed. Removal of the solvent after filtration of the catalyst afforded a residue which was chromatographed on a long column (1.0 m × 15 mm ID) using EtOAc/hexane (1:4) as eluent to give ventiloquinone F (**7**, 121 mg, 44%) as fine yellow crystals, m.p. 197−199 °C (from EtOAc/hexane) (ref.[2] m.p. 213 °C). IR: $\tilde{\nu}$ = 3696 (OH), 1642 and 1664 cm^{-1} (C=O). ^1H NMR: δ = 1.38 (d, ^3J = 6.2 Hz, 3 H, C3−CH_3), 1.54 (d, ^3J = 6.6 Hz, 3 H, C1−CH_3), 2.43 (ddd, ^2J = 17.5, ^3J = 10.9, ^5J = 2.2 Hz, 1 H, pseudoaxial 4-H), 2.83 (ddd, ^2J = 17.5, ^3J = 3.0, ^5J = 1.7 Hz, 1 H, pseudoequatorial 4-H), 3.75 (ddq, ^3J = 10.9, ^3J = 6.2, ^3J = 3.0 Hz, 1 H, 3-H), 3.95 (s, 3 H, OCH_3), 4.77 (ddq, ^3J = 6.6, ^5J = 2.2, ^5J = 1.7 Hz, 1 H, 1-H), 5.87 (s, 1 H, 8-H), 7.18 (s, 1 H, 10-H), 12.18 (s, D_2O exchangeable, 1 H, 5-OH) ppm. ^{13}C NMR: δ = 21.1, 21.8, 30.6, 56.6, 70.0, 73.3, 110.5, 111.9, 115.3, 116.1, 129.5, 149.3, 159.9, 160.3, 184.1, 184.8 ppm. $C_{16}H_{16}O_6$ (288.1): calcd. C 66.66, H 5.59; found C 66.40, H 5.35. HR MS ($C_{16}H_{16}O_5$): calcd. 288.0998; found 288.1002.

Further elution afforded isoventiloquinone F (**8**, 126 mg, 46%) as fine yellow crystals, m.p. 225−226 °C (from EtOAc/hexane). IR: $\tilde{\nu}$ = 3696 cm^{-1} (OH), 1643 and 1663 cm^{-1} (C=O). ^1H NMR: δ = 1.36 (d, ^3J = 6.4 Hz, 3 H, C3−CH_3), 1.56 (d, ^3J = 6.6 Hz, 3 H, C1−CH_3), 2.44 (ddd, ^2J = 17.6, ^3J = 9.4, ^5J = 1.0 Hz, 1 H, pseudoaxial 4-H), 2.91 (dd, ^2J = 17.6, ^3J = 3.4, pseudoequatorial 4-H), 3.91 (s, 3 H, OCH_3), 4.05 (m, 1 H, 3-H), 5.03 (dq, ^3J = 6.6, ^5J = 1.0 Hz, 1 H, 1-H), 6.12 (s, 1 H, 8-H), 7.33 (s, 1 H, 10-H), 12.16 (s, D_2O exchangeable, 1 H, 5-OH), ^{13}C NMR: δ = 21.2, 21.4, 29.8, 56.6, 63.2, 71.0, 110.5, 111.8, 116.1, 117.1, 129.3, 149.2, 160.2, 160.4, 184.1, 184.7 ppm. $C_{16}H_{16}O_5$ (288.1): calcd. C 66.66, H 5.59; found C 66.41, H 5.34. $C_{16}H_{16}O_5$: calcd. 288.0998; found 288.1003 (HRMS).

***rac*-(1*R*,3*R*)-5-Benzyloxy-7-hydroxy-1,3-dimethyl-1*H*-naphtho[2,3-*c*]pyran-6,9-dione (29):** A solution of quinone **26** (300 mg, 0.83 mmol) in EtOAc (100 mL) containing palladium catalyst (10% on C, 90 mg) and two drops of concentrated HCl solution was hydrogenated at 20 °C until 2 mol equivalent of hydrogen had been absorbed. Filtration of the reaction mixture and removal of the solvent produced a yellow clay which upon careful recrystallisation from ethanol afforded fine olive yellow crystals of quinone **29** (100 mg, 33%), m.p. 195−196 °C. IR: $\tilde{\nu}$ = 3350 cm^{-1} (OH), 1667 cm^{-1} (C=O). UV (ethanol): $\lambda_{max.}$ (ε) = 258 (4.18), 281 (4.19), 355 nm (3.52). ^1H NMR: δ = 1.29 (d, ^3J = 6.2 Hz, 3 H, C3−CH_3), 1.56 (d, ^3J = 6.6 Hz, 3 H, C1−CH_3), 2.36 (dd, ^2J = 17.4, ^3J = 9.2 Hz, 1 H, pseudoaxial 4-H), 2.89 (dd, ^2J = 17.4, ^3J = 3.2 Hz, 1 H, pseudoaxial 4-H), 3.94 (m, 1 H, 3-H), 4.92 (d, ^2J = 10.2 Hz, 1 H, CH_2Ph), 5.00 (d, ^2J = 10.2 Hz, 1 H, CH_2Ph), 5.07 (q, ^3J = 6.6 Hz, 1 H, 1-H), 6.32 (s, 1 H, 8-H), 7.41 (m, 3 H, 3′-, 4′-, and 5′-H of aryl ring), 7.52 (m, 2 H, 2′- and 6′-H of aryl ring), 7.69 (br. s, one D_2O exchangeable H, 2 H, 7-OH and 10-H) ppm. ^{13}C NMR: δ = 21.2, 21.5, 30.8, 63.6, 70.8, 76.0, 109.2, 120.5, 128.5 (× 2), 128.7 (× 2), 129.7, 132.6, 135.4 (× 2), 136.7, 149.4, 156.9, 157.5, 180.3, 184.6 ppm. $C_{22}H_{20}O_5$ (364.1): calcd. C 72.53, H 5.53; found C 72.91, H 5.63. HR MS ($C_{22}H_{20}O_5$): calcd. 364.1311; found 364.1312.

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