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New access to 1,3-diketones from aldehydes

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Abstract—A simple and efficient methodology to introduce an 1,3-diketone motif from various aldehyde precursors in three steps with good overall yields is described using β-ketosulphone **7** as masked equivalent of acetone.

Ifremer reported in 1999 the isolation of carotenoid metabolite **1** from the cultured marine micro-algae *Skeletonema costatum*.[1] This natural product, for which neither the absolute nor the relative configuration were elucidated, exhibited potent cytotoxicity against a variety of human carcinoma cell lines.[2] As a part of our interest in the total synthesis of biologically active molecules, especially anti-tumor agents, we drawn our attention towards the synthesis of the metabolite **1**, and we have established the retro-synthetic plan depicted in Figure 1. Our strategy was centered on introduction of a 1,3-diketone unit from aldehyde **2** at the final stage.

1,3-Diketones are important building blocks, and their usefulness in heterocyclic preparations, e.g. pyrazole,[3] isoxazole,[4] triazole[5] and benzopyran-4-ones[6] has been largely illustrated. Also, 1,3-diketones are key structural units in many chelating ligands for lanthanide and transition metals.[7] As a consequence, a number of methods have been developed over the years to introduce this moiety which met various degrees of success. One of the most popular approaches to introduce the 1,3-diketone motif from the ketone precursor, is based on the C-acylation of the corresponding enolates (or silyl enol ethers) with acylating agents, e.g. acid chlorides,[8] acyl cyanides[9] or 1-acylbenzotriazoles,[10] and some improvements[11] have been recently done to minimize side reactions such as *O*-acylation. However, to our knowledge less attention has been devoted to aldehydes.[12]

Also, in order to attach the diketone side chain from **2** to reach our target molecule **1**, we became interested in developing a good and reliable method compatible with sterically hindered aldehydes. As a model of hindered aldehyde, we retained cyclohexylcarboxaldehyde **3**.

Our initial efforts have been to prepare 1,3-diketone from dithiane in an umpolung fashion. Though unprecedented, we tried to condense the lithiated dithiane **4** of the corresponding cyclohexylcarboxaldehyde **3** with 3-chloro-2-(trimethylsiloxy)-1-propene[13] **5** as electrophile acetonylating reagent (see Scheme 1). Unfortunately, all attempts to carry out this reaction in various conditions (bases and additives) were unsuccessful: no reaction takes place. By contrast, the addition of more reactive electrophiles such as allybromide[14] to lithiated dithiane **4** led to the formation of the desired product in reasonable yield (60% yield non-optimized).

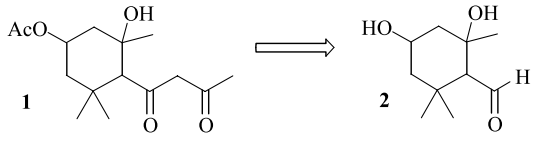

Figure 1. Retrosynthetic analysis of marine natural carotenoid metabolite **1**.

Keywords: Aldehydes; Sulfones; Alkylation; 1,3-Diketones.
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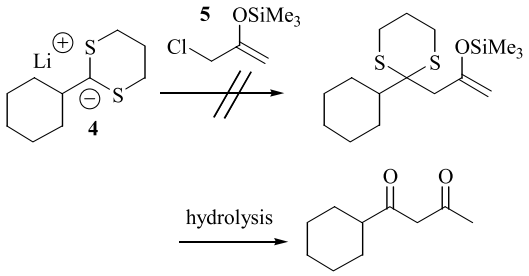
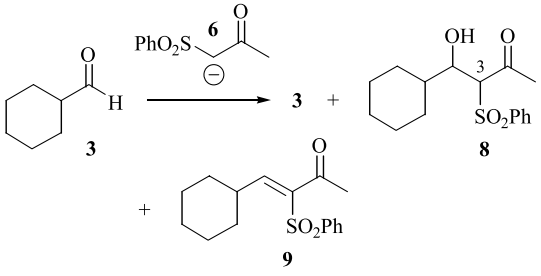


Scheme 1.

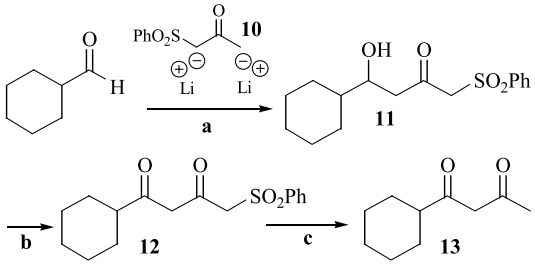
Next, it was considered that the monoanion **6**[15] of the 1-phenylsulfonylpropanone **7**, a masked nucleophilic acetonyl equivalent, could be condensed on the cyclohexylcarboxaldehyde **3** to afford the corresponding adduct **8** (see Scheme 2). Although, many conditions (NaH/THF, NaH/DMSO, LDA/THF, or DBU/PhH) to generate the stabilized carbanion **6** were screened, we always obtained a mixture (vide supra) of starting material, desired adduct **8** and unsaturated condensation compound **9**. The formation of this latter could be attributed to the acidity of the hydrogen on C-3. Also, quenching conditions were carefully investigated, however, the amounts of the byproduct **9** could be only slightly lowered by addition of saturated aqueous ammonium chloride at low temperature.

At this point, we turned our attention to an alternative strategy involving the condensation of the dianion **10** of the 1-phenylsulfonylpropanone **7** on aldehyde **3** (see Scheme 3). According to the work of Belletire,[16] the sulfone **7** was treated with 2.5 equimolar amounts of LDA in THF at low temperature to afford the colored dianion **10** which was then reacted with aldehyde **3** to give exclusively after work up the expected aldol **11** in high yield. In this condensation, no unsaturated compound was detected in the crude mixture (see vide supra). This aldol **11** was converted by oxidation with the Dess–Martin periodinane[17] (DMP) into the 1,3-diketone intermediate **12** in good yield. This method was found to be more efficient compared to PCC and Jones oxidation. Finally, the cleavage of the sulfonyl group of **12** was achieved with sodium-amalgam[18] to afford the diketone **13** in 77% yield (45% overall yield in 3 steps from aldehyde **3**).

To investigate the potential utility of this methodology, various aldehydes were readily converted to the corresponding diketones as summarized in Table 1. The different intermediates and final products were thus obtained in good to high yields for all steps, except for the removal of the sulfone group for cinnamaldehyde (entry 2). We were unable to suppress the competitive reduction of the



Scheme 2.



Scheme 3. Reagents and conditions: condensation: (a) 1.6 equiv of **10**, THF/HMPA (7/1), 4 h at 0 °C, then overnight at rt, 86%. Oxidation: (b) 1.0 equiv DMP, CH_2Cl_2, 6 h, rt, 76%. Desulfonation; (c) 5% Na(Hg), MeOH, −50 °C, then 2 h at −20 °C, 77%.

conjugate double bond on intermediate **17**, even using sodium-amalgam with NaH_2PO_4 to control pH of the medium.[19] All attempts to use samarium(II) iodide to cleave the sulfone group of **17**, with HMPA or DMPU as additives failed, leading to complete decomposition of the starting material.[20] It is especially noteworthy that sodium-amalgam mediated cleavage of sulfones can be applied to substrates containing isolated double bond, such as **25**, in this case no over reduction occurs.

In conclusion, we have developed a simple and efficient methodology to introduce an 1,3-diketone motif from aldehyde precursors in three steps with good overall yields. To evaluate the scope and the efficiency of the present methodology, various aldehydes have been used. We are now extending this methodology to the total synthesis of marine natural carotenoid metabolite **1** and the results will be published in due course.

1. Physical data and spectroscopic measurements

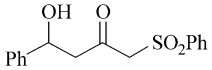
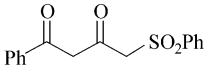
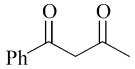
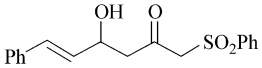
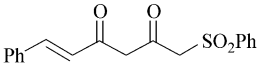
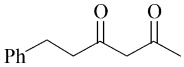
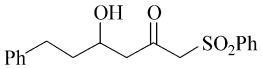
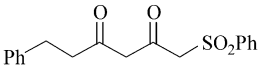
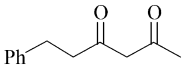
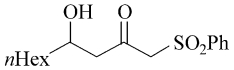
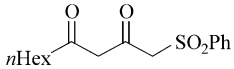
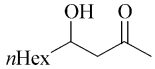
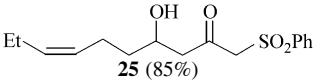
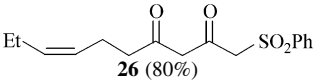
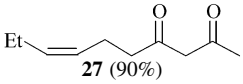
^{1}H NMR spectra were recorded on a Bruker AC 300 instrument at 300 MHz. The chemical shifts are expressed (ppm), referenced to residual chloroform (7.26 ppm). Data are reported as follows: δ, chemical shift; multiplicity (recorded as s, singlet; d, doublet; t, triplet; q, quintet and m, multiplet), coupling constants (J in Hertz, Hz), integration and assigment (aromatic, ar). H,H-COSY experiments were routinely carried out to ascertain H–H connectivities.

^{13}C NMR spectra were recorded on a Bruker AC 300 instrument at 75 MHz. The chemical shifts are expressed (ppm), reported from the central peak of deuterochloroform (76.9 ppm). DEPT (DEPT) experiments were used for evaluating CH multiplicities. When necessary, ^{13}C spectra were assigned with the aid of HETCOR experiments.

Mass spectra (MS) were obtained on a HP 5889 quadrupolar spectrometer in electronic impact (70 eV) or in chemical ionization (500 eV) with NH_3 gas. HMRS spectra were obtained on a JEOL AX500. Mass spectral data are reported as m/z.

IR spectra were recorded neat in KBr cells with a Bruker IFS 45 WHR Fourier transform spectrometer. The wave numbers (ν) are given in cm^{-1}.

Table 1

Entry	Aldehyde	Condensation[a] (yield)	Oxidation[a] (yield)	Desulfonation[a] (yield)
1	PhCHO	 **14** (92%)	 **15** (93%)	 **16** (77%)
2	(*E*)-PhCH=CHCHO	 **17** (77%)	 **18** (63%)	 **19** (63%)
3	$PhCH_2CH_2CHO$	 **20** (76%)	 **21** (94%)	 **19** (71%)
4	*n*-HexCHO	 **22** (85%)	 **23** (80%)	 **24** (90%)
5	(*Z*)-EtCH=CH$(CH_2)_2$CHO	 **25** (85%)	 **26** (80%)	 **27** (90%)

[a] See condition (a) in Scheme 3.

1.1. Chromatography

All reactions were monitored by thin-layer chromatography (TLC) carried out on precoated plate of silica gel 60F 254 (Merk, Art. 5735 alumina sheet).

Flash chromatography was performed on silica gel Merk 60, 230–400 mesh.

1.2. Solvents distillation

Tetrahydrofuran (THF) was distilled from sodium–benzophenone. Methanol (MeOH) was distilled from the corresponding magnesium derivative. Dimethylformamide (DMF) was distilled from calcium hydride under reduced pressure.

1.3. Usual procedures

All air and/or water sensitive reactions were carried out under nitrogen atmosphere with dry, freshly distilled solvents using standard syringe/septa techniques.

Yields refer to chromatographically and spectroscopically homogeneous materials, unless otherwise stated.

1.3.1. 1-Phenylsulfonyl-2-propanone 6.[16b] To a solution of chloroacetone (9.2 mL; 114.65 mmol) in 150 mL of freshly distilled DMF was added at rt sodium sulfinate (18.8 g; 114.65 mmol; 1 equiv). After stirring 24 h at rt, the reaction mixture was diluted with 20 mL of Et_2O and 20 mL of water. The aqueous phase was extracted with 3×15 mL Et_2O before washing with an aqueous NaCl solution and drying on $MgSO_4$. After evaporation of the solvent, the crude residue was purified on silica gel (eluant: petroleum ether/ethyl acetate: 7/3) to furnish 20 g of the desired product as pale yellow crystals (yield=88%). ^{1}H NMR ($CDCl_3$): $\delta=2.24$ (s, 3H, H_3); 4.09 (s, 2H, H_1); 7.54–7.67 (m, 3H, H_{ar}); 7.80–7.94 (m, 2H, H_{ar}). ^{13}C NMR ($CDCl_3$): $\delta=32.4$ (C_3); 68.7 (C_1); 129.1 (C_6 and $C_{6'}$); 130.3 (C_5 et $C_{5'}$); 135.3 (C_7); 139.5 (C_4); 197.0 (C_2). SM (CI/NH_3): M+1=199. IR: $\nu=1725$; 1322; 1151.

1.4. General procedure for aldolization

To a solution of diisopropylamine (8.8 mL; 62.5 mmol; 2.5 equiv) in 13 mL of anhydrous THF at 0 °C was added dropwise a solution of *n*-butyllithium 1.6 M in hexanes (39 mL; 62.5 mmol; 2.5 equiv) and the solution was stirred during 45 mn before cooling at −78 °C. At this temperature, 6 mL of HMPA were added followed by a solution of 1-phenylsulfonyl-2-propanone (5 g; 25 mmol) in 30 mL of THF. After 4 h at 0 °C, aldehyde (32.5 mmol; 1.3 equiv) was added to the resulting orange heterogenous solution and the reaction mixture was allowed to warm to rt overnight. Hydrolysis was achieved at 0 °C with a saturated aqueous solution of NH_4Cl (30 mL), subsequent treatments (Et_2O extraction, drying on $MgSO_4$, concentration and flash chromatography) afforded the desired compound.

1.4.1. 4-Cyclohexyl-4-hydroxy-1-phenylsulfonyl-2-butanone 11. (Eluant: CH_2Cl_2) 7 g of **11** were obtained as a yellow oil (yield=86%). ^{1}H NMR ($CDCl_3$): $\delta=1.00$–1.84 (m, 11H, $H_{cyclohexyl}$); 2.86 (d, $J=7.3$ Hz, 2H, H_3); 2.90 (s, 1H, OH); 3.77–3.86 (m, 1H, H_4); 4.22 (s, 2H, H_1); 7.26–7.91 (m, 5H, H_{ar}). ^{13}C NMR ($CDCl_3$): $\delta=26.0$; 26.1; 26.3; 28.1; 28.8 ($C_{cyclohexyl}$); 43.2 ($C_{cyclohexyl}$); 48.6 (C_3); 67.5 (C_1); 71.7 (C_4); 128.3 (2C, C_{ar}); 129.4 (2C, C_{ar}); 134.4 (C_{ar}); 138.7 (C_{ar}); 199.3 (C_2). SM (CI/NH_3): M+1=311. SM (EI) *m/z* (%): 227 (78); 199 (66); 183 (15); 141 (79); 77 (100); 55 (65); 41 (36). IR: 3520; 1715; 1310, 1152.

1.4.2. 4-Hydroxy-4-phenyl-1-phenylsulfonyl-2-butanone 14. (Eluants: petroleum ether/ethyl acetate: 6/4) 7 g of **14** were obtained as a yellow oil (Yield=92%). ^{1}H NMR ($CDCl_3$): $\delta=2.96$ and 3.08 (part AB of an ABX system, 2H, $J=17.2$, 9.2, 3.4 Hz, H_3); 4.18 (s, 2H, H_1); 5.07 (m, part X of the ABX system, 1H, H_4); 7.30–7.80 (m, 10H, H_{ar}). ^{13}C NMR ($CDCl_3$): $\delta=52.7$ (C_3); 66.8 (C_1); 69.5 (C_4); 125.7; 127.72; 128.2; 128.3; 129.8; 134.2; 138.5; 142.7

(C_{ar}); 197.7 (C_2). MS (CI/NH_3): M+18=332; M+1=305. MS (EI) *m/z* (%): 163 (5); 141 (18); 105 (44); 77 (100). IR: ν=3521; 1716; 1310; 1152.

1.4.3. (5*E*)-4-Hydroxy-6-phenyl-1-phenylsulfonyl-hex-5-en-2-one 17. (Eluants: petroleum ether/ethyl acetate: 5/5) 6.3 g of **17** were obtained as a yellow oil (yield=77%). ^{1}H NMR δ (ppm): 4.23 (s, 2H, H_1); 3.05 (m, 2H, H_3); 4.75 (qu., 1H, H_4); 6.20 (dd, 1H, H_5, J=6.2, 16 Hz); 6.64 (d, 1H, H_6, J=16 Hz). ^{13}C NMR δ (ppm): 50.9 (C_3); 67.5 (C_1); 68.4 (C_4); 126.6 (C_{ar}); 134.4 (C_{ar}); 136.2 (C_7); 138.5 (C_{ar}); 197.8 (C_2). MS (CI/NH_3): M−(H_2O)+18=330. MS (EI) *m/z* (%): 312 (5); 171 (93); 157 (35); 128 (87); 105 (100); 77 (48); 51 (30); 18 (25). IR: 3515; 3060; 3026; 2927; 1721; 1447; 1320; 1151; 969; 744.

1.4.4. 4-Hydroxy-6-phenyl-1-phenylsulfonyl-2-hexanone 20. (Eluants: petroleum ether/ethyl acetate: 6/4) 6.3 g of **20** were obtained as a yellow oil (yield=76%). ^{1}H NMR δ (ppm): 1.75 (m, 2H, H_5); 2.66 (m, 2H, H_6); 2.82 (d, 2H, H_3, J=5.8 Hz); 4.10 (m, 1H, H_4); 4.28 (s, 2H, H_1); 7.18–7.88 (m, 10H, H_{ar}). ^{13}C NMR δ (ppm): 31.6 (C_6); 38.2 (C_5); 51.1 (C_3); 66.7 (C_4); 66.9 (C_1); 125.9; 128.2; 128.4; 129.3; 134.3; 138.7; 141.6 (C_{ar}); 198.6 (C_2). MS (CI/NH_3): M+18=350. MS (EI) *m/z* (%): 172 (35); 141 (21); 91 (100); 77 (64). IR: 3526; 3026; 2927; 1716; 1602; 1584; 1447; 1309; 1151; 1083; 742.

1.4.5. 4-Hydroxy-1-phenylsulfonyl-2-decanone 22. (Eluants: petroleum ether/ethyl acetate: 6/4) 6.6 g of **22** were obtained as a yellow oil (yield=85%). ^{1}H NMR δ (ppm): 0.87 (m, 3H, H_{10}); 1.26 (m, 10H, H_5, H_6, H_7, H_8, H_9); 2.81 (m, 2H, H_3); 4.03 (m, 1H, H_4); 4.21 (s, 2H, H_1); 7.52–7.90 (m, 5H, H_{ar}). ^{13}C NMR δ (ppm): 14.3 (C_{10}); 22.8 (C_9); 25.6 (C_5); 29.5 (C_7); 32.0 (C_6); 36.9 (C_8); 51.4 (C_3); 67.7 (C_4); 67.9 (C_1); 128. 6 (2C, C_{ar}); 129.7 (2C, C_{ar}); 134.7 (C_{ar}); 138.9 (C_{ar}); 199.2 (C_2). MS (CI/NH_3): M+18=330. MS (EI) *m/z* (%): 227 (32); 199 (41); 141 (61); 77 (100); 43 (99). IR: 3521; 3063; 2925; 1716; 1585; 1494; 1447; 1310; 1152; 1083; 743.

1.4.6. (7*Z*)-4-Hydroxy-1-phenylsulfonyl-7-decen-2-one 25. (Eluants: petroleum ether/ethyl acetate: 6/4) 6.6 g of **25** were obtained as a yellow oil (yield=85%). ^{1}H NMR δ (ppm): 0.99 (m, 3H, H_{10}); 1.52 (m, 2H, H_6); 2.10 (m, 4H, H_6, H_9); 2.84 (m, 2H, H_3); 4.06 (m, 1H, H_4); 4.22 (s, 2H, H_1); 4.06 (m, 2H, H_7, H_8); 7.55–7.92 (m, 5H, H_{ar}). ^{13}C NMR δ (ppm): 14.3 (C_{10}); 20.5 (C_{11}); 23.1 (C_6); 36.4 (C_5); 51.1 (C_3); 67.2 (C_4); 67.5 (C_1); 127.8 (C_7 or C_8); 128.3 (C_{ar}); 129.4 (C_{ar}); 132.7 (C_7 or C_8); 134.4 (C_{ar}); 138.6 (C_{ar}); 198.7 (C_2). MS (CI/NH_3): M−(H_2O)+18=310. MS (EI) *m/z* (%): 224 (24); 141 (12); 83 (100); 77 (55); 69 (36); 55 (31); 41 (71). IR: 3518; 3061; 1715; 1483; 1310; 1152; 744.

1.5. General procedure for oxydation

To a solution of Dess–Martin periodinane (0.41 g; 1.0 mmol; 1.6 equiv) in 4.4 mL of CH_2Cl_2 was added at rt a solution of compound to oxidize (0.6 mmol) in 3 mL of CH_2Cl_2. The reaction mixture was stirred 6 h at rt then diluted with 15 mL of Et_2O. 10 mL of a 10% aqueous solution of $Na_2S_2O_3$ and 10 mL of a 10% aqueous solution of $NaHCO_3$ were successively added. Subsequent extraction with Et_2O (3×10 mL) afforded an organic phase which was submitted to usual treatments (drying on $MgSO_4$, concentration and a short flash chromatography) affording the desired compound.

1.5.1. 1-Cyclohexyl-4-phenylsulfonyl-1,3-butadione 12. (Eluant: CH_2Cl_2) 150 mg of **12** were obtained as a yellow oil (yield=76%). ^{1}H NMR ($CDCl_3$) δ (ppm): 1.25–1.80 (m, 11H, $H_{cyclohexyl}$); 4.02 (s, 2H, H_3); 5.67 (s, 2H, H_1); 7.44–7.59 (m, 3H, H_{ar}); 7.88–7.98 (m, 2H, H_{ar}). ^{13}C NMR ($CDCl_3$) δ (ppm): 25.7; 26.1; 28.1; 28.2; 29.4 (5C, $C_{cyclohexyl}$); 48.6 ($C_{cyclohexyl}$); 64.8 (C_1); 51.7 (C_3); 128.5 (2C, C_{ar}); 129.4 (2C, C_{ar}); 134.3 (C_{ar}); 138.7 (C_{ar}); 210.5 (C_4); 215.3 (C_2). MS (CI/NH_3): M+1=309. SM (EI) *m/z* (%): 308 (3); 225 (100); 183 (97); 141 (100); 111 (23); 77 (56); 55 (46). IR: 2995; 2935; 1602; 1322; 1151.

1.5.2. 1-Phenyl-4-phenylsulfonyl-1,3-butanedione 15. (Eluants: petroleum ether/ethyl acetate: 6/4) 0.17 g of **15** were obtained as a yellow solid (yield=93%). ^{1}H NMR δ (ppm): 4.17 (s, 2H, H_1); 6.38 (s, 1H, H_3); 7.40–7.80 (m, 10H, H_{ar}). ^{13}C NMR δ (ppm): 31.2 (C_1); 65.4 (C_3); 127.7; 128.5; 129.1; 129.6; 130.4; 133.5; 134.6; 138.8 (C_{ar}); 184.7 (C_4); 208.2 (C_2). MS (CI/NH_3): M+18=320; M+1=303. MS (EI) *m/z* (%): 160 (18); 147 (37); 118 (35); 105 (100); 77 (59). IR: 2995; 2936; 1603; 1573; 1451; 1308; 1159; 1085; 694.

1.5.3. (5*E*)-6-Phenyl-1-phenylsulfonyl-hexene-2,4-dione 18. (Eluants: petroleum ether/ethyl acetate: 3/7) 0.63 g of **17** were obtained as a red oil (yield=63%). ^{1}H NMR δ (ppm): 4.13 (s, 2H, H_1); 5.92 (s, 1H, H_3); 6.51 (d, 1H, H_6, J=15.8 Hz); 7.29–7.68 (m, 11H, H_{ar} and H_5). ^{13}C NMR δ (ppm): 65.9 (C_1); 102.4 (C_6); 121.8–141.9 (14C, 12C_{ar}, C_5, C_3); 178.5 (C_4); 185.8 (C_2). MS (CI/NH_3): M+18=346; M+1=329. MS (EI) *m/z* (%): 312 (12); 171 (100); 157 (33); 128 (61); 105 (65); 77 (35); 51 (15). IR: 3439; 3060; 3028; 2925; 1633; 1578; 1446; 1313; 1307; 1156; 1084.

1.5.4. 6-Phenyl-1-phenylsulfonyl-hexane-2,4-dione 19. (Eluants: petroleum ether/ethyl acetate: 6/4) 0.186 g of **18** were obtained as a brown oil (yield=94%). ^{1}H NMR δ (ppm): 2.78 (m, 4H, H_5 and H_6); 4.00 (s, 2H, H_1); 5.69 (s, 1H, H_3); 7.16–8.00 (m, 10H, H_{ar}). ^{13}C NMR δ (ppm): 31.5 (C_6); 40.3 (C_5); 64.7 (C_1); 102.6 (C_3); 126.7; 128.6; 128.7; 128.9; 129.5; 134.6; 138.8; 140.4 (C_{ar}); 179.4 (C_2); 195.1 (C_4). MS (CI/NH_3): M+18=348; M+1=331. MS (EI) *m/z* (%): 188 (27); 141 (30); 131 (54); 104 (62); 91 (100); 77 (81). IR: 3062; 3027; 2927; 1721; 1602; 1496; 1447; 1323; 1310; 1153; 1083; 700.

1.5.5. 1-Phenylsulfonyl-decane-2,4-dione 23. (Eluants: petroleum ether/ethyl acetate: 6/4) 0.15 g of **23** were obtained as a yellow oil (yield=80%). ^{1}H NMR δ (ppm): 0.86 (m, 3H, J=7 Hz, H_{10}); 1.27 (m, 8H, H_6, H_7, H_8, H_9); 1.55 (m, 2H, H_5); 4.00 (s, 2H, H_1); 5.65 (s, 1H, H_3); 7.49–7.90 (m, 5H, H_{ar}). ^{13}C NMR δ (ppm): 14.3 (C_{10}); 22.7 (C_9); 25.7 (C_5); 29.0 (C_7); 31.7 (C_6); 38.6 (C_8); 64.7 (C_1); 102.2 (C_3); 128.7 (2C, C_{ar}); 129.5 (2C, C_{ar}); 134.5 (C_{ar}); 138.9 (C_{ar}); 179.9 (C_4); 196.2 (C_2). MS (CI/NH_3): M+18=328; M+1=311. MS (EI) *m/z* (%): 240 (38); 225 (16); 183 (49); 169 (33); 141 (98); 125 (29); 113 (40); 99 (41); 85 (75); 77

(100); 69 (24); 55 (36); 43 (91). IR: 2995; 2936; 1602; 1445; 1317; 1308; 1159; 1085; 694.

1.5.6. (7*Z*)-1-Phenylsulfonyl-decene-2,4-dione 26. (Eluants: petroleum ether/ethyl acetate: 6/4) 0.15 g of **26** were obtained as a yellow oil (yield = 80%). ^{1}H NMR δ (ppm): 0.93 (t, 3H, J = 7 Hz, H_{10}); 1.90–2.15 (m, 2H, H_9); 2.19–2.45 (m, 4H, H_5 and H_6); 4.02 (s, 2H, H_1); 5.15–5.62 (m, 2H, H_3 and H_4); 5.70 (s, 1H, H_3); 7.49–7.99 (m, 5H, H_{ar}). ^{13}C NMR δ (ppm): 14.2 (C_{10}); 20.5 (C_9); 23.0 (C_5 or C_6); 38.4 (C_5 or C_6); 64.5 (C_1); 102.2 (C_7 and C_8); 126.3, 128.4, 129.4, 134.3, 138.5 (5C, C_{ar}), 179.8 (C_4); 195.1 (C_2). MS (CI/NH_3): M + 18 = 326; M + 1 = 309. MS (EI) *m/z* (%): 240 (56); 225 (12); 199 (15); 183 (29); 167 (26); 141 (77); 125 (31); 109 (53); 77 (100); 67 (48); 55 (46); 41 (75). IR: 2957; 2930; 1615; 1506; 1446; 1320; 1309; 1156; 1085.

1.6. General procedure for desulfonation

Turnings of sodium (0.46 g; 20 mmol; 12.2 equiv) were added to mercury (7.3 g; 36.4 mmol; 22 equiv) at rt. 8.3 mL of dry MeOH were then added to the corresponding amalgam and the temperature was cooled to −50 °C. A solution of 1,3-dione (1.7 mmol; 1 equiv) in 12 mL of MeOH was added and the reaction mixture was stirred 2 h at −20 °C before the hydrolysis was achieved with a saturated aquous solution of NH_4Cl (40 mL) at 0 °C. After filtration, the aqueous phase was extracted with 3 × 10 mL Et_2O before drying on $MgSO_4$. After evaporation of the solvent, the crude residue was purified by a short flash chromatography to afford the desired compound. All compounds were obtained under their enolic form.

1.6.1. 1-Cyclohexyl-butane-1,3-dione 13. (Eluants: CH_2Cl_2) 0.22 mg of **13** were obtained as a pale orange oil (yield = 77%). ^{1}H NMR ($CDCl_3$) δ (ppm): 0.69–1.89 (m, 10H, $H_{cyclohexyl}$); 2.06 (s, 3H, H_4); 2.22 (m, 1H, $H_{cyclohexyl}$); 3.60 (s, 2H, $H_{2'}$); 5.48 (s, 1H, H_2); 12.06 (s, 1H, OH). ^{13}C NMR δ (ppm): 24.0; 25.9; 27.8; 29.6 (4C, $C_{cyclohexyl}$); 28.5 (C_4); 46.4 (C_5); 98.1 (C_2); 192.6 (C_1 and C_3). MS (CI/NH_3): M + 1 = 169. MS (EI) *m/z* (%): 168 (18); 113 (12); 85 (100); 55 (24); 43 (35). HR MS: 168.1167 ($C_{10}H_{16}O_2$; calcd 168.1150). IR: 2966; 1612; 1492; 1364.

1.6.2. 1-Phenyl-butan-1,3-dione 16. (Eluants: petroleum ether/ethyl acetate: 7/3) 140 mg of **16** were obtained as a pale yellow oil (yield = 76%). ^{1}H NMR δ (ppm): 2.06 (s, 3H, H_1); 5.03 (m, 1H, H_3); 7.15–7.24 (m, 5H, H_{ar}) [10% of the 1–3 diketone form is detected: 2.18 (s, 3H, H_1); 6.20 (s, 2H, H_3); 7.43–7.84 (m, 5H, H_{ar})[21]]. ^{13}C NMR δ (ppm): 24.1 (C_1); 47.0 (C_3); 68.8 (C_2); 75.2 (C_4); 125.7 (2C, C_{ar}); 127.5 (Car); 128.5 (2C, C_{ar}); 144.5 (C_{ar}). MS (CI/NH_3): M + 1 = 163; M + 18 = 180. MS (EI) *m/z* (%): 146 (28); 105 (53); 77 (67); 43 (98). IR: 3436; 3062; 3030; 2925; 1713; 1603; 1494; 1449; 1360; 1323; 1158; 1083; 756; 701.

1.6.3. 6-Phenyl-hexan-2,4-dione 19. (Eluants: petroleum ether/ethyl acetate: 7/3) 224 mg of **19** were obtained as a brown oil (yield = 71%). ^{1}H NMR δ (ppm): 2.04 (s, 3H, H_1); 2.65 (m, 2H, H_5); 2.92 (m, 2H, H_6); 5.48 (s, 1H, H_3); 7.17–7.29 (m, 5H, H_{ar}). ^{13}C NMR δ (ppm): 25.1 (C_5); 31.8 (C_1); 40.3 (C_3); 100.3 (C_6); 126.5 (C_{ar}); 128.6 (2C, C_{ar}); 128.8 (2C, C_{ar}); 140.9 (C_{ar}); 191.3 (C_4); 193.5 (C_2). MS (CI/NH_3): M + 1 = 191; M + 18 = 208. SM (EI) *m/z* (%): 190 (21); 104 (67); 91 (100); 77 (30); 43 (100). HR MS: 190.0996 ($C_{12}H_{14}O_2$; calcd 190.0994). IR: 3027; 2928; 1706; 1603; 1496; 1454; 1361; 1134; 785; 750; 699.

1.6.4. Decane-2,4-dione 24. (Eluants: petroleum ether/ethyl acetate: 7/3) 265 mg of **24** were obtained as a yellow oil (yield = 90%). ^{1}H NMR δ (ppm): 0.86 (m, 3H, H_{10}); 1.26 (m, 16H, H_6–H_9); 2.02 (m, 3H, H_1); 2.22 (m, 2H, H_5); 5.47 (s, 1H, H_3). ^{13}C NMR δ (ppm): 14.2; 22.7; 25.2; 25.9; 29.1 (5C, C_{alk}); 31.8 (C_1); 38.5 (C_{alk}); 99.9 (C_3); 191.7 (C_4); 194.5 (C_2). MS (CI/NH_3): M + 1 = 171; M + 18 = 188. MS (EI) *m/z* (%): 170 (2); 113 (18); 100 (55); 85 (100); 72 (16); 43 (100). HR MS: 170.1304 ($C_{10}H_{18}O_2$; calcd 170.130). IR: 2956; 2929; 2858; 1613; 1460; 1364.

1.6.5. (7*Z*)-Decene-2,4-dione 27. (Eluants: petroleum ether/ethyl acetate: 7/3) 265 mg of **27** were obtained as a yellow oil (yield = 90%). ^{1}H NMR δ (ppm): 0.88 (t, 3H, J = 7 Hz, H_{10}); 1.95 (s, 3H, H_1); 1.95 (m, 2H, H_9); 2.25 (m, 4H, H_5–H_6); 5.15–5.41 (m, 2H, H_7–H_8); 5.42 (s, 1H, H_3). ^{13}C NMR δ (ppm): 13 (C_{10}); 20 (C_9); 22 (C_6); 24 (C_1); 37 (C_5); 99 (C_3); 126 and 132 (C_7 and C_8); 190 and 192 (C_2 and C_4). MS (CI/NH_3): M + 1 = 169; M + 18 = 186. MS (EI) *m/z* (%): 168 (2); 110 (11); 100 (30); 85 (100); 67 (27); 55 (14); 43 (71). HR MS: 168.1154 ($C_{10}H_{16}O_2$; calcd 168.1150). IR: 2956; 2863; 1713; 1620; 1454; 1360; 1142.

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