

Supporting Information

for

Homogeneous and heterogeneous photoredox-catalyzed hydroxymethylation of ketones and keto esters: catalyst screening, chemoselectivity and dilution effects

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Experimental part

General Methods

TiCl(OiPr)₃, TiCl₂(OiPr)₂ and TiCl(OiPr)₃ were prepared according to [1-3]. Methyl 6-oxoheptanoate was prepared following [4]. TiO₂ pigment was purchased from Kremer Pigmente, TiO₂ P25 was a gift from Degussa AG. All other chemicals were purchased from Acros Organics or Sigma-Aldrich and were used as received. ¹H NMR and ¹³C NMR spectra were recorded on a Bruker AV 300 or Bruker DRX 500 spectrometer. HRMS were run on a Thermo Scientific LTQ Orbitrap XL mass spectrometer. All irradiations were carried out in pyrex or quartz vessels. All irradiation experiments except reactions done according to method b, were carried

out in a Luzchem LZ-C4 reactor (≈ 100 W) using coated and non-coated high-pressure mercury lamps ($\lambda = 254, 300, 350$ nm). In method b a Rayonet reactor (200 W) with coated high-pressure mercury lamps ($\lambda = 300$ nm) was used as light source.

Homogeneous catalyzed reactions

Argon gas was passed through a mixture of 0.75 mmol (1 equiv) ketone in 6 mL of methanol containing 0.5 equiv titanium(IV) catalyst of the type $\text{TiCl}_n(\text{OiPr})_{4-n}$ ($n = 0-4$) for 15 min. The degassed solution was irradiated with UV light (254–300 nm) for 72 h at room temperature. After irradiation, the solution was poured into water and extracted four times with CH_2Cl_2 . The organic phase was dried (Na_2SO_4) and the solvent was removed under reduced pressure. The residual was purified via column chromatography.

Heterogeneous catalyst reactions

Method a: Argon gas was passed through a mixture of 0.75 mmol (1 equiv) ketone in 6 mL methanol containing 1.4 wt % TiO_2 (0.5 mol % photoredox catalyst) for 15 min. The degassed solution was irradiated with UV light (350 nm) for 48 h at room temperature. After irradiation, the suspension was centrifuged to remove the nanoparticles. The supernatant solution was removed under reduced pressure and the residual was purified via column chromatography. In the case of acetophenone, the concentration of the substrate and product in supernatant was determined by a gas chromatograph (Hewlett-Packard HP-6890) equipped with flame ionization detector.

Method b: 3.72 mmol acetophenone dissolved in methanol (10 mL) was slowly added (441 $\mu\text{L}/\text{h}$) to a TiO_2 P25 (10 mg) in methanol (30 mL) suspension, while the reaction

solution was irradiated (300 nm) for 24 h at 15 °C. After irradiation, the suspension was centrifuged to remove the nanoparticles. The concentration of the substrate and product in supernatant was determined by a gas chromatograph (Hewlett-Packard HP-6890) equipped with flame ionization detector.

2-Phenylpropane-1,2-diol (**4**) [5]: $^1\text{H-NMR}$ (CDCl_3 , 300 MHz): δ (ppm) 1.50 (s, 3H), 2.41 (brs, 1H, OH), 2.97 (brs, 1H, OH), 3.67 (dd, $J = 47.3, 11.2$ Hz, 2H), 7.26 (t, $J = 7.1$ Hz, 1H), 7.35 (t, $J = 7.4$ Hz, 2H), 7.43 (d, $J = 7.4$ Hz, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 75 MHz): δ (ppm) 26.5 (q, C-1), 71.5 (t, C-7), 75.4 (s, C-2), 125.6 (d, C-5, C-5'), 127.7 (d, C-6), 128.9 (d, C-4, C-4'), 145.5 (s, C-3).

2,3-Diphenylbutane-2,3-diol (dl und meso-**5**) [6]: $^1\text{H-NMR}$ (CDCl_3 , 300 MHz): δ (ppm) 1.51, (s, 6H), 1.58 (s, 6H), 7.18-7.26 (m, 20H); $^{13}\text{C-NMR}$ (CDCl_3 , 75 MHz): δ (ppm) 24.7 (q), 24.9 (q), 126.6 (d), 126.8 (d), 126.9 (d), 127.0 (d), 127.1 (d), 143.1 (s), 143.5 (s).

1-Phenylethanol (**6**) [7]. $^1\text{H-NMR}$ (CDCl_3 , 300 MHz): δ (ppm) 1.50 (d, $J = 6.5$ Hz, 3H), 1.86 (brs, 1H, OH) 4.91 (q, $J = 6.4$ Hz, 1H), 7.25-7.40 (m, 5H); $^{13}\text{C-NMR}$ (CDCl_3 , 75 MHz): δ [ppm]: 25.7 (q), 71.0 (d), 125.9 (d), 128.1 (d), 129.1 (d).

1,1-Diphenylethane-1,2-diol (**7**) [8]. $^1\text{H-NMR}$ ($d_4\text{-MeOH}$, 300 MHz): δ (ppm) 4.11 (s, 2H), 7.21 (d, $J = 7.2$ Hz), 7.29 (t, $J = 7.4$ Hz), 7.44 (d, $J = 7.3$ Hz, 4H); $^{13}\text{C-NMR}$ ($d_4\text{-MeOH}$, 75 MHz): δ (ppm) 69.9 (t), 79.5 (s) 127.8 (d), 128.9 (d), 130.5 (d), 146.5 (s).

2-(2-Fluorophenyl)propane-1,2-diol (**10**). $^1\text{H-NMR}$ (300 MHz, CDCl_3): δ (ppm) 7.60 (t, $J = 8.0$ Hz, 1H), 7.25 (m, 1H), 7.14 (t, $J = 7.5$ Hz, 1H), 7.00 (m, 1H), 3.93 (d, $J = 11.1$ Hz, 1H), 3.69 (d, $J = 11.2$ Hz, 1H), 3.28 (s, 1H, OH), 2.51 (s, 1H, OH), 1.54 (s, 3H); $^{13}\text{C-NMR}$ (75 MHz, CDCl_3): δ (ppm) 161.2 (s), 157.9 (s), 131.7 (s), 131.6 (s), 129.3 (d), 129.2 (d), 128.2 (s), 128.2 (s), 124.4 (s), 124.3 (s), 116.3 (d), 115.9 (d), 74.2 (s), 74.2 (s), 69.4 (t), 69.3 (t), 24.7 (q), 24.7 (q)

2-(4-Nitrophenyl)propane-1,2-diol (**14**) [9]. $^1\text{H-NMR}$ (300 MHz, CDCl_3): δ (ppm) 8.19 (d, $J = 8.8$ Hz, 2H), 7.63 (d, $J = 8.8$ Hz, 2H), 3.80 (d, $J = 11.0$ Hz, 1H), 3.70 (d, $J = 11.0$, 1H), 2.41 (brs, 2H, OH), 1.55 (s, 3H); $^{13}\text{C-NMR}$ (75 MHz, CDCl_3): δ (ppm) 152.8 (s), 147.2 (s), 126.4 (d), 123.7 (d), 75.0 (s), 70.7 (t), 26.2 (q).

2-(*p*-Tolyl)propane-1,2-diol (**15**) [10]. $^1\text{H-NMR}$ (300 MHz, CDCl_3): δ (ppm) 7.32 (d, $J = 8.2$ Hz, 2H), 7.17 (d, $J = 8.1$ Hz, 2H), 3.73 (d, $J = 11.1$ Hz), 3.57 (d, $J = 11.0$ Hz) 2.87 (brs, 2H, OH), 2.34 (s, 3H), 1.49 (s, 3H); $^{13}\text{C-NMR}$ (75 MHz, CDCl_3): δ (ppm) 142.2 (s), 136.9 (s), 129.9 (d), 125.2 (d), 74.9 (s), 71.2 (t), 26.2 (q), 21.1 (q).

2-Methylpentane-1,2-diol (**18**) [11]. $^1\text{H-NMR}$ (CDCl_3 , 300 MHz): δ (ppm) 0.91 (t, $J = 7.0$ Hz, 3H), 1.13 (s, 3H), 1.29-1.48 (m, 4H), 2.79 (s, 2H, OH), 3.40 (q, $J = 11.1$ Hz, 2H, H-6); $^{13}\text{C-NMR}$ (CDCl_3 , 75 MHz): δ (ppm) 14.8 (q), 17.1 (t), 23.2 (q), 41.1 (t), 69.7 (t), 73.3 (s).

1-(Hydroxymethyl)cyclohexanol (**19**) [12]. $^1\text{H-NMR}$ (CDCl_3 , 300 MHz): δ (ppm) 1.25-1.66 (m, 10H), 1.92 (brs, 1H, OH), 2.10 (brs, 1H, OH), 3.45 (s, 2H); $^{13}\text{C-NMR}$ (CDCl_3 , 75 MHz): δ (ppm) 21.6 (t), 25.6 (t), 34.1 (t), 69.9 (t), 71.5 (s).

1,1-Diphenylmethanol (**9**) [13]. $^1\text{H-NMR}$ (CDCl_3 , 300 MHz): δ (ppm) 2.21 (brs, OH), 5.79 (s, 1H), 7.22-7.7.37 (m, 10H); $^{13}\text{C-NMR}$ (CDCl_3 , 75 MHz): δ (ppm) 76.4 (d), 126.7 (d), 127.7 (d), 128.6 (d), 143.9 (s).

1-(2-Fluorophenyl)ethanol (**12**) [14]. $^1\text{H-NMR}$ (300 MHz, CDCl_3): δ (ppm) 7.51-7.45 (m, 1H), 7.27-7.20 (m, 1H), 7.17-7.11 (m, 1H), 7.04-6.98 (m, 1H), 5.18 (q, $J = 6.5$ Hz, 1H), 2.26 (brs, 1H, OH), 1.50 (d, $J = 6.5$ Hz, 3H); $^{13}\text{C-NMR}$ (75 MHz, CDCl_3): δ (ppm) 161.5 (s), 158.3 (s), 132.9 (s), 132.7 (s), 128.9 (d), 128.8 (d), 126.8 (d), 126.8 (d), 124.5 (d), 124.5 (d), 115.6 (d), 115.3 (d), 64.7 (d), 64.6 (d), 24.2 (q).

1-(*p*-Tolyl)ethanol (**17**) [15]. $^1\text{H-NMR}$ (300 MHz, CDCl_3): δ (ppm) 7.26 (d, $J = 7.9$ Hz, 2H), 7.15 (d, $J = 8$ Hz, 2H), 4.85 (q, $J = 6.4$ Hz, 1H), 2.34 (s, 3H), 1.86 (brs, 1H, OH),

1.47 (d, $J = 6.5$ Hz, 3H): ^{13}C -NMR (75 MHz, CDCl_3): δ (ppm) 143.0 (s), 137.3 (s), 129.3 (d), 125.5 (d), 70.4 (d), 25.2 (q), 21.2 (q).

1,1,2,2-Tetraphenylethane-1,2-diol (**8**) [16]. ^1H -NMR (CDCl_3 , 300 MHz): δ (ppm) 3.05 (s, 2H, OH), 7.18-7.19 (m, 12H), 7.30-7.33 (m, 8H).

2,3-Bis(2-fluorophenyl)butane-2,3-diol (**11**). ^1H -NMR (300 MHz, CDCl_3): δ (ppm) 7.49-7.43 (m, 2H), 7.31-7.05 (m, 8H), 7.04-6.80 (m, 6H), 3.25 (d, $J = 6.2$ Hz, 2H), 3.15 (d, $J = 6.0$ Hz, 2H), 1.77 (s, 6H), 1.64 (s, 6H); ^{13}C -NMR (75 MHz, CDCl_3): δ (ppm) 162.7 (s), 162.7 (s), 159.5 (s), 159.4 (s), 130.8 (t), 130.7 (t), 130.5 (t), 130.5 (t), 129.9 (t), 129.8 (t), 129.7 (t), 124.1 (t), 124.1 (t), 123.7 (t), 123.7 (t), 116.9 (t), 116.6 (t), 116.5 (t), 116.3 (t), 80.2 (s), 80.2 (s), 80.1 (s), 80.0 (s), 24.9 (q), 24.9 (q), 24.5 (q), 24.4 (q); HR-MS: exact mass (ESI): m/z $[\text{M}+\text{Na}]^+$ calcd. for $\text{C}_{16}\text{H}_{16}\text{F}_2\text{O}_2$: 301.1011 found: 301.1008

2,3-Bis(4-methoxyphenyl)butane-2,3-diol (dl and meso) (**13**) [17]. ^1H -NMR (300 MHz, CDCl_3): δ (ppm) 7.16-7.09 (m, 4H), 6.79-6.75 (m, 4H), 3.80 (s, 12H), [1.56] (s, 6H), 1.47 (s, 6H); ^{13}C -NMR (75 MHz, CDCl_3): δ (ppm) 158.5 (s), 158.4 (s), 136.0 (s), 135.7 (s), 128.5 (d), 128.1 (d), 112.6 (d), 112.4 (d), 78.7 (s), 78.5 (s), 55.2 (q).

2,3-Bis(4-methylphenyl)butane-2,3-diol (dl and meso) (**16**) [17]. ^1H -NMR (300 MHz, CDCl_3): δ (ppm) 7.19-7.06 (m, 16H), 2.36 (s, 6H), 2.35 (s, 6H), 1.56 (s, 6H), 1.48 (s, 6H); ^{13}C -NMR (75 MHz, CDCl_3): δ (ppm) 141.0 (s), 140.7 (s), 136.6 (s), 136.5 (s), 128.1 (d), 127.9 (d), 127.4 (d), 126.9 (d), 78.9 (s), 78.6 (s), 25.3 (q), 25.1 (q), 21.1 (q), 21.1 (q).

Methyl 2,3-dihydroxy-2-phenylpropanoate (**26**) [18]. ^1H -NMR (300 MHz, CDCl_3): δ (ppm) 7.60-7.55 (m, 2H), 7.41-7.29 (m, 3H), 4.26 (d, $J = 11.5$ Hz, 1H), 4.08 (brs, 1H, OH), 3.85 (s, 3H), 3.75 (d, $J = 11.5$ Hz, 1H), 2.53 (brs, 1H, OH); ^{13}C -NMR (75 MHz,

CDCl₃): δ (ppm) 174.3 (s), 138.2 (s), 128.6 (d), 128.5 (d), 125.5 (d), 79.9 (s), 68.4 (t), 53.7 (q).

Methyl 6,7-dihydroxy-6-methylheptanoate (**31**). ¹H-NMR (300 MHz, CDCl₃): δ (ppm) 3.62 (s, 3H), 3.37 (q, $J = 11.0$ Hz, 2H), 2.99 (s, 2H), 2.29 (t, $J = 7.4$ Hz, 2H), 1.64-1.53 (m, 2H), 1.49-1.40 (m, 2H), 1.39-1.26 (m, 2H), 1.10 (s, 3H); ¹³C-NMR (75 MHz, CDCl₃): δ (ppm) 174.4 (s), 72.9 (s), 69.6 (t), 51.6 (q), 38.2 (t), 33.9 (t), 25.5 (t), 23.3 (t), 23.1 (q); HR-MS: exact mass (ESI): m/z [M+Na]⁺ cal. for C₉H₁₈O₄: 213.1097 found: 213.1096.

4-Hydroxy-4-phenyldihydrofuran-2(3*H*)-one (**28**) [19]. ¹H-NMR (300 MHz, d₄-MeOH): δ (ppm) 7.56 (d, $J = 8.4$ Hz, 2H), 7.42 (t, $J = 7.4$ Hz, 2H), 7.35 (d, $J = 7.1$ Hz, 1H), 4.48 (dd, $J = 22.4, 10.0$ Hz,), 2.99 (dd, $J = 141.4, 17.1$ Hz); ¹³C (75 MHz, d₄-MeOH): δ (ppm) 177.7, 142.1, 129.3, 128.7, 126.2, 80.7, 78.8, 44.2.

5-Hydroxy-5-methyltetrahydro-2*H*-pyran-2-one (**29**). ¹H-NMR (300 MHz, CDCl₃): δ (ppm) 3.62 (dd, $J = 58.6, 12.1$ Hz, 2H), 3.16 (brs, 1H, OH), 2.81-2.53 (m, 2H,), 2.44-2.33 (m, 1H), 2.01-1.86 (m, 1H), 1.38 (s, 3H); ¹³C-NMR (75 MHz, CDCl₃): δ (ppm) 127.8 (s), 87.0 (s), 68.4 (t), 29.8 (t), 29.7 (t), 23.1 (q); HR-MS: exact mass (ESI): m/z [M+Na]⁺ cald. for C₆H₁₀O₃: 153.0522 found: 153.0522.

6-(Hydroxymethyl)-6-methyltetrahydro-2*H*-pyran-2-one (**30**) [20]. ¹H-NMR (300 MHz, CDCl₃): δ (ppm) 3.56 (dd, $J = 35.7, 11.9$ Hz, 2H), 2.59-2.36 (m, 3H), 2.05-1.85 (m, 3H), 1.66-1.59 (m, 1H), 1.34 (s, 3H); ¹³C-NMR (75 MHz, CDCl₃): δ (ppm) 171.6 (s), 84.6 (s), 69.4 (t), 29.7 (t), 28.7 (t), 23.5 (q), 16.9 (t); HR-MS: exact mass (ESI): m/z [M+Na]⁺ cald. for C₇H₁₂O₃: 167.0679 found: 167.0678.

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