Supporting information

Phase-Vanishing Reactions that Use Fluorous Media as a Phase Screen. Facile, Controlled Bromination of Alkenes by Dibromine and Dealkylation of Aromatic Ethers by Boron Tribromide

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General Information. ^1H NMR spectra were recorded with a JEOL JMN-500 (500 MHz) or a JEOL JMN-270 (270 MHz) spectrometer using CDCl_3 and acetone- d_6 as a solvent. Chemical shifts are reported in parts per million (δ) downfield from internal tetramethylsilane. ^{13}C NMR spectra were recorded with a JEOL JMN-270 (67.5 MHz) or a JEOL JMN-500 (125 MHz). Mass spectra were obtained on a Shimadzu GCMS-QP 5050A instrument. Infrared spectra were obtained on a JASCO FT/IR-5300 spectrometer. Absorptions are reported in reciprocal centimeters. All products are known compounds and were identified by spectral data with comparison of literature data.

General Procedure for Phase-Vanishing Bromination of Alkenes (Table 1, entry 1; Method A).

Bromine (2 mmol, 320 mg) was added slowly to FC-72 (1.5 mL) in a test tube (13 mm ϕ x 105 mm) with a septum by using a glass pipette and then cyclohexene (2 mmol, 164 mg) in hexane (1.5 mL) was added slowly, forming three layers. The test tube was covered with aluminum foil in order to shield the reaction from light and kept at room temperature. After 2 days, the bromine layer disappeared and the fluorous layer recovered transparency. The hexane layer was taken up with a pipette. Then, additional hexane (2 mL x 4) was placed on the residual FC-72 layer, followed by decanting off. The combined hexane layer was washed with aqueous 2% $\text{Na}_2\text{S}_2\text{O}_3$ (30 mL) and water (30 mL), dried over MgSO_4 , and concentrated. Purification by a short column chromatography on silica gel with hexane gave trans-1,2-dibromocyclohexane (1.62 mmol, 392 mg) in 81% yield.

General Procedure for Phase-Vanishing Bromination of Alkenes (Table 1, entry 2; Method B).

Bromine (2.1 mmol, 335 mg) was added slowly to FC-72 (1.5 mL) in a test tube (13 mm ϕ x 105 mm) with a septum by using a glass pipette and then cyclohexene (2 mmol, 164 mg) in hexane (1.5 mL) was added slowly, forming three layers. The test tube was covered with aluminum foil in order to shield the reaction from light and kept at room temperature. Gentle stirring of the bromine layer using a magnetic stirrer was carried out, taking care not to mix the three layers. After 4 h, the bromine layer disappeared. The hexane layer was taken up with a pipette. Then, additional hexane (2 mL x 4) was placed on the residual FC-72 layer, followed by decanting off. The combined hexane layer was washed with aqueous 2% $\text{Na}_2\text{S}_2\text{O}_3$ (30 mL) and water (30 mL), dried over MgSO_4 , and concentrated. Purification by a short column chromatography on silica gel with hexane gave trans-1,2-dibromocyclohexane (1.8 mmol, 435 mg) in 90% yield.

trans-1,2-Dibromocyclohexane (Table 1, entries 1-3). ^1H NMR (270MHz, CDCl_3)¹ δ 1.49-1.53 (m, 2H), 1.78-1.92 (m, 4H), 2.41-2.50 (m, 2H), 4.52 (s, 2H); ^{13}C NMR (67.5 MHz, CDCl_3)¹ δ 22.3, 31.8, 55.0; MS (EI, 70 eV), m/z (rel intensity)² 244 (M^- , 15), 242 (M^- , 23), 240 (M^- , 15), 163 ($[\text{M}-\text{Br}]^+$, 20), 161 ($[\text{M}-\text{Br}]^+$, 20), 119 (18), 81 (100); IR (neat)² 2920, 2850, 2350, 1440, 1425, 1360, 1335, 1260, 1175, 990, 960, 900, 860, 800, 730 cm^{-1} .

trans-1,2-Dibromocyclopentane (Table 1, entry 4). ^1H NMR (270MHz, CDCl_3)³ δ 1.95-2.06 (m, 2H), 2.11-2.22 (m, 2H), 2.59-2.73 (m, 2H), 4.57-4.60 (m, 2H); ^{13}C NMR (67.5 MHz, CDCl_3) δ 21.25, 33.95, 57.30; MS (EI, 70 eV), m/z (rel intensity) 149 ($[\text{M}-\text{Br}]^+$, 68), 147 ($[\text{M}-\text{Br}]^+$, 70), 68 (52), 67 (100); IR (neat) 2960, 1435, 1315, 1280, 1160, 1125, 885 cm^{-1} .

trans-1,2-Dibromocycloheptane (Table 1, entry 5). ^1H NMR (270MHz, CDCl_3) δ 1.56-1.72 (m,

4H), 1.80-1.92 (m, 2H), 2.00-2.12(m, 2H), 2.30-2.40 (m, 2H), 4.64-4.69 (m, 2H); ^{13}C NMR (67.5 MHz, CDCl_3) δ 23.24, 26.52, 33.21, 60.13; MS (EI, 70 eV), m/z (rel intensity) 177 ($[\text{M}-\text{Br}]^+$, 51), 175 ($[\text{M}-\text{Br}]^+$, 53), 96 (57), 95(100), 68 (44), 67 (73); IR (neat) 2920, 2850, 2350, 1448, 1360, 1210, 1160, 1115, 1000, 908, 820, 740, 700 cm^{-1} .

1,2-Dibromooctane (Table 1, entry 6). ^1H NMR (270MHz, CDCl_3)⁴ δ 0.86-0.92 (m, 3H), 1.30-1.59 (m, 8H), 1.75-1.85 (m, 1H), 2.07-2.16 (m, 1H), 3.63 (t, 1H, $J = 10\text{ Hz}$), 3.85 (dd, 1H, $J = 10, 4.6\text{ Hz}$), 4.12-4.22(m, 1H); ^{13}C NMR (67.5 MHz, CDCl_3)⁵ δ 14.01, 22.56, 26.27, 28.49, 31.57, 35.96, 36.24, 52.95; MS (EI, 70 eV), m/z (rel intensity)⁴ 193 ($[\text{M}-\text{Br}]^+$, 47), 191 ($[\text{M}-\text{Br}]^+$, 48), 151 (47), 149 (52), 135 (47), 111 (76), 109 (24), 83 (37), 69 (100); IR (neat) 2910, 2850, 1460, 1140, 900, 730 cm^{-1} .

2, 3-Dibromooctane (Table 1, entry 7). Products were obtained as diastereomer mixture. ^1H NMR (500MHz, CDCl_3) δ 0.89 (t, 3.0H, $J = 6.4\text{ Hz}$), 1.25-1.50 (m, 5.0H), 1.55-1.63 (m, 1H), 1.75 (d, 2.0H, $J = 6.4\text{ Hz}$, (2R*3R*)), 1.79 (m, 0.6H), 1.84 (d, 1.0H, $J = 6.9\text{ Hz}$, (2R*3S*)), 1.9 (m, 0.4H), 2.05 (m, 1.0H), 4.06-4.12 (m, 0.33H, (2R*3R*)), 4.16-4.24 (m, 1.0H), 4.38-4.46 (m, 0.67H, (2R*3S*)); ^{13}C NMR (125 MHz, CDCl_3) δ 14.07, 21.61, 22.53, 25.12, 26.73, 27.53, 31.02, 31.09, 33.95, 37.16, 52.43, 60.15, 61.73; MS (EI, 70 eV), m/z (rel intensity) 2R*3S* isomer, 193 ($[\text{M}-\text{Br}]^+$, 16), 191 ($[\text{M}-\text{Br}]^+$, 16), 111 (83), 69 (100); 2R*3R* isomer, 193 ($[\text{M}-\text{Br}]^+$, 9), 191 ($[\text{M}-\text{Br}]^+$, 9), 111 (76), 69 (100); IR (neat) a mixture of two diastereomers; 2960, 2930, 2860, 1455, 1380, 1200, 1150, 1062, 987, 730 cm^{-1} .

The stereochemistry of the product was assigned on the basis of the authentic sample. The authentic 2,3-dibromooctane which was prepared from cis-2-octene by a previous bromination method⁶ has 2R*3S* configuration.⁷ The diastereomer ratio (2R*3R*/2R*3S*) was determined by relative integration of the following methine proton signals in the proton NMR: δ 4.06-4.12 (2R*3R*) and 4.38-4.46 (2R*3S*).

2, 3-Dibromooctane (Table 1, entry 8). Products were obtained as diastereomer mixture. ^1H NMR (500MHz, CDCl_3) δ 0.91 (t, 3.0H, $J = 6.87\text{ Hz}$), 1.24-1.50 (m, 5.0H), 1.56-1.66 (m, 1.0H), 1.77 (d, 0.2H, $J = 6.87\text{ Hz}$, (2R*3S*)), 1.86 (d, 2.8H, $J = 6.87\text{ Hz}$, (2R*3R*)), 1.90 (m, 1.0H), 2.1 (m, 1.0H), 4.08-4.14 (m, 0.93H, (2R*3R*)), 4.20-4.28 (m, 1.0H), 4.42-4.48 (m, 0.07H, (2R*3S*)); ^{13}C NMR (125 MHz, CDCl_3) δ 13.96, 21.47, 22.40, 25.01, 26.59, 27.41, 30.98, 33.80, 37.05, 52.31, 61.62; MS (EI, 70 eV), m/z (rel intensity) 2R*3R* isomer, 193 ($[\text{M}-\text{Br}]^+$, 6), 191 ($[\text{M}-\text{Br}]^+$, 6), 111 (61), 69 (100); 2R*3S* isomer, 193 ($[\text{M}-\text{Br}]^+$, 3), 191 ($[\text{M}-\text{Br}]^+$, 3), 111 (36), 69 (100); IR (neat) a mixture of two diastereomers; 2930, 2860, 1452, 1380, 1320, 1271, 1199, 1153, 987, 877, 847, 762, 729 cm^{-1} .

The stereochemistry of the product was assigned on the basis of the authentic sample. The authentic 2,3-dibromooctane which was prepared from cis-2-octene by a previous bromination method⁶ has 2R*3S* configuration.⁷ The diastereomer ratio (2R*3R*/2R*3S*) was determined by relative integration of the following methine proton signals in the proton NMR: δ 4.08-4.14 (2R*3R*) and 4.42-4.48 (2R*3S*).

(1,2-Dibromoethyl)benzene (Table 1, entry 9). ^1H NMR (270MHz, CDCl_3)⁸ δ 3.98-4.11 (m, 2H) 5.14 (dd, 1H, $J = 10.22, 5.60\text{ Hz}$), 7.36-7.41 (m, 5H); ^{13}C NMR (67.5 MHz, CDCl_3)⁸ δ 35.07, 50.89, 127.53, 128.74, 129.06, 138.46; MS (EI, 70 eV), m/z (rel intensity) 266 (18), 264 (M^+ , 29), 262 (16), 183 (58), 169 (13), 104 (100), 91 (23), 77 (45); IR (KBr)⁹ 3110, 1450, 1220, 1195, 1150, 1130, 900, 760, 680, 580 cm^{-1} .

Ethyl 2,3-dibromopropionate (Table 1, entry 10). ^1H NMR (270MHz, CDCl_3)¹⁰ δ 1.33 (t, , 3H, $J = 7.0\text{ Hz}$), 3.67 (dd, 1H, $J = 4.6, 4.3\text{ Hz}$), 3.93 (t, 1H, $J = 9.9\text{ Hz}$), 4.30 (q, 3H, $J = 7.0\text{ Hz}$), 4.43 (dd, 1H, $J = 11.2, 4.3\text{ Hz}$); ^{13}C NMR (67.5 MHz, CDCl_3)¹⁰ δ 13.96, 29.76, 41.16, 62.32, 166.71; MS (EI, 70 eV), m/z (rel intensity)¹¹ 232 ($[\text{M}-\text{CH}_2\text{CH}_3]^+$, 43), 215 (48), 181 ($[\text{M}-\text{Br}]^+$, 85), 179 ($[\text{M}-\text{Br}]^+$, 84), 151 (33), 135 (19), 106 (96), 73 (23), 55(100); IR (neat) 2970, 1740, 1410, 1365, 1340, 1240, 1200, 1140, 1115, 940, 840, 780 cm^{-1} .

**Comparison Study for Table 2:
Procedure with H_2O as a Phase Screen.**

Bromine (1.91 mmol, 307 mg) was added slowly to H₂O (1.5 mL) by using a glass pipette in a test tube (13 mm ϕ x 105 mm) with a septum and then cyclohexene (3.92 mmol, 322 mg) in hexane (1.5 mL) was added slowly, forming three layers. The test tube was covered with aluminum foil in order to shield the reaction from light and kept at room temperature. After 2 days, bromine layer remained at the bottom. The hexane layer was taken up with a pipette. Additional hexane (2 mL x 4) was placed on the residual H₂O layer, followed by decanting off. The combined hexane layer was washed with aqueous 2% Na₂S₂O₃ (30 mL) and water (30 mL), dried over MgSO₄, and concentrated. Purification by a short column chromatography on silica gel with hexane gave trans-1,2-dibromocyclohexane (0.065 mmol, 15.8 mg) in 3% yield.

Procedure with CH₃CN as a Phase Screen.

Bromine (2.48 mmol, 397 mg) was added slowly to CH₃CN (1.5 mL) by using a glass pipette in a test tube (13 mm ϕ x 105 mm) with a septum and then cyclohexene (4.96 mmol, 407 mg) in hexane (1.5 mL) was added slowly, forming three layers. The test tube was covered with aluminum foil in order to shield the reaction from light and kept at room temperature. After 2 days, bromine layer disappeared. The hexane layer was taken up with a pipette. Additional hexane (2 mL x 4) was placed on the residual CH₃CN layer, followed by decanting off. The combined hexane layer was washed with aqueous 2% Na₂S₂O₃ (30 mL) and water (30 mL), dried over MgSO₄, and concentrated. Purification by a short column chromatography on silica gel with hexane gave trans-1,2-dibromocyclohexane (0.81 mmol, 195 mg) in 32% yield. The CH₃CN layer was washed with aqueous 2% Na₂S₂O₃ (30 mL) and water (30 mL), dried over MgSO₄, and concentrated. Purification by a short column chromatography on silica gel with hexane gave trans-1,2-dibromocyclohexane (0.92 mmol, 222 mg) in 37% yield.

General Procedure for Phase-Vanishing Demethylation of Aromatic Ethers by Boron Tribromide (Scheme 2).

Boron tribromide (2.3 mmol, 583 mg) was added slowly to FC-72 (3.0 mL) in a test tube (14.4 mm ϕ x 130 mm) with a septum by using a glass pipette and then 1-methoxynaphthalene (2.3 mmol, 368 mg) in dichloromethane (3.0 mL) was added, forming three layers. The solution was stirred slowly without mixing three phases and kept overnight at room temperature. The bottom boron tribromide layer disappeared. The dichloromethane layer was taken up with a pipette. Additional dichloromethane (2 mL x 4) was placed on the residual FC-72 layer, followed by decanting off. The combined dichloromethane layer was shaken with water (20 mL) to hydrolyze boron complexes contained and dried over MgSO₄. After evaporation, purification by a short column chromatography on silica gel with (benzene/AcOEt = 1/1) gave 1-naphthol (2.21 mmol, 320 mg) in 94% yield.

Phenol (Scheme 2). ¹H NMR (270MHz, CDCl₃)¹² δ 6.83 (d, 2H, J = 7.7 Hz), 6.92 (t, 1H, J = 1.3 Hz), 7.20-7.28 (m, 2H); IR (KBr)¹³ 3400, 2900, 2850, 1600, 1460, 1380, 1220, 740, 680 cm⁻¹.

1-Naphthol (Scheme 2). ¹H NMR (270MHz, CDCl₃)¹⁴ δ 6.81 (d, 1H, J = 6.6 Hz), 7.29 (d, 1H, J = 7.6 Hz), 7.33-7.52 (m, 3H), 7.78-7.84 (m, 1H), 8.15-8.19 (m, 1H); IR (KBr)¹⁵ 3310, 1599, 1518, 1458, 1387, 1271, 1240, 1084, 1043, 875, 790, 766, 710 cm⁻¹.

Resorcinol (Scheme 2). ¹H NMR (270MHz, acetone-d₆)¹⁶ δ 6.30 (m, 3 H), 6.95 (t, 1H, J = 7.9 Hz), 8.17 (s, 1H); IR (KBr)¹⁷ 3258, 1608, 1491, 1381, 1298, 1151, 964, 842, 773, 740, 680 cm⁻¹.

4-Phenylphenol (Scheme 2). ¹H NMR (270MHz, CDCl₃)¹⁸ δ 6.90 (d, 2H, J = 8.6 Hz), 7.31 (m, 1H), 7.40-7.55 (m, 6H); IR (KBr)¹⁹ 3422, 1599, 1523, 1487, 1462, 1425, 1377, 1259, 1202, 833, 758 cm⁻¹.

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