Supporting information

A Self-Assembled Molecular Cage for Substrate-Selective Epoxidation Reactions in Aqueous Media.


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General information

All reactions involving air- or moisture sensitive compounds were carried out under argon using standard Schlenk and vacuum line techniques. Dimethylformamide (DMF) was purchased from Aldrich and was used without further purification before use. Acetone-d₆ was purchased from Euriso-Top without purification before use. Deionized water was used without further purification. Styrene, 4-methylstyrene, 3-methylstyrene, α-methylstyrene and cis-β-methylstyrene were filtered over basic alumina prior to use. All other chemicals were purchased from Alfa Aesar, Acros, Fluka and Aldrich without purification before use. ¹H NMR and ¹³C NMR spectra were measured on Mercury Varian 300 MHz, Bruker 400 MHz or Bruker 500 MHz spectrometer. ¹H NMR chemical shifts are given in ppm, and were calibrated by using the residual undeuterated solvent as internal reference (CHCl₃ (7.26 ppm), Acetone-d₆ (2.05 ppm)). ¹³C NMR chemical shifts were recorded in ppm from the solvent peak employed as internal reference (CDCl₃ (77.0 ppm)). IR spectra were measured on a Bruker Alpha-P instrument as neat film. UV-vis spectra were measured on a Hewlett Packard 8453. MS measurements were performed on a UHR-ToF Bruker Daltonik (Bremen, Germany) maXis, which was coupled to a Bruker cryospray unit, an ESI-ToF MS capable of resolution of at least 40.000 FWHM. Detection was in positive-ion mode and the source voltage was 5 kV. The flow rates were 500 µL/hour. The drying gas (N₂), was held at - 35 °C and the spray gas was held at - 40 °C. The machine was calibrated prior to every experiment via direct infusion of the Agilent ESI-ToF low concentration tuning mixture, which provided an m/z range of singly charged peaks up to 2700 Da in both ion modes.
Experiments

Compounds 1(1) 2-Zn@1, (1) 2-Co@1, (1) 2-MnCl, (2) 6, (3) (3) an 25(4) were synthesized as described in literature.

1. Synthesis of supramolecular host-guest complex 2-MnCl@1.

To a flame dried schlenk flask were added cage 1 (481.7 mg, 36.1 μmol) and 2-MnCl (25.6 mg, 36.2 μmol). Deoxygenated DMF (10.0 mL) was added under an N₂ atmosphere and the resulting solution was degassed three times by freeze-pump-thaw and subsequently heated to 70 °C for 16 h. After cooling the reaction to room temperature diethylether (100 mL) was added and the precipitate was collected by filtration. The purple residue was washed with diethylether (2 x 50 mL) and collected with acetone (200 mL). Removal of the solvents resulted in a purple powder (466.6 mg, 33.2 μmol, 92%). Exact mass ESI-MS see table S1, figure S1 and figure S2. 1H-NMR spectrum see figure S3

Table S1: Exact mass ESI-MS signals of host-guest complex 2-MnCl@1.
Figure S1: Cryo UHR ESI-TOF mass spectrum of host-guest complex \([2-\text{MnCl@1}]\) with a spray temperature of -40 °C and a dry gas temperature of -35 °C.

Figure S2: Cryo UHR ESI-TOF mass spectrum of \([2-\text{MnCl@1}]^{13+}\) \([(\text{C}_8\text{H}_8\text{N}_4\text{Zn})_6\text{Fe}_8(\text{C}_4\text{O}_4\text{N}_8\text{MnCl})_3(\text{CF}_3\text{SO}_3)_3]^{13+}\) (top) and simulated isotopic distribution (below) with a spray temperature of -40 °C and a dry gas temperature of -35 °C.
2. General procedure for epoxidation reactions

Epoxidation reactions were performed as follows: Substrate (0.3 mmol) and catalyst (0.5 µmol) were mixed in a 10 mL vial and solvent was added (2 mL). After addition of the oxidant (0.4 mmol) the mixture was stirred at 600 rpm for 20 minutes under air. Products were extracted with n-pentane (3 x 10 mL), dried over MgSO₄ and filtered. Solvents were removed under reduced pressure (40 °C, 500 mbar). Triphenylmethane (60 µmol) was added as a reference and the products were quantified by ¹H-NMR spectroscopy (CDCl₃ was used as the solvent for analysis). An example of a spectrum used for analysis with the assignment of the signals to starting material, products and remaining solvents is depicted in Figure S4.

Figure S4: ¹H-NMR spectrum of a reaction mixture after work-up with the assignment of the signals: a) styrene (3), b) triphenylmethane, c) Styrene oxide (4), d) phenylacetaldehyde (5), e) iodobenzene, f) n-pentane (used for extraction), g) water, h) acetone (used for cleaning of flasks and nmr tubes).
3. Monitoring the epoxidation reaction over time

\[ \text{2-MnCl@1 (15.0 mg; 1.1 \mu mol), 3 (63.3 mg; 0.661 mmol), acetonitrile (2.0 mL), water (2.0 mL) and S1 (233 mg; 0.72 mmol; 1,2 equivalents) were handled according to the generalized epoxidation procedure. After 2, 5, 10, 15, 20, 25 and 30 minutes a sample (0.25 mL) was taken from the reaction mixture and added to n-pentane (10 mL). The solution was dried over MgSO}_4, filtered and solvent removed up to 500 mbar at 40 °C. triphenylmethane (25 \mu mol) was added as standard and the reaction mixture was analyzed by \textsuperscript{1}H-NMR (CDCl}_3). The results from two separate experiments were averaged to give the depicted turnover numbers towards epoxide 4 for both encapsulated 2-MnCl@1 and 2-MnCl (Table S2 and representative \textsuperscript{1}H-NMR spectra in Figure S5).} \]

Table S2: Turnover numbers towards the epoxide in styrene epoxidation.

<table>
<thead>
<tr>
<th>Time</th>
<th>2-MnCl@1 (TON)</th>
<th>2-MnCl (TON)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>34</td>
<td>48</td>
</tr>
<tr>
<td>10</td>
<td>116</td>
<td>64</td>
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<tr>
<td>15</td>
<td>169</td>
<td>78</td>
</tr>
<tr>
<td>20</td>
<td>203</td>
<td>111</td>
</tr>
<tr>
<td>25</td>
<td>243</td>
<td>94</td>
</tr>
<tr>
<td>30</td>
<td>238</td>
<td>92</td>
</tr>
</tbody>
</table>

\*The sample was taken after 3 minutes instead of 2 minutes.

Figure S5: Stacked \textsuperscript{1}H-NMR spectra of epoxidation of styrene with 2-MnCl@1. a) styrene (3), b) triphenylmethane, c) styrene oxide (4), d) phenylacetaldehyde (5)
4. Synthesis of styrene oxide (4) with iodosylbenzene (S2) as oxidant and catalyst 2-MnCl$_2$I

2-MnCl$_2$I (6.8 mg; 0.48 µmol), 3 (28.3 mg; 0.27 mmol), acetonitrile (2.0 mL) and S2 (79.7 mg; 0.36 mmol; 1.3 equivalents) were handled according to the generalized epoxidation procedure to give 4 (47 µmol; 17%; TON = 98) and 5 (15.7 µmol; 6%; TON = 33) (1H-NMR spectrum in Figure S6). Repeating the reaction with a 1:1 acetonitrile/water mixture resulted in product 4 (112.8 µmol; 37%; TON = 235) and product 5 (47.6 µmol; 16%; TON = 99) (1H-NMR spectrum in Figure S7).

Figure S6: 1H-NMR spectrum of epoxidation of styrene in acetonitrile with iodosylbenzene as oxidant: a) styrene (3), b) triphenylmethane, c) styrene oxide (4), d) phenylacetaldehyde (5), e) iodosylbenzene, f) n-pentane, g) water, h) acetonitrile.

Figure S7: 1H-NMR spectrum of a reaction mixture after work-up with the assignment of the signals: a) styrene (3), b) triphenylmethane, c) Styrene oxide (4), d) phenylacetaldehyde (5), e) iodosylbenzene, f) n-pentane (used for extraction), g) water, h) acetone (used for cleaning of flasks and nmr tubes).
5. Synthesis of styrene oxide (4) with 2-MnCl and 4 equivalents ZnTPP

2-MnCl (0.5 mg; 0.71 µmol) and zinc tetraphenylporphyrin (ZnTPP; 2.3 mg; 3.4 µmol; 4.8 equivalents) were dissolved in dichloromethane (2.0 mL) and stirred for 15 minutes. Solvent was removed under vacuum and 3 (27.9 mg; 0.27 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (115 mg; 0.36 mmol; 1.3 equivalents) were added. After 20 minutes of reaction products were extracted with pentane (3 x 10 mL). The combined organic fractions were dried over MgSO\textsubscript{4}, filtered and solvent removed under reduced pressure (40 ºC, 500 mbar). Triphenylmethane (13.3 mg; 54.5 µmol) was added as a reference. Products were quantified by \textsuperscript{1}H-NMR (CDCl\textsubscript{3} was used as solvent) spectroscopy to give styrene oxide (4) (109.3 µmol; 41%; TON = 154) and phenylacetaldehyde (5) (57.1 µmol; 21%; TON = 108) (\textsuperscript{1}H-NMR spectrum in Figure S8).

![Figure S8: \textsuperscript{1}H-NMR spectrum of epoxidation of styrene with 2-MnCl with the assignment of the signals: a) styrene (3), b) triphenylmethane, c) Styrene oxide (4), d) phenylacetaldehyde (5), e) iodobenzene, f) n-pentane, g) water, h) acetone and acetonitrile, i) benzaldehyde (due to oxidative cleavage).](image)

6. Synthesis of styrene oxide (4) with [MnTPP][Cl] (6) and 4 equivalents pyridine

A stock solution of pyridine in water (2.4 mM; 50 mL) was prepared. 6 (0.4 mg; 0.57 µmol), 3 (27.4 mg; 0.26 mmol), acetonitrile (1.0 mL), stock solution (1.0 mL) and S1 (116 mg; 0.36 mmol; 1.4 equivalents) were handled according to the generalized epoxidation procedure to give styrene oxide (4) (16 µmol; 6%; TON = 28) and phenylacetaldehyde (5) (5.6 µmol; 2%; TON = 10) (\textsuperscript{1}H-NMR spectrum in Figure S9).

![Figure S9: \textsuperscript{1}H-NMR spectrum of epoxidation of styrene with 6 in presence of 4 equivalents of pyridine. Assignment of the signals: a) styrene (3), b) triphenylmethane, c) Styrene oxide (4), d) phenylacetaldehyde (5), e) iodobenzene, f) n-pentane, g) water, h) acetone.](image)
7. Competition experiment between Styrene (3) and 4-benzhydrylstyrene (8) with Mn(TPP)Cl (6)

\[
\text{Mn(TPP)Cl (6, 0.4 mg; 0.57 µmol), 3 (30.3 mg; 0.29 mmol), 8 (80.2 mg; 0.30 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (94.2 mg; 0.29 mmol) were handled according to the generalized epoxidation procedure to give 9 and 4. The ratio between the two products was analyzed by } ^1\text{H-NMR (300 MHZ, CDCl}_3) \text{ for the epoxide C-H signals which resulted in a ratio of 1,59:1 (61:39)( } ^1\text{H-NMR spectrum is depicted in Figure S10). Anisole was added to the sample (16.6 mg; 0.15 mmol) as external standard to determine the total epoxide yield (36.8 µmol; TTON = 65).}
\]

\[
\begin{align*}
\text{Figure S10: } ^1\text{H-NMR spectrum of the product ratio between 4-benzhydrylstyrene (8) and styrene (3). The assigned peaks correspond to: a) styrenes 8 and 3, b) C-H signal of 8 and 9, c) epoxides 9 (c1) and 4 (c2), d) aldehydes 5 (d2) and (4-benzhydrylphenyl)acetaldehyde (d1).}
\end{align*}
\]

8. Competition experiment between Styrene (3) and 4-benzhydrylstyrene (8) with 2-MnCl@1

\[
\text{2-MnCl@1 (7.3 mg; 0.52 µmol), 3 (27.9 mg; 0.27 mmol), 8 (74.1 mg; 0.27 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (93.2 mg; 0.29 mmol) were handled according to the generalized epoxidation procedure to give 9 and 4. The ratio between the two products was analyzed by } ^1\text{H-NMR (300 MHZ, CDCl}_3) \text{ for the epoxide C-H signals which resulted in a ratio of 0.56:1 (36:64)( } ^1\text{H-NMR spectrum is depicted in Figure S11). Anisole was added to the sample (8.9 mg; 82.3 µmol) as external standard to determine the total epoxide yield (106 µmol; TTON = 204).}
\]
9. Competition experiment between Styrene (3) and 4-benzhydrylstyrene (8) with 2-MnCl

\[
\begin{align*}
8 & \quad + \quad 3 \\
\text{2-MnCl (0.5 mg; 0.71 µmol), 3 (31.8 mg; 0.31 mmol), 8 (80.5 mg; 0.30 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (96.0 mg; 0.30 mmol) were handled according to the generalized epoxidation procedure to give 9 and 4.} \\
\text{The ratio between the two products was analyzed by } ^1H-\text{NMR (300 MHz, CDCl}_3) \text{ for the epoxide C-H signals which resulted in a ratio of 0.27:1 (21:79).} \\
\text{Anisole was added to the sample (8.6 mg; 80 µmol) as external standard to determine the total epoxide yield (47.7 µmol; TTON = 67).}
\end{align*}
\]

Figure S12: $^1H$-NMR spectrum of the product ratio between 4-benzhydrylstyrene (8) and styrene (3). The assigned peaks correspond to: a) styrenes 8 and 3, b) C-H signal of 8 and 9, c) epoxides 9 (c1) and 4 (c2), d) aldehydes 5 (d2) and (4-benzhydrylphenyl)acetaldehyde (d1).
10. Competition experiment between Styrene (3) and 3,4-di-tert-butylstyrene (11) with Mn(TPP)Cl (6)

$$
\begin{align*}
\text{3} & + \text{11} \\
\text{6 (0.2 mol%),} & \text{Ph(OAc)$_2$ (1.0 equiv)} \\
\text{H$_2$O/CH$_3$CN 1:1} & \text{rt}, 20 \text{ min} \\
\rightarrow & \text{4} + \text{10}
\end{align*}
$$

6 (0.4 mg; 0.57 µmol), 3 (31.0 mg; 0.30 mmol), 11 (68.3 mg; 0.32 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (96.2 mg; 0.30 mmol) were handled according to the generalized epoxidation procedure to give 10 and 4. Triphenylmethane was added to the sample (7.3 mg; 30 µmol) as external standard and the ratio between the two products was analyzed by $^1$H-NMR (300 MHz, CDCl$_3$) for the epoxide C-H signals which resulted in a ratio of 1.64:1 (62:38) and total epoxide yield (23.3 µmol; TTON = 41) ($^1$H-NMR spectrum is depicted in Figure S13).

![Figure S13: $^1$H-NMR spectrum of the product ratio between 3,5-di-tert-butylstyrene (11) and styrene (3). The assigned peaks correspond to: a) styrenes 11 and 3, b) triphenylmethane, c) epoxides 10 (c1) and 4 (c2), d) aldehydes 5 and (2,5-di-tert-butylphenyl)acetaldehyde.](image)

11. Competition experiment between Styrene (3) and 3,4-di-tert-butylstyrene (11) with 2-MnCl@1

$$
\begin{align*}
\text{3} & + \text{11} \\
\text{2-MnCl@1 (0.2 mol%),} & \text{Ph(OAc)$_2$ (1.0 equiv)} \\
\text{H$_2$O/CH$_3$CN 1:1} & \text{rt}, 20 \text{ min} \\
\rightarrow & \text{4} + \text{10}
\end{align*}
$$

2-MnCl@1 (7.0 mg; 0.50 µmol), 3 (28.7 mg; 0.28 mmol), 11 (61.6 mg; 0.28 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (94.6 mg; 0.29 mmol) were handled according to the generalized epoxidation procedure to give 10 and 4. Triphenylmethane was added to the sample (9.8 mg; 40.1 µmol) as external standard and the ratio between the two products was analyzed by $^1$H-NMR (300 MHz, CDCl$_3$) for the epoxide C-H signals which resulted in a ratio of 0.51:1 (66:34) and total epoxide yield (87.8 µmol; TTON = 176) ($^1$H-NMR spectrum is depicted in Figure S14).
Figure S14: ¹H-NMR spectrum of the product ratio between 3,5-di-tert-butylstyrene (11) and styrene (3). The assigned peaks correspond to: a) styrenes 11 and 3, b) triphenylmethane, c) epoxides 10 (c1) and 4 (c2), d) aldehydes 5 and (2,5-di-tert-butylphenyl)acetaldehyde.

12. Competition experiment between Styrene (3) and 3,4-di-tert-butylstyrene (11) with 2-MnCl

![Chemical reaction diagram]

2-MnCl (0.4 mg; 0.57 µmol), 3 (36.2 mg; 0.35 mmol), 11 (67.2 mg; 0.31 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (98.3 mg; 0.31 mmol) were handled according to the generalized epoxidation procedure to give 10 and 4. Triphenylmethane was added to the sample (9.1 mg; 37.2 µmol) as external standard and the ratio between the two products was analyzed by ¹H-NMR (300 MHZ, CDCl₃) for the epoxide C-H signals which resulted in a ratio of 0.27:1 (21:79) and total epoxide yield (39.4 µmol; TTON = 69) (¹H-NMR spectrum is depicted in Figure S15).

Figure S15: ¹H-NMR spectrum of the product ratio between 3,5-di-tert-butylstyrene (11) and styrene (3). The assigned peaks correspond to: a) styrenes 11 and 3, b) triphenylmethane, c) epoxides 10 (c1) and 4 (c2), d) aldehydes 5 and (2,5-di-tert-butylphenyl)acetaldehyde.
13. Competition experiment between Styrene (3) and 3,4-di-tert-butylstyrene (11) with varying catalyst concentration

\[ \text{Catalyst: MnCl}_2 \]

3, 26, catalyst (see Table S3), S1, acetonitrile and water were handled as for the previous experiment (10) although the amount of the catalyst was varied. The results are summarized in Table S1 and representative 1H-NMR spectra are depicted in Figure S16.

**Table S3: Catalyst concentration dependence on size-selectivity**

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>Catalyst loading</th>
<th>Ratio 4:24</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-MnCl</td>
<td>0.03 mol%</td>
<td>71:29</td>
</tr>
<tr>
<td>2-MnCl</td>
<td>0.2 mol%</td>
<td>79:21</td>
</tr>
<tr>
<td>2-MnCl</td>
<td>1.0 mol%</td>
<td>82:18</td>
</tr>
<tr>
<td>2-MnCl@1</td>
<td>0.03 mol%</td>
<td>68:32</td>
</tr>
<tr>
<td>2-MnCl@1</td>
<td>0.2 mol%</td>
<td>66:34</td>
</tr>
</tbody>
</table>

**Figure S16:** 1H-NMR spectrum of the product ratio between 3,5-di-tert-butylstyrene (11) and styrene (3): left: 2-MnCl (a) 1.0 mol%, (b) 0.2 mol%, (c) 0.03 mol%, right: 2-MnCl@1 (d) 0.2 mol%, (e) 0.02 mol%.
14. Synthesis of 2-(m-tolyl)oxirane (12)

\[
\text{S3} + \text{S1} \xrightarrow{2\text{-MnCl@1 (0.2 mol\%)}} \text{H}_2\text{O/CH}_2\text{CN} 1:1 \text{ rt, 20 min} \rightarrow \text{12}
\]

2-MnCl@1 (6.8 mg; 0.48 µmol), S3 (34.4 mg; 0.27 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (108 mg; 0.34 mmol; 1.2 equivalents) were handled according to the generalized epoxidation procedure to give 12 (141 µmol; 48%; TON = 299) (1\textsuperscript{H}-NMR spectrum is depicted in Figure S17). Data for epoxide 12 were in agreement with published data.\([5]\)

Figure S17: \textsuperscript{1}H-NMR spectrum of epoxidation of 3-methylstyrene with 2-MnCl@1 with the assignment of the signals: a) 3-methylstyrene (S3), b) triphenylmethane, c) 2-(m-tolyl)oxirane (12), d) 2-(m-tolyl)acetaldehyde, e) iodobenzene, f) n-pentane, g) water.

15. Synthesis of 2-(p-tolyl)oxirane (13)

\[
\text{S4} + \text{S1} \xrightarrow{2\text{-MnCl@1 (0.2 mol\%)}} \text{H}_2\text{O/CH}_2\text{CN} 1:1 \text{ rt, 20 min} \rightarrow \text{13}
\]

2-MnCl@1 (7.1 mg; 0.51 µmol), S4 (32.4 mg; 0.27 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (110 mg; 0.34 mmol; 1.3 equivalents) were handled according to the generalized epoxidation procedure to give 13 (78 µmol; 28%; TON = 153) (1\textsuperscript{H}-NMR spectrum is depicted in Figure S18). Data for epoxide 13 were in agreement with published data.\([6]\)

Figure S18: \textsuperscript{1}H-NMR spectrum of epoxidation of 4-methylstyrene with 2-MnCl@1 with the assignment of the signals: a) 4-methylstyrene (S4), b) triphenylmethane, c) 2-(p-tolyl)oxirane (13), d) 2-(p-tolyl)acetaldehyde, e) iodobenzene, f) n-pentane, g) water, h) DCM, i) 4-methylbenzaldehyde.
16. Synthesis of 2-(naphthalene-2-yl)oxirane (14)

\[
\text{2-MnCl@1 (6.8 mg; 0.48 µmol), S5 (42.1 mg; 0.27 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (116 mg; 0.36 mmol; 1,3 equivalents) were handled according to the generalized epoxidation procedure to give 14 (78 µmol; 29%; TON = 163)(^1H-NMR spectrum is depicted in Figure S19). Data for epoxide 14 were in agreement with published data.}[^7]
\]

**Figure S19:** ^1H-NMR spectrum of epoxidation of 2-vinylnaphthalene with 2-MnCl@1 with the assignment of the signals: a) 2-vinylnaphthalene (S5), b) triphenylmethane, c) 2-(naphthalene-2-yl)oxirane (14), d) 2-(naphthalene-2-yl)acetaldehyde, e) acetonitrile, f) n-pentane, g) water.

17. Synthesis of 2-(4-fluorophenyl)oxirane (15)

\[
\text{2-MnCl@1 (6.9 mg; 0.49 µmol), S6 (40.5 mg; 0.33 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (124 mg; 0.39 mmol; 1,2 equivalents) were handled according to the generalized epoxidation procedure to give 15 (106 µmol; 32%; TON = 216)(^1H-NMR spectrum is depicted in Figure S20). Data for epoxide 15 were in agreement with published data.}[^8]
\]

**Figure S20:** ^1H-NMR spectrum of epoxidation of 4-fluorostyrene with 2-MnCl@1 with the assignment of the signals: a) 4-fluorostyrene (S6), b) triphenylmethane, c) 2-(4-fluorophenyl)oxirane (15), d) 2-(4-fluorophenyl)acetaldehyde, e) iodobenzene, f) n-pentane, g) water, h) acetonitrile, i) acetone.
18. Synthesis of 2-(4-methoxyphenyl)acetaldehyde (S8) and 4-methoxybenzaldehyde (S9)

\[ \begin{array}{c}
\text{S7} \quad \text{S1} \quad \text{2-MnCl@1 (0.2 mol\%)} \\
\text{H}_2\text{O/CH}_3\text{CN 1:1} \quad \text{rt, 20 min} \\
\text{S8} \quad \text{S9}
\end{array} \]

2-MnCl@1 (7.0 mg; 0.50 µmol), S7 (43.6 mg; 0.31 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (129 mg; 0.40 mmol; 1.3 equivalents) were handled according to the generalized epoxidation procedure to give S8 (59 µmol; 19%; TON = 118) and S9 (27 µmol; 9%; 53 TON) (1H-NMR spectrum is depicted in Figure S21). Data for aldehydes S8\(^9\) and S9\(^{10}\) were in agreement with published data.

![1H-NMR spectrum of epoxidation of 4-methoxystyrene (S7) with 2-MnCl@1 with the assignment of the signals: a) 2-(4-methoxyphenyl)acetaldehyde (S8), b) triphenylmethane, c) 4-methoxybenzaldehyde (S9), d) iodobenzene, e) acetonitrile, f) n-pentane, g) water.](image)


\[ \begin{array}{c}
\text{S10} \quad \text{S1} \quad \text{2-MnCl@1 (0.2 mol\%)} \\
\text{H}_2\text{O/CH}_3\text{CN 1:1} \quad \text{rt, 20 min} \\
\text{17}
\end{array} \]

2-MnCl@1 (7.2 mg; 0.52 µmol), S10 (47.8 mg; 0.27 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (110 mg; 0.34 mmol; 1.3 equivalents) were handled according to the generalized epoxidation procedure to give 17 (18 µmol; 7%; TON = 34) (1H-NMR spectrum is depicted in Figure S22). Data for epoxide 17 were in agreement with published data.\(^{11}\)

![1H-NMR spectrum of epoxidation of trans-stilbene (S10) with 2-MnCl@1 with the assignment of the signals: a) triphenylmethane, b) trans-stilbene oxide (17) c) acetone, d) acetonitrile, e) water, f) n-pentane.](image)
20. Synthesis of cis-stilbene oxide (18)

\[
\text{S11} + \text{S1} \xrightarrow{2-\text{MnCl}@1 (0.2 mol\%)} \text{H}_2\text{O}/\text{CH}_3\text{CN 1:1, rt, 20 min}}
\]

2-MnCl@1 (7.2 mg; 0.51 µmol), S11 (53.4 mg; 0.30 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (122 mg; 0.38 mmol; 1,3 equivalents) were handled according to the generalized epoxidation procedure to give 18 (138 µmol; 47%; TON = 271)(\(^1\)H-NMR spectrum is depicted in Figure S23). Data for epoxide 18 were in agreement with published data.\(^{[12]}\)

Figure S23: \(^1\)H-NMR spectrum of epoxidation of cis-stilbene (S11) with 2-MnCl@1 with the assignment of the signals: a) cis-stilbene, b) triphenylmethane, c) cis-stilbene oxide (18) d) trans-stilbene oxide (17), e) 2-phenylacetophenone, f) heptaldehyde, g) water, h) n-pentane, i) iodobenzene.

21. Synthesis of trans-1-phenyl-1,2-epoxypropane (19)

\[
\text{S12} + \text{S1} \xrightarrow{2-\text{MnCl}@1 (0.2 mol\%)} \text{H}_2\text{O}/\text{CH}_3\text{CN 1:1, rt, 20 min}}
\]

2-MnCl@1 (6.7 mg; 0.48 µmol), S12 (28.8 mg; 0.24 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (112 mg; 0.35 mmol; 1,4 equivalents) were handled according to the generalized epoxidation procedure to give 19 (163 µmol; 67%; TON = 339)(\(^1\)H-NMR spectrum is depicted in Figure S24). Data for epoxide 19 were in agreement with published data.\(^{[11]}\)

Figure S24: \(^1\)H-NMR spectrum of epoxidation of trans-β-methylstyrene (S12) with 2-MnCl@1 with the assignment of the signals: a) triphenylmethane, b) trans-1-phenyl-1,2-epoxypropane (19), c) 1-phenylpropan-2-one, d) benzoaldehyde, e) iodobenzene, f) n-pentane.
22. Synthesis of cis-1-phenyl-1,2-epoxypropane (20)

\[
\begin{align*}
\text{S13} & \quad + \quad \text{S1} \\
& \xrightarrow{2-\text{MnCl}@1 (0.2 \text{ mol\%})} \\
& \quad \xrightarrow{\text{H}_2\text{O}/\text{CH}_3\text{CN} 1:1} \\
& \text{S13} & \quad \text{S1} & \quad \text{20} \\
& \quad \xrightarrow{\text{rt}, 20 \text{ min}}
\end{align*}
\]

2-MnCl@1 (6.9 mg; 0.49 µmol), S13 (34.4 mg; 0.29 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (120 mg; 0.37 mmol; 1,3 equivalents) were handled according to the generalized epoxidation procedure to give 20 (90 µmol; 31%; TON = 184)(1H-NMR spectrum is depicted in Figure S25). Data for epoxide 20 were in agreement with published data.[13]

Figure S25: 1H-NMR spectrum of epoxidation of cis-β-methylstyrene (S13) with 2-MnCl@1 with the assignment of the signals: a) cis-β-methylstyrene (S13), b) triphenylmethane, c) cis-1-phenyl-1,2-epoxypropane (20), d) 1-phenylpropan-2-one, e) iodobenzene, f) n-pentane, g) acetaldehyde.

23. Synthesis of 2-methyl-2-phenyloxirane (21) and acetophenone (S15)

\[
\begin{align*}
\text{S14} & \quad + \quad \text{S1} \\
& \xrightarrow{2-\text{MnCl}@1 (0.2 \text{ mol\%})} \\
& \quad \xrightarrow{\text{H}_2\text{O}/\text{CH}_3\text{CN} 1:1} \\
& \text{S14} & \quad \text{S1} & \quad \text{21} & \quad \text{S15} \\
& \quad \xrightarrow{\text{rt}, 20 \text{ min}}
\end{align*}
\]

2-MnCl@1 (7.2 mg; 0.52 µmol), S14 (33.7 mg; 0.29 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (119 mg; 0.0.37 mmol; 1,3 equivalents) were handled according to the generalized epoxidation procedure to give 21 (30 µmol; 10%; TON = 57) and S14 (52 µmol; 18%; TON = 101)(1H-NMR spectrum is depicted in Figure S26). Data for epoxide 21[12] and acetophenone S15[11] were in agreement with published data.

Figure S26: 1H-NMR spectrum of epoxidation of α-methylstyrene (S14) with 2-MnCl@1 with the assignment of the signals: a) triphenylmethane, b) α-methylstyrene (S14), c) 2-methyl-2-phenyloxirane (21), d) 2-phenylpropanal, e) acetophenone (S15), f) ethyl acetate, acetonitrile and acetone, g) n-pentane.
24. Synthesis of 1,2-epoxydecane (22)

\[
\begin{align*}
\text{S16} \quad &+ \quad \text{S1} \quad \xrightarrow{2\text{-MnCl}@1 (0.2 \text{ mol\%})} \quad \text{22} \\
\text{H}_2\text{O}/\text{CH}_3\text{CN} \quad &1:1 \\
\text{rt}, 20 \text{ min} 
\end{align*}
\]

2-MnCl@1 (7.0 mg; 0.50 µmol), S16 (48.1 mg; 0.34 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (126 mg; 0.39 mmol; 1,1 equivalents) were handled according to the generalized epoxidation procedure to give 22 (2 µmol; 1%; TON = 3) (\textsuperscript{1}H-NMR spectrum is depicted in Figure S27). Data for epoxide 22 were in agreement with published data.\textsuperscript{[11]}

Figure S27: \textsuperscript{1}H-NMR spectrum of epoxidation of 1-decene (S16) with 2-MnCl@1 with the assignment of the signals: a) 1,2-epoxydecane (22), b) triphenylmethane, c) 1-decene (S16).

25. Synthesis of \textit{trans}-4,5-epoxyoctane (23)

\[
\begin{align*}
\text{S17} \quad &+ \quad \text{S1} \quad \xrightarrow{2\text{-MnCl}@1 (0.2 \text{ mol\%})} \quad \text{23} \\
\text{H}_2\text{O}/\text{CH}_3\text{CN} \quad &1:1 \\
\text{rt}, 20 \text{ min} 
\end{align*}
\]

2-MnCl@1 (6.8 mg; 0.48 µmol), S17 (30.5 mg; 0.27 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (107 mg; 0.33 mmol; 1,2 equivalents) were handled according to the generalized epoxidation procedure to give 23 (9 µmol; 3%; TON = 19) (\textsuperscript{1}H-NMR spectrum is depicted in Figure S28). Data for epoxide 23 were in agreement with published data.\textsuperscript{[11]}

Figure S28: \textsuperscript{1}H-NMR spectrum of epoxidation of \textit{trans}-4-octene (S17) with 2-MnCl@1 with the assignment of the signals: a) \textit{trans}-4-octene (S17), b) triphenylmethane, c) \textit{trans}-4,5-epoxyoctane (23).
26. Synthesis of \textit{cis}-4,5-epoxyoctane (24)

\begin{align*}
\text{cis}-4\text{-octene} + \text{iodoester} &\xrightarrow{\text{2-MnCl\textsuperscript{@}1 (0.2 mol\%)}; \text{H}_2\text{O}/\text{CH}_3\text{CN 1:1; rt, 20 min}}} \text{4,5-epoxyoctane (24)} \\
\end{align*}

2-MnCl\textsuperscript{@}1 (6.7 mg; 0.48 µmol), S18 (26.5 mg; 0.24 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (113 mg; 0.35 mmol; 1.5 equivalents) were handled according to the generalized epoxidation procedure to give 24 (29 µmol; 12%; TON = 60) (\textsuperscript{1}H-NMR spectrum is depicted in Figure S29). Data for epoxide 24 were in agreement with published data.\cite{14}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figureS29}
\caption{\textsuperscript{1}H-NMR spectrum of epoxidation of \textit{cis}-4-octene (S18) with 2-MnCl\textsuperscript{@}1 with the assignment of the signals: a) \textit{cis}-4-octene (S18), b) triphenylmethane, c) \textit{cis}-4,5-epoxyoctane (24).}
\end{figure}

27. Synthesis of 2,3-epoxycyclooctane (25)

\begin{align*}
\text{cis-cyclooctene} + \text{iodoester} &\xrightarrow{\text{2-MnCl\textsuperscript{@}1 (0.2 mol\%)}; \text{H}_2\text{O}/\text{CH}_3\text{CN 1:1; rt, 20 min}}} \text{2,3-epoxycyclooctane (25)} \\
\end{align*}

2-MnCl\textsuperscript{@}1 (7.3 mg; 0.52 µmol), S19 (30.7 mg; 0.28 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (118 mg; 0.37 mmol; 1.3 equivalents) were handled according to the generalized epoxidation procedure to give 25 (54 µmol; 19%; TON = 103) (\textsuperscript{1}H-NMR spectrum is depicted in Figure S30). Data for epoxide 25 were in agreement with published data.\cite{11}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figureS30}
\caption{\textsuperscript{1}H-NMR spectrum of epoxidation of \textit{cis}-cyclooctene (S19) with 2-MnCl\textsuperscript{@}1 with the assignment of the signals: a) \textit{cis}-cyclooctene (S19), b) triphenylmethane, c) 2,3-epoxycyclooctane (25), d) iodo benzene, e) acetone and acetonitrile.}
\end{figure}
28. Synthesis of 2,3-epoxycyclohexane (26)

\[
\text{S20} + \text{S1} \xrightarrow{2\text{-MnCl}@1 (0.2 mol\%)} \text{H}_2\text{O}/\text{CH}_3\text{CN 1:1}}
\]

\[
\text{rt, 20 min}
\]

2-MnCl@1 (7.1 mg; 0.51 µmol), S20 (24.4 mg; 0.29 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (115 mg; 0.36 mmol; 1,2 equivalents) were handled according to the generalized epoxidation procedure to give 26 (44 µmol; 15%; TON = 86) (1H-NMR spectrum is depicted in Figure S31). Data for epoxide 26 were in agreement with published data.\[14\]

Figure S31: 1H-NMR spectrum of epoxidation of cyclohexene (S20) with 2-MnCl@1 with the assignment of the signals: a) cyclohexene (S20), b) triphenylmethane, c) 2,3-epoxycyclohexane (25), d) iodobenzene, e) acetonitrile, f) n-pentane, g) water.

29. Synthesis of 2-(4-benzhydrylphenyl)oxirane (9) with 2-MnCl@1

\[
\text{8} + \text{S1} \xrightarrow{2\text{-MnCl}@1 (0.2 mol\%)} \text{H}_2\text{O}/\text{CH}_3\text{CN 1:1}}
\]

\[
\text{rt, 20 min}
\]

2-MnCl@1 (7.0 mg; 0.50 µmol), 8 (80.2 mg; 0.30 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (118 mg; 0.37 mmol; 1,2 equivalents) were handled according to the generalized epoxidation procedure to give 9 (56 µmol; 19%; TON = 112) (1H-NMR spectrum is depicted in Figure S32). Methoxybenzene (14.2 mg; 131 µmol) was used as the standard for 1H-NMR to avoid overlapping signals of the substrate and product with triphenylmethane. Data for epoxide 9 were in agreement with the isolated product prepared by epoxidation of 9 with 3-chloroperbenzoic acid (below, 31).
30. **Synthesis of 2-(4-benzhydrylphenyl)oxirane (9) with 2-MnCl**

![Diagram](image)

**2-MnCl** (0.4 mg; 0.57 µmol), 8 (79.8 mg; 0.30 mmol), acetonitrile (1.0 mL), water (1.0 mL) and **S1** (114 mg; 0.35 mmol; 1,2 equivalents) were handled according to the generalized epoxidation procedure to give 9 (6 µmol; 2%; TON = 10) (1H-NMR spectrum is depicted in Figure S33). Methoxybenzene (9.3 mg; 86 µmol) was used as the standard for 1H-NMR to avoid overlapping signals of the substrate and product with triphenylmethane. Data for epoxide 9 were in agreement with the isolated product prepared by epoxidation of 9 with 3-chloroperbenzoic acid (below, 31).

![Figure S32: 1H-NMR spectrum of epoxidation of 4-benzhydrylstyrene (8) with 2-MnCl@1 with the assignment of the signals: a) 4-benzhydrylstyrene (8), b) methoxybenzene, c) 2-(4-benzhydrylphenyl)oxirane (9), d) 2-(4-benzhydrylphenyl)acetaldehyde, e) iodobenzene, f) n-pentane, g) water, h) acetone.](image)

![Figure S33: 1H-NMR spectrum of epoxidation of 4-benzhydrylstyrene (8) with 2-MnCl with the assignment of the signals: a) 4-benzhydrylstyrene (8), b) methoxybenzene, c) 2-(4-benzhydrylphenyl)oxirane (9), d) 2-(4-benzhydrylphenyl)acetaldehyde, e) iodobenzene, f) n-pentane, g) water, h) acetone.](image)
31. Synthesis of 2-(4-benzhydrylphenyl)oxirane (9) with 3-chloroperbenzoic acid (S21) as oxidant

To a solution of 4-benzhydrylstyrene (8; 135 mg; 0.5 mmol) in dichloromethane (5 mL) was slowly added under continuous stirring 3-chloroperbenzoic acid (S21, 129 mg; 70 wt% solution; 0.52 mmol). After 30 minutes additional 3-chloroperbenzoic acid (120 mg; 0.49 mmol) was added. The progress of the reaction was monitored by TLC (SiO₂; hexanes:Ethyl acetate 98:2). Upon full conversion of the substrate the mixture was poured in a saturated aqueous solution of sodium thiosulfate (50 mL) and the products extracted with dichloromethane (20 mL). The organic fraction was separated, washed with saturated aqueous sodium thiosulfate solution (20 mL) and a saturated aqueous solution of sodium bicarbonate (20 mL). The organic fraction was dried over anhydrous magnesium sulfate, filtered and solvents removed under reduced pressure. The crude product was purified by column chromatography (SiO₂) using a gradient from 2% ethylacetate in hexanes to 10% to yield the product 9 as a colorless oil (39 mg; 0.14 mmol; 27%) \(^1\)H-NMR (Figure S34, 400 MHz, CDCl₃): 7.19-7.31 (m, 8H), 7.10-7.12 (m, 6H), 5.55 (s, 1H), 3.84 (dd, J = 4,1 Hz, J = 2.6 Hz, 1H), 3.13 (dd, J = 5.5 Hz, J = 4.1 Hz, 1H), 2.81 (dd, J = 5.5 Hz, J = 2.6 Hz, 1H); \(^1\)C-NMR (Figure S35, MHz, CDCl₃): 144.2, 143.8, 143.8, 135.7, 129.7, 129.5, 128.5, 126.5, 125.7, 56.7, 52.4, 51.3; IR (neat): 3024, 1599, 1494, 1449, 873, 746, 699, 607 cm\(^{-1}\); Exact mass GC-EI: C₂₁H₁₈O calculated: 286.1358 found: 286.1353.

Figure S34: \(^1\)H-NMR spectrum of 2-(4-benzhydrylphenyl)oxirane (9).

Figure S35: \(^1\)C-NMR spectrum of 2-(4-benzhydrylphenyl)oxirane (9).
32. Synthesis of 2-(3,5-di-tert-butylphenyl)oxirane (10) with 2-MnCl@1

2-MnCl@1 (6.9 mg; 0.49 µmol), 11 (64.8 mg; 0.30 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (117 mg; 0.36 mmol; 1,2 equivalents) were handled according to the generalized epoxidation procedure to give 10 (24 µmol; 8%; TON = 49) (1H-NMR spectrum is depicted in Figure S36). Data for epoxide 10 were in agreement with published data.\[^{[15]}\]

33. Synthesis of 2-(3,5-di-tert-butylphenyl)oxirane (10) with 2-MnCl

2-MnCl (0.4 mg; 0.57 µmol), 11 (61.3 mg; 0.28 mmol), acetonitrile (1.0 mL), water (1.0 mL) and S1 (114 mg; 0.35 mmol; 1,3 equivalents) were handled according to the generalized epoxidation procedure to give 10 (10 µmol; 3%; TON = 17) (1H-NMR spectrum is depicted in Figure S37). Data for epoxide 10 were in agreement with published data.\[^{[15]}\]
Figure S37: 1H-NMR spectrum of epoxidation of 3,5-di-tert-butylstyrene (11) with 2-MnCl@1 with the assignment of the signals: a) 3,5-di-tert-butylstyrene (11), b) triphenylmethane, c) 2-(5-di-tert-butylphenyl)oxirane (10), d) 2-(5-di-tert-butylphenyl)acetaldehyde, e) iodobenzene, f) n-pentane, g) water, h) acetone.

34. 2-MnCl@2 cage model with the estimated pore sizes

In order to estimate the size of the pores the hydrogen-hydrogen distances on the edges of the pores were measured in a molecular model of 2-MnCl@2 (Figure S38).

Figure S38: Molecular model (Spartan '08, MM SYBYL FF) (left) and space filling model (right) with the estimated size of the pores.

From the molecular models (DFT, B3LYP and 6-31G basis set, Spartan '08) of the bulky substrates 4-benzhydrylstyrene 8 and 3,5-di-tert-butylstyrene 11 the sizes of the substrates were estimated (Figure S39).

Figure S39: Molecular model (Spartan '08, DFT, B3LYP 6-31G) of substrate 8(left) and 11 (right) with their estimated dimensions.

The above estimated dimensions show that both substrate 8 and 11 only barely fit through the pores of the cage. The other substrates (and epoxide products) shown in scheme 3 (main text) are much smaller, and hence should experience (much) less size-discrimination by the cage.
References in the supporting information