Electronic Supplementary Information

for

Chitosan bis(halophenylcarbamate)-(isobutyrylamide)s based chiral stationary phases for enantiomeric separation

Sheng Tang, Qin Bin, Zi-Wei Feng, Wei Chen, Shao-Hua Huang and Zheng-Wu Bai

School of Chemistry and Environmental Engineering, Wuhan Institute of Technology, Wuhan 430073, China.

Key Laboratory of Biobased Materials, Qingdao Institute of Bioenergy and Bioprocess Technology, Chinese Academy of Sciences, Qingdao 266101, China.

*Corresponding author:
Zheng-Wu Bai (Z.W. Bai), E-mail Address: zwbai@wit.edu.cn
Tel. and fax: +86 27 87195680
Table of Contents

1. $^1$H NMR spectrum of chitosan
2. $^1$H NMR spectra of chitosan bis(halophenylcarbamate)-(isobutyrylamide)s
3. IR spectra of chitosan bis(halophenylcarbamate)-(isobutyrylamide)s
4. Structures of the tested chiral analytes
5. Numbers of the racemates recognized and baseline separated by CSPs1-6, CSPa and CSPb in each mobile phase
6. Elemental analysis results of P1-P6
7. Enantioseparation results of CSPa and CSPb
8. Eluent tolerance of CSP3 towards organic solvents
1. $^1$H NMR spectrum of chitosan

![Fig. S1 $^1$H NMR spectrum of chitosan (400 MHz, TFA-$d$, 25 °C)]

2. $^1$H NMR spectra of chitosan bis(halophenylcarbamate)-(isobutyrylamide)s

![Fig. S2 $^1$H NMR spectrum of chitosan bis(3,5-dichlorophenylcarbamate)-(isobutyrylamide) (P2) (600 MHz, DMSO-$d_6$, 90 °C)]
Fig. S3 $^1$H NMR spectrum of chitosan bis(3,4-dichlorophenylcarbamate)-(isobutyrylamide) (P3) (600 MHz, DMSO-$d_6$, 90 °C)

Fig. S4 $^1$H NMR spectrum of chitosan bis(4-chloro-3-trifluoromethylphenylcarbamate)-(isobutyrylamide) (P4) (600 MHz, DMSO-$d_6$, 90 °C)
**Fig. S5** $^1$H NMR spectrum of chitosan bis(3-chlorophenylcarbamate)-(isobutrylamide) (P5) (600 MHz, DMSO-$d_6$, 90 °C)

**Fig. S6** $^1$H NMR spectrum of chitosan bis(4-trifluoromethoxyphenylcarbamate)-(isobutrylamide) (P6) (600 MHz, DMSO-$d_6$, 90 °C)
3. IR spectra of chitosan bis(halophenylcarbamate)-(isobutyrylamide)s

**Fig. S7** IR spectrum of chitosan bis(4-chlorophenylcarbamate)-(isobutyrylamide) (P1)

**Fig. S8** IR spectrum of chitosan bis(3,5-dichlorophenylcarbamate)-(isobutyrylamide) (P2)
**Fig. S9** IR spectrum of chitosan bis(3,4-dichlorophenylcarbamate)-(isobutyrylamide) (P3)

**Fig. S10** IR spectrum of chitosan bis(4-chloro-3-trifluoromethylphenylcarbamate)-(isobutyrylamide) (P4)
**Fig. S11** IR spectrum of chitosan bis(3-chlorophenylcarbamate)-(isobutyrylamide) (P5)

**Fig. S12** IR spectrum of chitosan bis(4-trifluoromethoxyphenylcarbamate)-(isobutyrylamide) (P6)
4. Structures of the tested chiral analytes

Fig. S13 Structures of the tested chiral analytes.
5. Numbers of the racemates recognized and baseline separated by CSPs1-6, CSPa and CSPb in each mobile phase

**Fig. S14** Numbers of the racemates recognized and baseline separated in the mobile phase of \( n \)-hexane/isopropanol (90/10).

**Fig. S15** Numbers of the racemates recognized and baseline separated in the mobile phase of \( n \)-hexane/ethanol (90/10).
Fig. S16 Numbers of the racemates recognized and baseline separated in the mobile phase of \( n \)-hexane/ethanol/methanol (90/5/5). Since CSP2 was destroyed when it was tested in the eluent of \( n \)-hexane/ethanol/methanol (90/5/5), the enantioseparation results of CSP2 were not available.

6. Elemental analysis results of P1-P6

<table>
<thead>
<tr>
<th>Chiral selectors</th>
<th>Calculated values</th>
<th>Observed values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>H</td>
</tr>
<tr>
<td>P1 (C_{24}H_{25}Cl_{2}N_{3}O_{7})_n</td>
<td>53.54%</td>
<td>4.68%</td>
</tr>
<tr>
<td>P2 (C_{24}H_{25}Cl_{4}N_{3}O_{7})_n</td>
<td>47.47%</td>
<td>3.82%</td>
</tr>
<tr>
<td>P3 (C_{24}H_{23}Cl_{4}N_{3}O_{7})_n</td>
<td>47.47%</td>
<td>3.82%</td>
</tr>
<tr>
<td>P4 (C_{24}H_{23}Cl_{6}F_{6}N_{3}O_{7})_n</td>
<td>46.31%</td>
<td>3.44%</td>
</tr>
<tr>
<td>P5 (C_{24}H_{25}Cl_{2}N_{3}O_{7})_n</td>
<td>53.54%</td>
<td>4.68%</td>
</tr>
<tr>
<td>P6 (C_{24}H_{25}F_{6}N_{3}O_{9}·6H_{2}O)_n</td>
<td>41.88%</td>
<td>5.00%</td>
</tr>
</tbody>
</table>
### 7. Enantioseparation results of CSPa and CSPb

Table S2 Enantioseparation results of CSPa and CSPb

<table>
<thead>
<tr>
<th>S.N.</th>
<th>CSPa</th>
<th>CSPb</th>
<th>S.N.</th>
<th>CSPa</th>
<th>CSPb</th>
<th>M.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$k_1$</td>
<td>$\alpha$</td>
<td>$R_s$</td>
<td>$k_1$</td>
<td>$\alpha$</td>
<td>$R_s$</td>
</tr>
<tr>
<td>1</td>
<td>0.65(+)</td>
<td>1.51</td>
<td>1.68</td>
<td>1.03(+)</td>
<td>1.49</td>
<td>2.12</td>
</tr>
<tr>
<td></td>
<td>0.54(+)</td>
<td>1.87</td>
<td>3.07</td>
<td>0.70(+)</td>
<td>1.64</td>
<td>2.62</td>
</tr>
<tr>
<td></td>
<td>0.66(+)</td>
<td>1.79</td>
<td>3.79</td>
<td>0.72(+)</td>
<td>1.64</td>
<td>2.63</td>
</tr>
<tr>
<td>2</td>
<td>1.24(+)</td>
<td>1.20</td>
<td>1.37</td>
<td>1.53(-)</td>
<td>1.30</td>
<td>1.80</td>
</tr>
<tr>
<td></td>
<td>1.19(+)</td>
<td>1.46</td>
<td>2.94</td>
<td>1.15(-)</td>
<td>1.21</td>
<td>1.14</td>
</tr>
<tr>
<td></td>
<td>1.43(+)</td>
<td>1.79</td>
<td>5.00</td>
<td>1.09(-)</td>
<td>1.21</td>
<td>1.19</td>
</tr>
<tr>
<td>3</td>
<td>1.19</td>
<td>1.00</td>
<td>0.00</td>
<td>2.09</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>0.68(+)</td>
<td>1.06</td>
<td>0.28</td>
<td>1.34</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>0.98</td>
<td>1.00</td>
<td>0.00</td>
<td>1.24</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>2.95(-)</td>
<td>1.06</td>
<td>0.48</td>
<td>3.74(+)</td>
<td>1.10</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>1.71</td>
<td>1.00</td>
<td>0.00</td>
<td>1.90</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>2.29</td>
<td>1.00</td>
<td>0.00</td>
<td>1.60</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>0.63</td>
<td>1.00</td>
<td>0.00</td>
<td>0.95(+)</td>
<td>1.12</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>0.43</td>
<td>1.00</td>
<td>0.00</td>
<td>0.65(+)</td>
<td>1.13</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>0.69</td>
<td>1.00</td>
<td>0.00</td>
<td>0.57(+)</td>
<td>1.13</td>
<td>0.38</td>
</tr>
<tr>
<td>6</td>
<td>5.71(R)</td>
<td>1.27</td>
<td>1.46</td>
<td>9.85(S)</td>
<td>1.09</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>3.23(R)</td>
<td>1.11</td>
<td>0.77</td>
<td>4.89</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>4.10</td>
<td>1.00</td>
<td>0.00</td>
<td>3.82(R)</td>
<td>1.10</td>
<td>0.45</td>
</tr>
<tr>
<td>7</td>
<td>6.11(R)</td>
<td>2.09</td>
<td>3.00</td>
<td>7.61(R)</td>
<td>1.25</td>
<td>0.39</td>
</tr>
</tbody>
</table>
Continued Table S2

<table>
<thead>
<tr>
<th>S.N.</th>
<th>CSPa</th>
<th>CSPb</th>
<th>S.N.</th>
<th>CSPa</th>
<th>CSPb</th>
<th>M.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(k_1)</td>
<td>(\alpha)</td>
<td>(R_s)</td>
<td>(k_1)</td>
<td>(\alpha)</td>
<td>(R_s)</td>
</tr>
<tr>
<td>15</td>
<td>1.14(S)</td>
<td>1.22</td>
<td>0.84</td>
<td>1.62(R)</td>
<td>1.34</td>
<td>1.60</td>
</tr>
<tr>
<td></td>
<td>0.58(S)</td>
<td>1.12</td>
<td>0.32</td>
<td>0.83(R)</td>
<td>1.34</td>
<td>1.55</td>
</tr>
<tr>
<td></td>
<td>0.97</td>
<td>1.00</td>
<td>0.00</td>
<td>0.73(R)</td>
<td>1.21</td>
<td>0.47</td>
</tr>
<tr>
<td>16</td>
<td>25.10</td>
<td>1.00</td>
<td>0.00</td>
<td>32.69(R)</td>
<td>1.30</td>
<td>1.27</td>
</tr>
<tr>
<td></td>
<td>7.73(R)</td>
<td>1.63</td>
<td>2.20</td>
<td>11.45(R)</td>
<td>1.18</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>9.07(R)</td>
<td>1.50</td>
<td>2.98</td>
<td>7.77(R)</td>
<td>1.13</td>
<td>0.68</td>
</tr>
<tr>
<td>17</td>
<td>Retention time &gt;120 min</td>
<td>17.56(R)</td>
<td>1.28</td>
<td>0.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.37(R)</td>
<td>1.61</td>
<td>2.57</td>
<td>6.37(R)</td>
<td>1.25</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>9.62(2R,3S)</td>
<td>1.79</td>
<td>3.63</td>
<td>3.94(R)</td>
<td>1.15</td>
<td>0.54</td>
</tr>
</tbody>
</table>

S.N.: serials number of the analytes; M.P.: mobile phase: A: \(n\)-hexane/isopropanol (90/10); B: \(n\)-hexane/ethanol (90/10); C: \(n\)-hexane/ethanol/methanol (90/5/5).

“+”, “-”, “R”, “S” and “(2R,3S)” refer to the optical rotation or configuration of the first-eluted enantiomer. Flow rate: 1.0 ml min\(^{-1}\). Detection temperature: 25 °C.

Enantioseparation results of CSPa and CSPb were cited from our most recently reported work.\(^1\)
8. Eluent tolerance of CSP3 towards organic solvents

Table S3 Comparison in enantioseparation ability of CSP3 before and after being flushed by various organic solvents

<table>
<thead>
<tr>
<th>S.N.</th>
<th>S.</th>
<th>k₁</th>
<th>α</th>
<th>Rₛ</th>
<th>k₁</th>
<th>α</th>
<th>Rₛ</th>
<th>k₁</th>
<th>α</th>
<th>Rₛ</th>
<th>k₁</th>
<th>α</th>
<th>Rₛ</th>
<th>k₁</th>
<th>α</th>
<th>Rₛ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>0.39</td>
<td>1.43</td>
<td>2.51</td>
<td>0.43</td>
<td>1.54</td>
<td>3.24</td>
<td>0.41</td>
<td>1.57</td>
<td>3.37</td>
<td>0.42</td>
<td>1.56</td>
<td>3.49</td>
<td>0.38</td>
<td>1.52</td>
<td>2.75</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1.44</td>
<td>1.29</td>
<td>3.14</td>
<td>1.87</td>
<td>1.32</td>
<td>4.36</td>
<td>1.79</td>
<td>1.29</td>
<td>3.13</td>
<td>1.88</td>
<td>1.31</td>
<td>4.66</td>
<td>1.58</td>
<td>1.29</td>
<td>2.99</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>0.59</td>
<td>1.00</td>
<td>0.00</td>
<td>0.78</td>
<td>1.00</td>
<td>0.00</td>
<td>0.78</td>
<td>1.00</td>
<td>0.00</td>
<td>0.76</td>
<td>1.00</td>
<td>0.00</td>
<td>0.62</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>4.72</td>
<td>1.36</td>
<td>5.46</td>
<td>7.01</td>
<td>1.42</td>
<td>5.88</td>
<td>5.91</td>
<td>1.44</td>
<td>6.26</td>
<td>6.82</td>
<td>1.43</td>
<td>6.28</td>
<td>4.69</td>
<td>1.41</td>
<td>5.57</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>0.47</td>
<td>1.00</td>
<td>0.00</td>
<td>0.60</td>
<td>1.00</td>
<td>0.00</td>
<td>0.53</td>
<td>1.00</td>
<td>0.00</td>
<td>0.58</td>
<td>1.00</td>
<td>0.00</td>
<td>0.46</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>8.90</td>
<td>1.22</td>
<td>3.20</td>
<td>15.25</td>
<td>1.21</td>
<td>3.21</td>
<td>15.17</td>
<td>1.17</td>
<td>3.08</td>
<td>15.42</td>
<td>1.20</td>
<td>3.16</td>
<td>9.44</td>
<td>1.22</td>
<td>2.90</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>1.24</td>
<td>1.16</td>
<td>1.56</td>
<td>1.87</td>
<td>1.19</td>
<td>1.76</td>
<td>1.61</td>
<td>1.19</td>
<td>2.04</td>
<td>1.88</td>
<td>1.20</td>
<td>2.11</td>
<td>1.30</td>
<td>1.18</td>
<td>1.56</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>1.64</td>
<td>1.00</td>
<td>0.00</td>
<td>2.74</td>
<td>1.00</td>
<td>0.00</td>
<td>2.61</td>
<td>1.00</td>
<td>0.00</td>
<td>2.54</td>
<td>1.00</td>
<td>0.00</td>
<td>1.68</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>1.28</td>
<td>1.16</td>
<td>1.61</td>
<td>2.00</td>
<td>1.18</td>
<td>1.96</td>
<td>1.79</td>
<td>1.18</td>
<td>2.28</td>
<td>2.00</td>
<td>1.18</td>
<td>2.31</td>
<td>1.34</td>
<td>1.17</td>
<td>1.71</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>2.23</td>
<td>1.05</td>
<td>0.39</td>
<td>3.11</td>
<td>1.08</td>
<td>0.22</td>
<td>2.85</td>
<td>1.00</td>
<td>0.00</td>
<td>3.06</td>
<td>1.06</td>
<td>0.31</td>
<td>2.37</td>
<td>1.03</td>
<td>0.10</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>1.84</td>
<td>1.18</td>
<td>1.66</td>
<td>3.04</td>
<td>1.19</td>
<td>1.66</td>
<td>2.61</td>
<td>1.19</td>
<td>1.62</td>
<td>2.91</td>
<td>1.19</td>
<td>1.71</td>
<td>1.84</td>
<td>1.25</td>
<td>1.14</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>31.65</td>
<td>1.11</td>
<td>1.56</td>
<td>Retention time &gt; 120 min</td>
<td>37.84</td>
<td>1.05</td>
<td>0.44</td>
<td>43.29</td>
<td>1.04</td>
<td>0.43</td>
<td>28.80</td>
<td>1.17</td>
<td>1.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>25.47</td>
<td>1.12</td>
<td>1.52</td>
<td>Retention time &gt; 120 min</td>
<td>45.20</td>
<td>1.00</td>
<td>0.00</td>
<td>33.64</td>
<td>1.03</td>
<td>0.20</td>
<td>23.57</td>
<td>1.16</td>
<td>1.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>2.90</td>
<td>1.00</td>
<td>0.00</td>
<td>4.44</td>
<td>1.00</td>
<td>0.00</td>
<td>4.54</td>
<td>1.00</td>
<td>0.00</td>
<td>4.46</td>
<td>1.00</td>
<td>0.00</td>
<td>3.35</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>1.36</td>
<td>1.00</td>
<td>0.00</td>
<td>2.11</td>
<td>1.00</td>
<td>0.00</td>
<td>2.13</td>
<td>1.05</td>
<td>0.33</td>
<td>1.98</td>
<td>1.07</td>
<td>0.68</td>
<td>1.43</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>7.56</td>
<td>1.00</td>
<td>0.00</td>
<td>12.89</td>
<td>1.00</td>
<td>0.00</td>
<td>10.31</td>
<td>1.00</td>
<td>0.00</td>
<td>12.73</td>
<td>1.00</td>
<td>0.00</td>
<td>8.18</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>S.N.</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>13.25</td>
<td>1.07</td>
<td>0.51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>3.62</td>
<td>1.16</td>
<td>1.69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>4.03</td>
<td>1.81</td>
<td>7.79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention time &gt; 120 min</td>
<td>18.53</td>
<td>1.04</td>
<td>0.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.41</td>
<td>1.18</td>
<td>2.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.10</td>
<td>1.98</td>
<td>8.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.67</td>
<td>1.18</td>
<td>2.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.10</td>
<td>1.97</td>
<td>8.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

S.N.: serials number of the analytes; (a) initial enantioseparation results of CSP3; (b) after CSP3 worked for 100 h during the initial enantioseparation and then was placed aside for two months; (c) after CSP3 was flushed by pure ethyl acetate; (d) after CSP3 was flushed by pure chloroform; (e) after CSP3 was flushed by n-hexane/THF (70/30); mobile phase for enantioseparations: n-hexane/ethanol (90/10); flow rate: 1.0 ml min\(^{-1}\); detection temperature: 25 °C.

References