Lithium 2,2,6,6-Tetramethylpiperidide-Mediated α- and β-Lithiations of Epoxides: Solvent-Dependent Mechanisms

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Supporting Information

I Plot of k_{obsd} vs [THF] in pentane cosolvent for the β-lithiation of 2,3-dimethyl-2-butene oxide (**3**, 0.004 M) by LiTMP (0.10 M).

II Plot of k_{obsd} vs [LiTMP] in THF (1.75 M) and pentane cosolvent for the β-lithiation of 2,3-dimethyl-2-butene oxide (**3**, 0.004 M).

III Plot of k_{obsd} vs [LiTMP] in THF (9.0 M) and pentane cosolvent for the β-lithiation of 2,3-dimethyl-2-butene oxide (**3**, 0.004 M).

IV Plot of k_{obsd} vs [THF] in pentane cosolvent for the α-lithiation of *cis*-cyclooctene oxide (**1**, 0.004 M) by LiTMP (0.10 M).

V Plot of k_{obsd} vs [LiTMP] in THF (5.0 M) and pentane cosolvent for the α-lithiation of *cis*-cyclooctene oxide (**1**, 0.004 M).

VI Plot of k_{obsd} vs [Me_2NEt] in pentane cosolvent for the β-lithiation of 2,3-dimethyl-2-butene oxide (**3**, 0.004 M) by LiTMP (0.10 M).

VII Plot of k_{obsd} vs [LiTMP] in Me_2NEt (3.0 M) and pentane cosolvent for the β-lithiation of 2,3-dimethyl-2-butene oxide (**3**, 0.004 M).

VIII Plot of k_{obsd} vs [Me_2NEt] in pentane cosolvent for the α-lithiation of *cis*-cyclooctene oxide (**1**, 0.004 M) by LiTMP (0.10 M).

IX Plot of k_{obsd} vs [LiTMP] in Me_2NEt (3.0 M) and pentane cosolvent for the α-lithiation of *cis*-cyclooctene oxide (**1**, 0.004 M).

X Table of data for plot in Section I.

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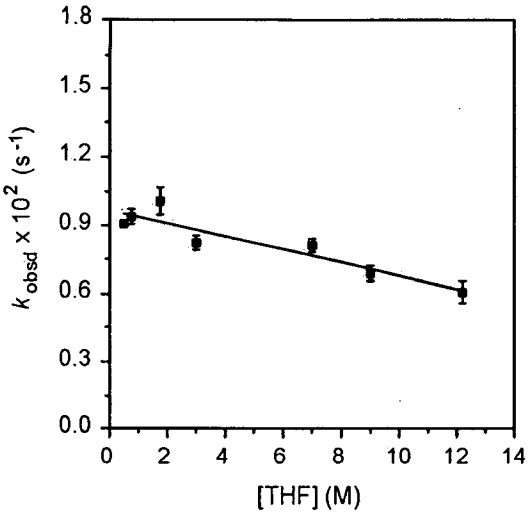
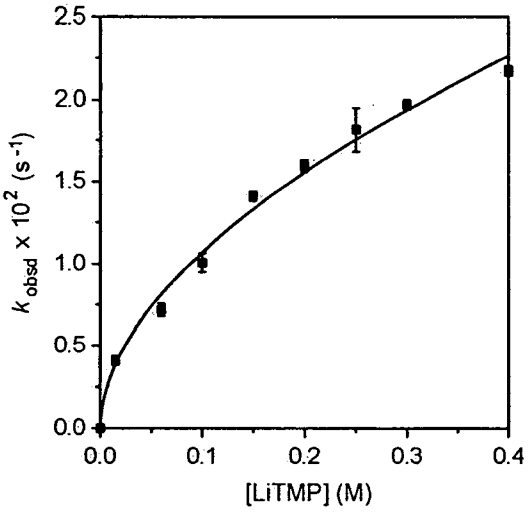
XX Table of data for k_{obsd} in various ligands (0.5 M) and pentane cosolvent for the α-lithiation of *cis*-cyclooctene oxide (**1**, 0.004 M).

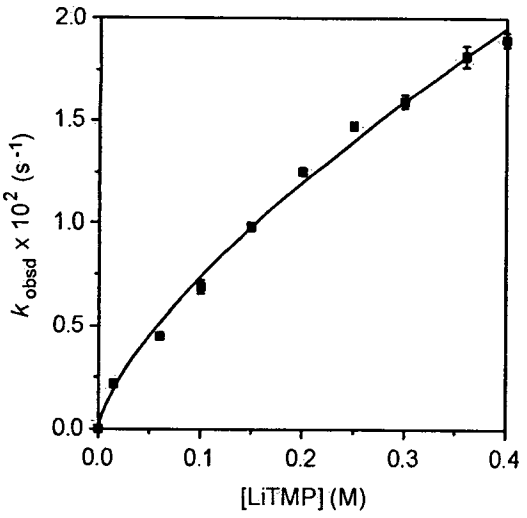
XXI Calculated energies of reactants and transition structures for the β- and α-lithiation of *cis*-2,3-butene oxide using Gaussian 98W at the B3LYP level of density functional theory with the 6-31(d) basis set.



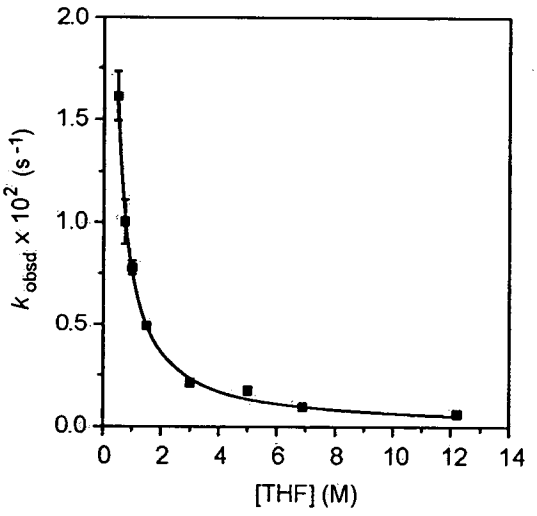
I. Plot of k_{obsd} vs [THF] in pentane cosolvent for the β-lithiation of 2,3-dimethyl-2-butene oxide (**3**, 0.004 M) by LiTMP (0.10 M) at 0 °C. The curve depicts an unweighted least-squares fit to $k_{obsd} = k[THF] + k'$ ($k = -2.9 \pm 0.5 \times 10^{-4}$, $k' = 9.7 \pm 0.3 \times 10^{-3}$).



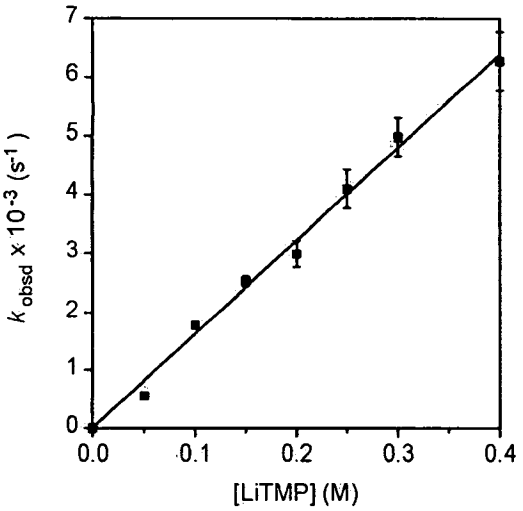
II. Plot of k_{obsd} vs [LiTMP] in THF (1.75 M) and pentane cosolvent for the β-lithiation of 2,3-dimethyl-2-butene oxide (**3**, 0.004 M) at 0 °C. The curve depicts an unweighted least-squares fit to $k_{obsd} = k[LiTMP]^n$ ($k = 0.37 \pm 0.02 \times 10^{-1}$, $n = 0.53 \pm 0.03$).



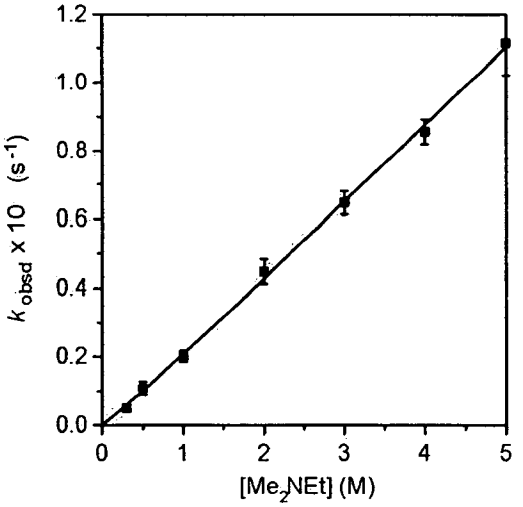
III. Plot of k_{obsd} vs [LiTMP] in THF (9.0 M) and pentane cosolvent for the β-lithiation of 2,3-dimethyl-2-butene oxide (**3**, 0.004 M) at 0 °C. The curve depicts an unweighted least-squares fit to $k_{obsd} = k[\text{LiTMP}]^n$ ($k = 0.37 \pm 0.01 \times 10^{-1}$, $n = 0.70 \pm 0.03$).



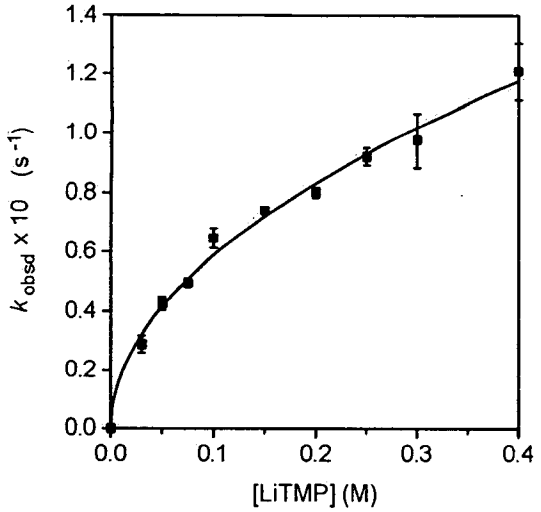
IV. Plot of k_{obsd} vs [THF] in pentane cosolvent for the α-lithiation of *cis*-cyclooctene oxide (**1**, 0.004 M) by LiTMP (0.10 M) at 0 °C. The curve depicts an unweighted least-squares fit to $k_{obsd} = k[\text{THF}]^n$ ($k = 7.6 \pm 0.1 \times 10^{-3}$, $n = -1.07 \pm 0.03$).



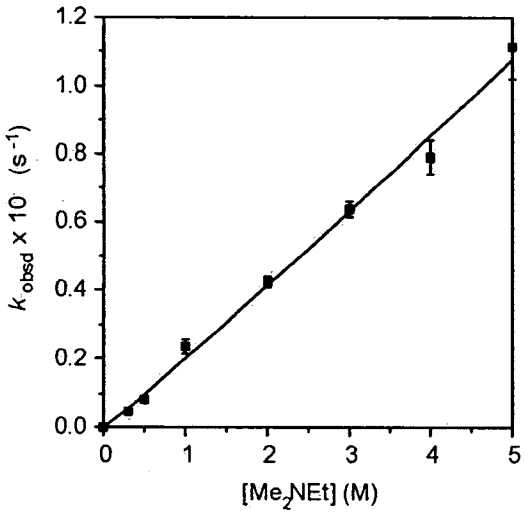
V. Plot of k_{obsd} vs [LiTMP] in THF (5.0 M) and pentane cosolvent for the α-lithiation of *cis*-cyclooctene oxide (**1**, 0.004 M) at 0 °C. The curve depicts an unweighted least-squares fit to $k_{obsd} = k[\text{LiTMP}]^n$ ($k = 1.6 \pm 0.1 \times 10^{-2}$, $n = 0.98 \pm 0.05$).



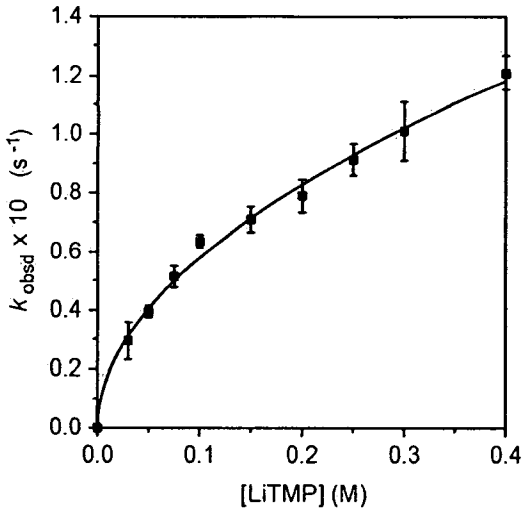
VI. Plot of k_{obsd} vs [Me_2NEt] in pentane cosolvent for the β-lithiation of 2,3-dimethyl-2-butene oxide (**3**, 0.004 M) by LiTMP (0.10 M) at 0 °C. The curve depicts an unweighted least-squares fit to $k_{obsd} = k[Me_2NEt]^n$ ($k = 2.1 \pm 0.1 \times 10^{-2}$, $n = 1.03 \pm 0.03$).



VII. Plot of k_{obsd} vs [LiTMP] in Me_2NEt (3.0 M) and pentane cosolvent for the β-lithiation of 2,3-dimethyl-2-butene oxide (**3**, 0.004 M) at 0 °C. The curve depicts an unweighted least-squares fit to $k_{obsd} = k[\text{LiTMP}]^n$ ($k = 0.18 \pm 0.01$, $n = 0.50 \pm 0.02$).



VIII. Plot of k_{obsd} vs [Me_2NEt] in pentane cosolvent for the α-lithiation of *cis*-cyclooctene oxide (**1**, 0.004 M) by LiTMP (0.10 M) at 0 °C. The curve depicts an unweighted least-squares fit to $k_{obsd} = k[Me_2NEt]^n$ ($k = 2.0 \pm 0.2 \times 10^{-2}$, $n = 1.04 \pm 0.06$).



IX. Plot of k_{obsd} vs [LiTMP] in Me_2NEt (3.0 M) and pentane cosolvent for the α-lithiation of *cis*-cyclooctene oxide (**1**, 0.004 M) at 0 °C. The curve an unweighted least-squares fit to $k_{obsd} = k[\text{LiTMP}]^n$ ($k = 1.9 \pm 0.1 \times 10^{-1}$, $n = 0.51 \pm 0.02$).

X. Table of data for plot in Section I

[THF] (M)	$k_{obsd}1$ (s^{-1})	$k_{obsd}2$ (s^{-1})	k_{obsd} (avg) (s^{-1})
0.50	0.0091 ± 7E-4	0.0090 ± 3E-4	0.0091 ± 1E-4
0.75	0.0092 ± 5E-4	0.0096 ± 8E-4	0.0094 ± 3E-4
1.75	0.0105 ± 8E-4	0.010 ± 1E-3	0.010 ± 1E-3
3.00	0.0080 ± 4E-4	0.0085 ± 7E-4	0.0082 ± 3E-4
7.00	0.0079 ± 8E-4	0.0083 ± 9E-4	0.0081 ± 3E-4
9.00	0.0066 ± 3E-4	0.0071 ± 2E-4	0.0069 ± 3E-4
12.2	0.0057 ± 5E-4	0.0064 ± 5E-4	0.0061 ± 5E-4

XI. Table of data for plot in Section II

[LiTMP] (M)	$k_{obsd}1$ (s^{-1})	$k_{obsd}2$ (s^{-1})	k_{obsd} (avg) (s^{-1})
0.015	0.0039 ± 2E-4	0.0042 ± 2E-4	0.0041 ± 2E-4

0.060	0.0074 ± 3E-4	0.0069 ± 2E-4	0.0071 ± 4E-4
0.10	0.0105 ± 8E-4	0.010 ± 1E-3	0.010 ± 1E-3
0.15	0.0143 ± 5E-4	0.0139 ± 5E-4	0.0139 ± 3E-4
0.20	0.016 ± 1E-3	0.0157 ± 9E-4	0.0159 ± 3E-4
0.25	0.0172 ± 8E-4	0.019 ± 2E-3	0.018 ± 1E-3
0.30	0.019 ± 2E-3	0.020 ± 2E-3	0.0197 ± 3E-4
0.40	0.0215 ± 6E-4	0.022 ± 2E-3	0.0217 ± 3E-4

XII. Table of data for plot in Section III

[LiTMP] (M)	$k_{obsd}1$ (s^{-1})	$k_{obsd}2$ (s^{-1})	k_{obsd} (avg) (s^{-1})
0.015	0.0021 ± 2E-4	0.0023 ± 1E-4	0.0022 ± 1E-4
0.060	0.0044 ± 2E-4	0.0046 ± 2E-4	0.0045 ± 1E-4
0.10	0.0066 ± 3E-4	0.0071 ± 2E-4	0.0069 ± 3E-4
0.15	0.0097 ± 5E-4	0.0099 ± 1E-4	0.0098 ± 1E-4
0.20	0.012 ± 1E-3	0.0127 ± 8E-4	0.0125 ± 2E-4
0.25	0.0147 ± 9E-4	0.015 ± 1E-3	0.0147 ± 1E-4
0.30	0.016 ± 1E-3	0.0157 ± 7E-4	0.0159 ± 3E-4
0.35	0.0185 ± 8E-4	0.018 ± 2E-3	0.0181 ± 5E-4
0.40	0.019 ± 2E-3	0.0187 ± 8E-4	0.0189 ± 3E-4

XIII. Table of data for plot in Section IV

[THF] (M)	$k_{obsd}1$ (s^{-1})	$k_{obsd}2$ (s^{-1})	k_{obsd} (avg) (s^{-1})
0.50	0.015 ± 1E-3	0.017 ± 2E-3	0.016 ± 1E-3
0.75	0.011 ± 1E-3	0.0093 ± 8E-4	0.010 ± 1E-3
1.0	0.0075 ± 8E-4	0.0080 ± 8E-4	0.0078 ± 3E-4
1.5	0.0049 ± 3E-4	0.0050 ± 5E-4	0.0049 ± 1E-4
3.0	0.0022 ± 1E-4	0.0021 ± 1E-4	0.0021 ± 1E-4
5.0	0.00173 ± 7E-5	0.0018 ± 2E-4	0.00177 ± 6E-5
6.9	0.00094 ± 7E-5	0.00097 ± 1E-5	0.00096 ± 2E-5
12.2	0.00064 ± 6E-5	0.00060 ± 4E-5	0.00062 ± 3E-5

XIV. Table of data for plot in Section V

[LiTMP] (M)	$k_{obsd}1$ (s^{-1})	$k_{obsd}2$ (s^{-1})	k_{obsd} (avg) (s^{-1})
0.05	0.00054 ± 5E-5	0.00059 ± 5E-5	0.00057 ± 4E-5
0.10	0.00173 ± 7E-5	0.0018 ± 2E-4	0.00177 ± 6E-5
0.15	0.0025 ± 2E-4	0.0026 ± 1E-4	0.00252 ± 8E-5
0.20	0.0028 ± 2E-4	0.0031 ± 2E-4	0.0030 ± 2E-4
0.25	0.0039 ± 1E-4	0.0043 ± 3E-4	0.0041 ± 3E-4
0.30	0.0047 ± 5E-4	0.0052 ± 4E-4	0.0050 ± 3E-4
0.40	0.0059 ± 6E-4	0.0066 ± 5E-4	0.0063 ± 5E-4

XV. Table of data for plot in Section VI

[Me_2NEt] (M)	$k_{obsd}1$ (s^{-1})	$k_{obsd}2$ (s^{-1})	k_{obsd} (avg) (s^{-1})
0.30	0.0045 ± 5E-4	0.0056 ± 6E-4	0.0050 ± 8E-4
0.50	0.0095 ± 8E-4	0.012 ± 1E-3	0.011 ± 2E-3
1.00	0.019 ± 2E-3	0.021 ± 2E-3	0.020 ± 2E-3
2.00	0.042 ± 3E-3	0.047 ± 5E-3	0.045 ± 3E-3
3.00	0.062 ± 5E-3	0.067 ± 5E-3	0.065 ± 3E-3
4.00	0.09 ± 1E-2	0.083 ± 7E-3	0.086 ± 4E-3
5.00	0.10 ± 1E-2	0.12 ± 1E-2	0.111 ± 9E-3

XVI. Table of data for plot in Section VII

[LiTMP] (M)	$k_{obsd}1$ (s^{-1})	$k_{obsd}2$ (s^{-1})	k_{obsd} (avg) (s^{-1})
0.030	0.027 ± 3E-3	0.031 ± 3E-3	0.029 ± 3E-3
0.050	0.044 ± 3E-3	0.041 ± 3E-3	0.043 ± 2E-3
0.075	0.0488 ± 9E-4	0.051 ± 4E-3	0.050 ± 1E-3
0.10	0.062 ± 5E-3	0.067 ± 5E-3	0.065 ± 3E-3

0.15	0.073 ± 7E-3	0.075 ± 7E-3	0.074 ± 1E-3
0.20	0.079 ± 8E-3	0.081 ± 6E-3	0.080 ± 2E-3
0.25	0.09 ± 1E-2	0.09 ± 1E-2	0.09 ± 3E-3
0.30	0.091 ± 8E-3	0.10 ± 1E-2	0.097 ± 9E-3
0.40	0.13 ± 1E-2	0.11 ± 1E-2	0.12 ± 1E-2

XVII. Table of data for plot in Section VIII

[Me_2NEt] (M)	$k_{obsd}1$ (s^{-1})	$k_{obsd}2$ (s^{-1})	k_{obsd} (avg) (s^{-1})
0.30	0.0043 ± 5E-4	0.0052 ± 6E-4	0.0047 ± 6E-4
0.50	0.0087 ± 6E-4	0.0081 ± 6E-4	0.0084 ± 4E-4
1.00	0.022 ± 1E-3	0.025 ± 2E-3	0.023 ± 2E-3
2.00	0.041 ± 3E-3	0.043 ± 2E-3	0.042 ± 2E-3
3.00	0.062 ± 4E-3	0.065 ± 6E-3	0.064 ± 2E-3
4.00	0.076 ± 7E-3	0.082 ± 7E-3	0.079 ± 5E-3
5.00	0.12 ± 1E-2	0.105 ± 8E-3	0.111 ± 9E-3

XVIII. Table of data for plot in Section IX

[LiTMP] (M)	$k_{obsd}1$ (s^{-1})	$k_{obsd}2$ (s^{-1})	k_{obsd} (avg) (s^{-1})
0.030	0.025 ± 3E-3	0.034 ± 3E-3	0.029 ± 6E-3
0.050	0.038 ± 4E-3	0.041 ± 3E-3	0.040 ± 2E-3
0.075	0.049 ± 5E-3	0.054 ± 5E-3	0.051 ± 4E-3
0.10	0.062 ± 4E-3	0.065 ± 6E-3	0.064 ± 2E-3
0.15	0.068 ± 7E-3	0.074 ± 7E-3	0.071 ± 4E-3
0.20	0.075 ± 7E-3	0.083 ± 9E-3	0.079 ± 6E-3
0.25	0.087 ± 9E-3	0.095 ± 9E-3	0.091 ± 5E-3
0.30	0.09 ± 1E-2	0.108 ± 9E-3	0.10 ± 1E-2
0.40	0.12 ± 1E-2	0.12 ± 1E-2	0.12 ± 1E-2

XIX. Table of data for k_{obsd} in various ligands (0.5 M) and pentane cosolvent for the β-lithiation of 2,3-dimethyl-2-butene oxide (**3**, 0.004 M) at 0 °C.

	$k_{obsd}1$ (s^{-1})	$k_{obsd}2$ (s^{-1})	k_{obsd} (avg) (s^{-1})
THF	0.0091 ± 7E-4	0.0090 ± 3E-4	0.0091 ± 1E-4
Me_2NEt	0.0095 ± 8E-4	0.012 ± 1E-3	0.011 ± 2E-3
2,2-Me_2THF	0.00346 ± 8E-5	0.0037 ± 4E-4	0.0036 ± 1E-4
n-BuOMe	0.0054 ± 3E-4	0.0060 ± 5E-4	0.0057 ± 4E-4
t-BuOMe	0.00193 ± 8E-5	0.0018 ± 2E-4	0.00188 ± 6E-5
Et_3N	0.00097 ± 7E-5	0.0009 ± 1E-4	0.00093 ± 6E-5
n-Pr_3N	0.00042 ± 5E-5	0.00047 ± 5E-5	0.00044 ± 4E-5
$MeOCH_2CH_2NMe_2$	0.022 ± 2E-3	0.020 ± 1E-3	0.021 ± 1E-3

XX. Table of data for k_{obsd} in various ligands (0.5 M) and pentane cosolvent for the α-lithiation of *cis*-cyclooctene oxide (**1**, 0.004 M) at 0 °C.

	$k_{obsd}1$ (s^{-1})	$k_{obsd}2$ (s^{-1})	k_{obsd} (avg) (s^{-1})
THF	0.015 ± 1E-3	0.017 ± 2E-3	0.016 ± 1E-3
Me_2NEt	0.0087 ± 6E-4	0.0081 ± 6E-4	0.0084 ± 4E-4
2,2-Me_2THF	0.0071 ± 7E-4	0.0075 ± 8E-4	0.0073 ± 3E-4
n-BuOMe	0.00771 ± 7E-5	0.0069 ± 1E-4	0.0073 ± 5E-4
t-BuOMe	0.0034 ± 1E-4	0.00312 ± 8E-5	0.0033 ± 2E-4
Et_3N	0.0013 ± 1E-4	0.0015 ± 1E-4	0.0014 ± 1E-4
n-Pr_3N	0.00115 ± 7E-5	0.0013 ± 1E-4	0.00120 ± 1E-4
$MeOCH_2CH_2NMe_2$	0.0072 ± 5E-4	0.0077 ± 2E-4	0.0075 ± 3E-4

XXI. Calculated energies of reactants and transition structures for the β- and α-lithiation of *cis*-2,3-butene oxide using Gaussian 98W at the B3LYP level of density functional theory with the 6-31(d) basis set.

	E (Hartrees)
Cis-2,3-butene oxide	-232.30846
Me_2O	-154.94045
Me_3N	-174.34784
$(Me_2NLi)_2(Me_2O)_2$	-594.01449
$(Me_2NLi)_4$	-568.21992
16; $[(Me_2NLi)(Me_2O)(\mathbf{15})]^{\ddagger}$	-529.28830
17; $[(Me_2NLi)(Me_2O)(\mathbf{15})]^{\ddagger}$	-529.28004
18; $[(Me_2NLi)(Me_3N)(\mathbf{15})]^{\ddagger}$	-548.69440
19; $[(Me_2NLi)(Me_3N)(\mathbf{15})]^{\ddagger}$	-548.68676
20; $[(Me_2NLi)_2(Me_2O)(\mathbf{15})]^{\ddagger}$	-671.34230
21; $[(Me_2NLi)_2(Me_2O)(\mathbf{15})]^{\ddagger}$	-671.34470
22; $[(Me_2NLi)_2(Me_2O)(\mathbf{15})]^{\ddagger}$	-671.34342
23; $[(Me_2NLi)_2(Me_2O)(\mathbf{15})]^{\ddagger}$	-671.34729
24; $[(Me_2NLi)_2(Me_2O)(\mathbf{15})]^{\ddagger}$	-671.34715
25; $[(Me_2NLi)_2(Me_3N)(\mathbf{15})]^{\ddagger}$	-690.75123
26; $[(Me_2NLi)_2(Me_3N)(\mathbf{15})]^{\ddagger}$	-690.75317
27; $[(Me_2NLi)_2(Me_3N)(\mathbf{15})]^{\ddagger}$	-690.75741