

Frustrated Lewis Pairs Catalyzed Asymmetric Metal-Free Hydrogenations and Hydrosilylations

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Supervisor: Prof. Yong Huang

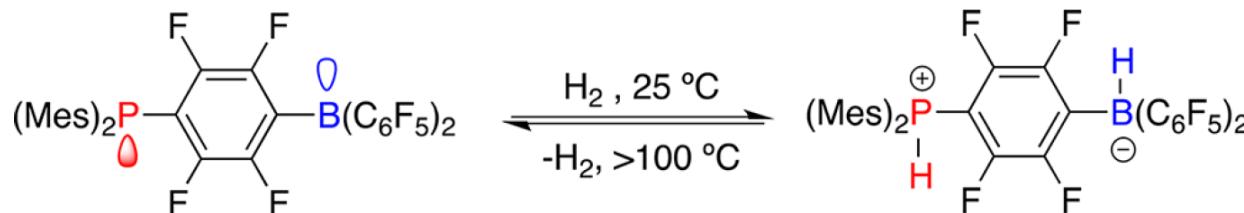
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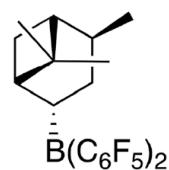
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- 2. Chiral **Diene**-derived Boron Lewis Acids
 - 2.1 Hydrogenation of Imines and Silyl Enol Ethers
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- 5. Summary

1. Frustrated Lewis Pairs (FLPs) in hydrogenation

- Heterolytic cleavage of H-H

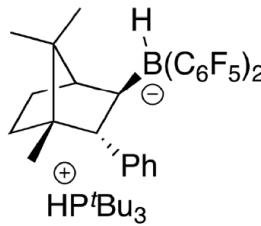


- Representative catalysts for asymmetric hydrogenation and hydrosilylation



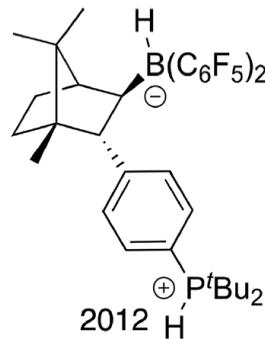
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Klankmayer, J.



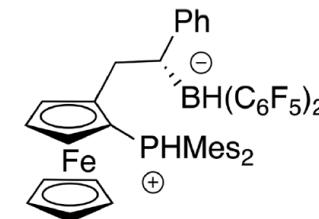
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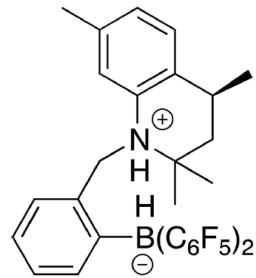
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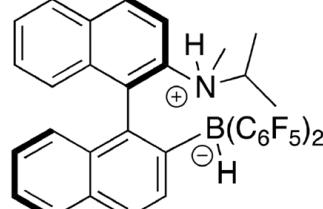
2017

Erker, G.



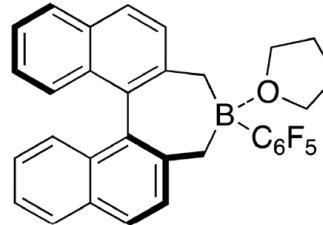
2011

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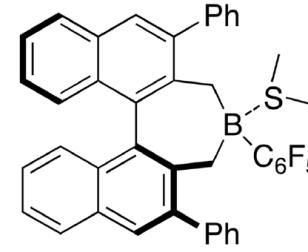
2015

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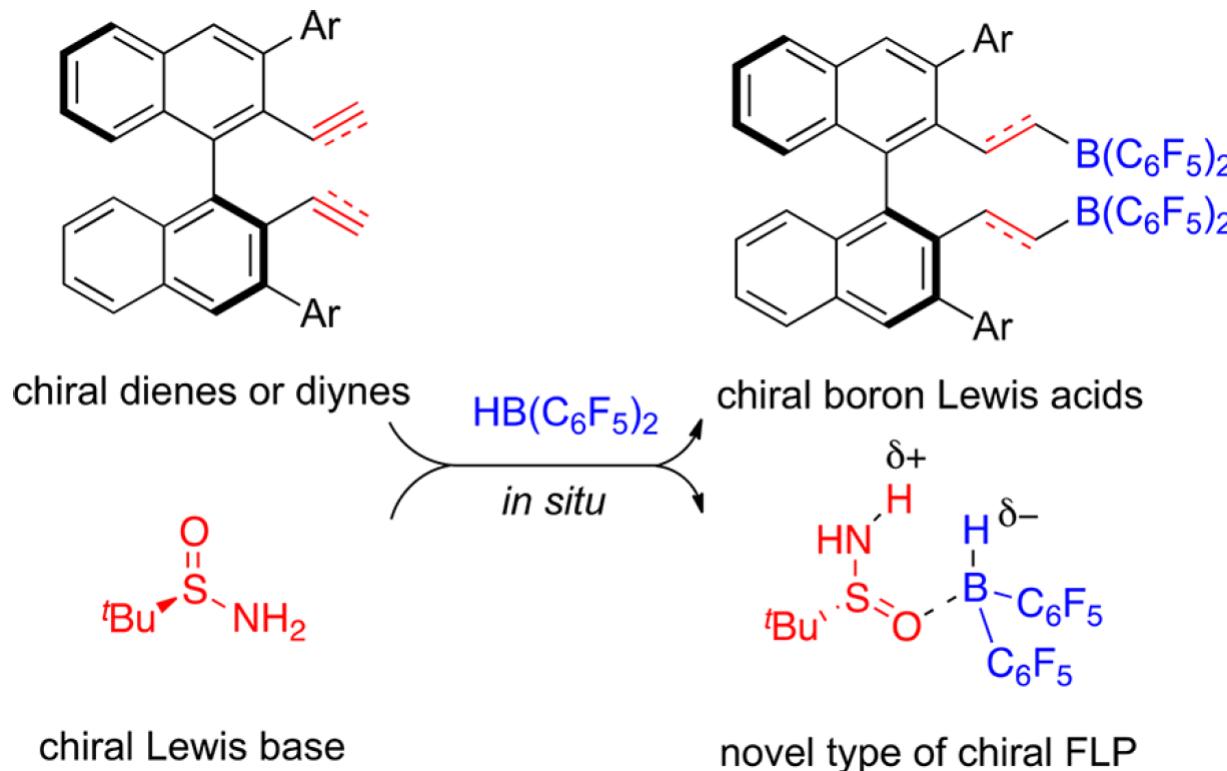
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2016

Oestreich, M.

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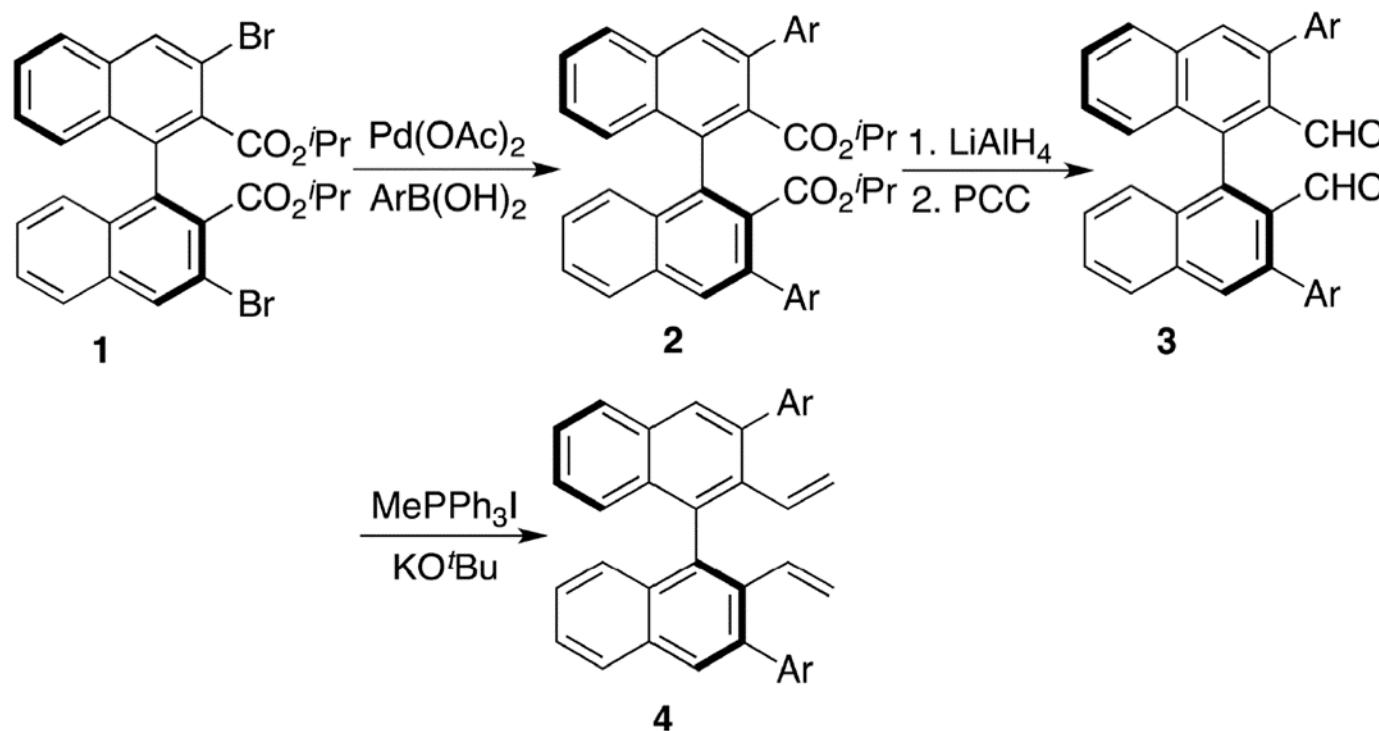


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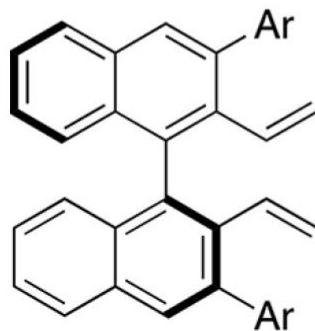
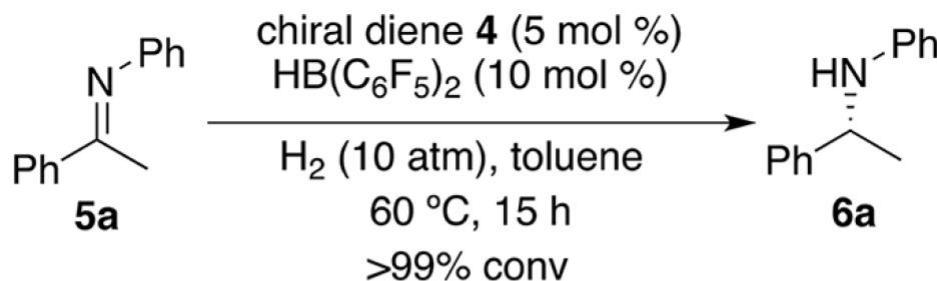
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2. Chiral Diene-derived Boron Lewis Acids

- Synthesis of Chiral Dienes

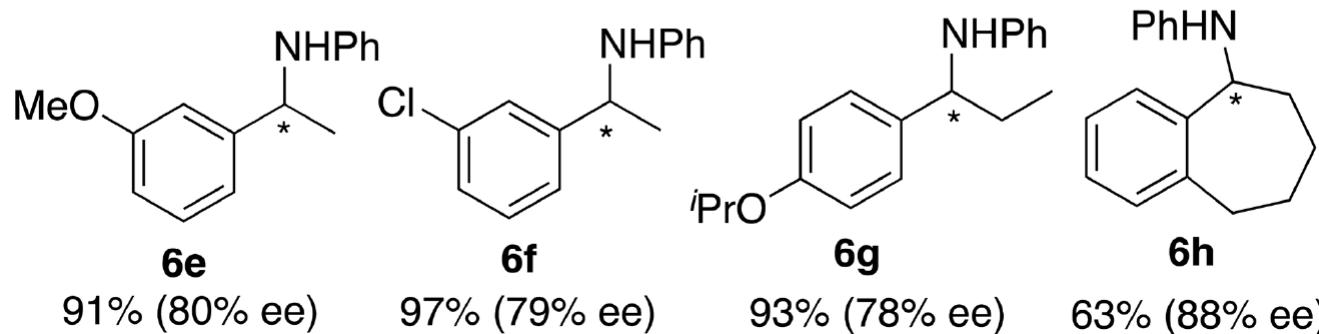
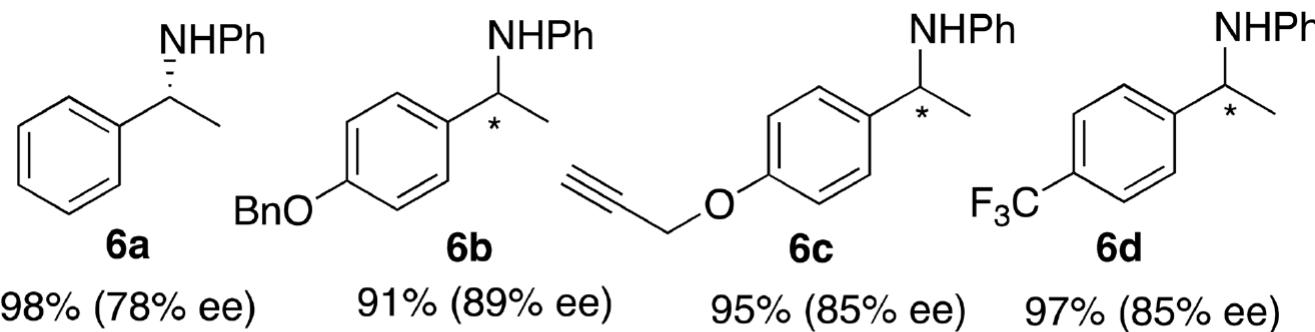
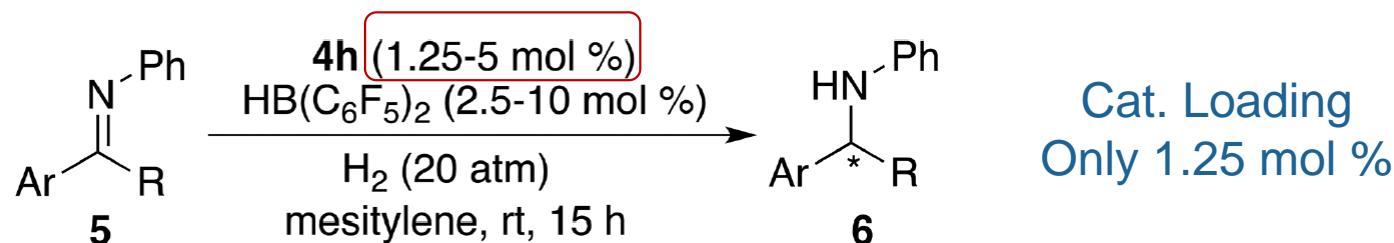


2.1. Hydrogenation of Imines and Silyl Enol Ethers

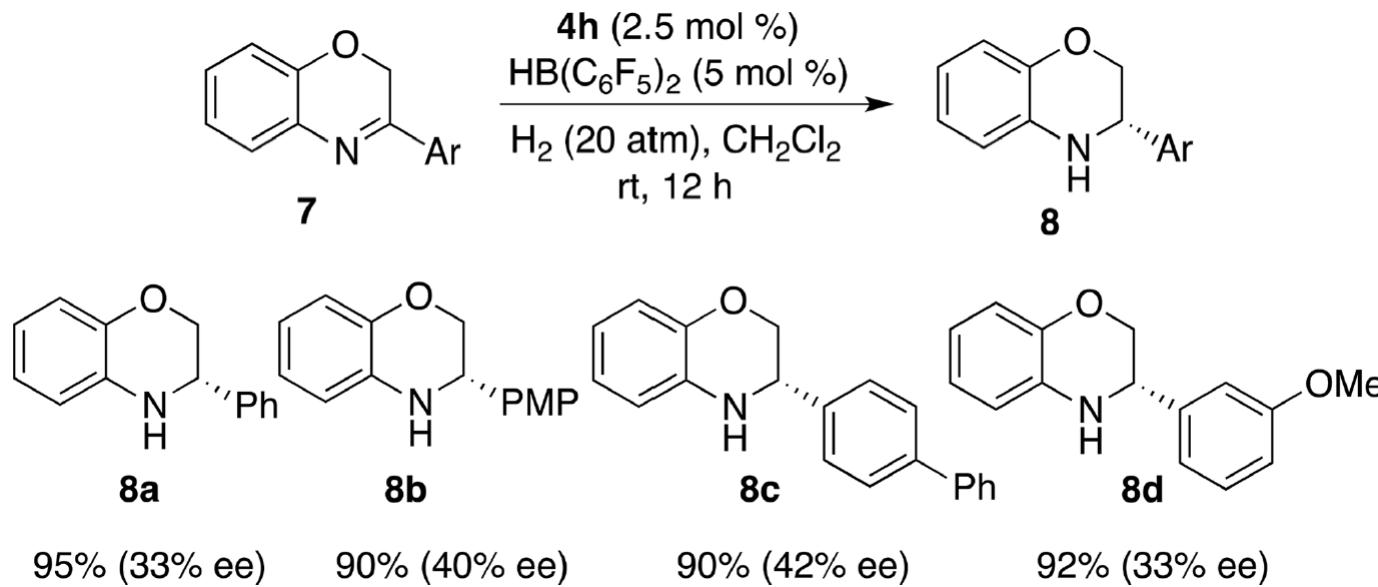


4a: Ar = 4-MeC ₆ H ₄	20% ee
4b: Ar = 4- <i>t</i> BuC ₆ H ₄	16% ee
4c: Ar = 4-MeOC ₆ H ₄	17% ee
4d: Ar = 3-MeC ₆ H ₄	22% ee
4e: Ar = 2-MeOC ₆ H ₄	26% ee
4f: Ar = 2,4,6-Me ₃ C ₆ H ₂	25% ee
4g: Ar = 3,5- <i>t</i> Bu ₂ C ₆ H ₃	40% ee
4h: Ar = 3,5-(3,5- <i>t</i> Bu ₂ C ₆ H ₃) ₂ C ₆ H ₃	60% ee

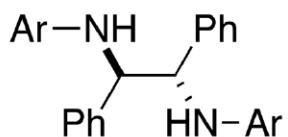
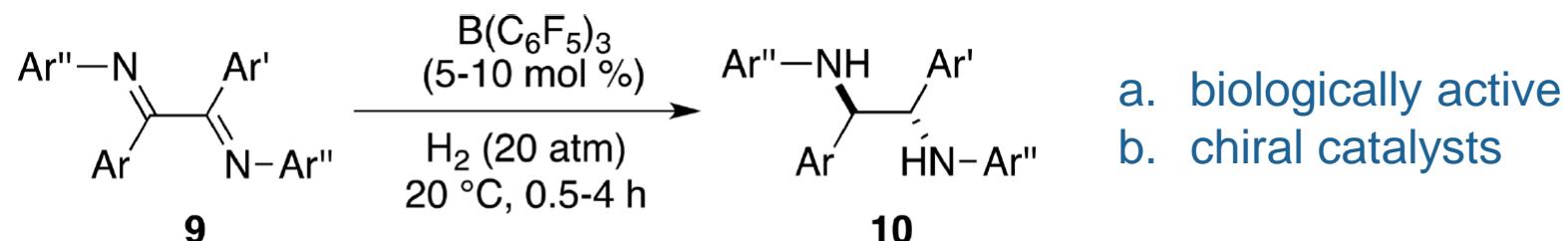
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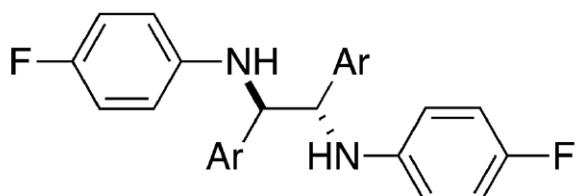
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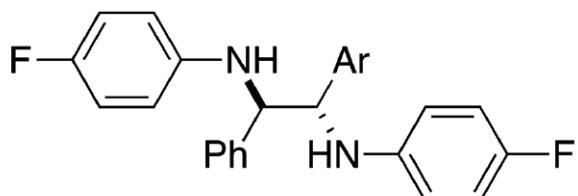
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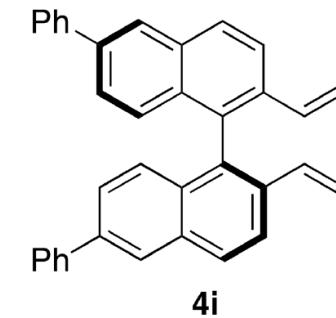
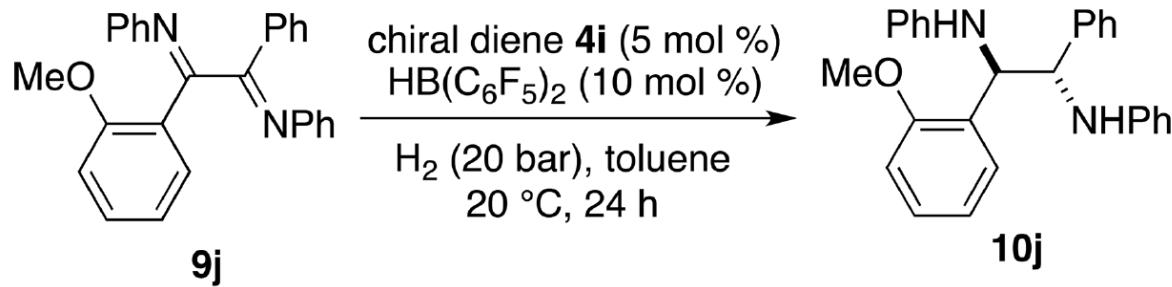
10a: Ar = Ph, 94%
10b: Ar = 2-MeC₆H₄, 95%
10c: Ar = 4-FC₆H₄, 98%



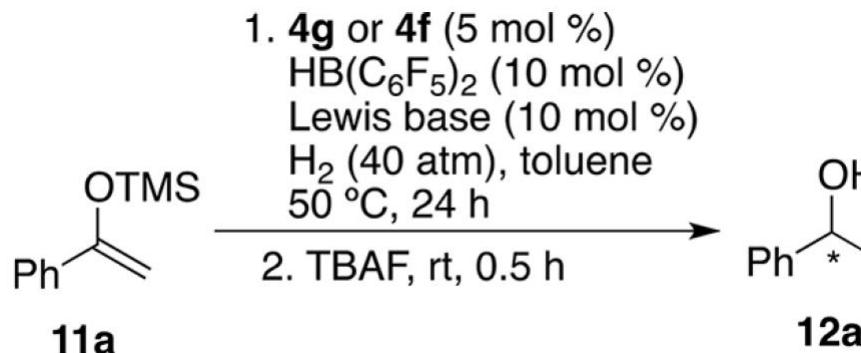
10d: Ar = 4-MeC₆H₄, 99%
10e: Ar = 4-BrC₆H₄, 97%
10f: Ar = 3-MeOC₆H₄, 99%

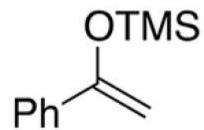
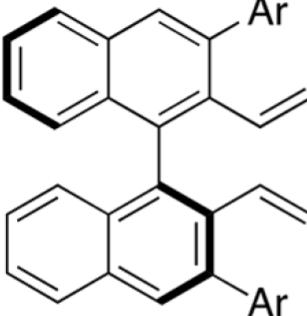
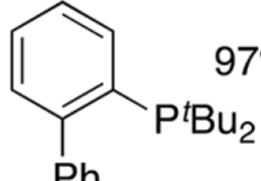


10g: Ar = 4-CF₃C₆H₄, 95%
10h: Ar = 3-FC₆H₄, 97%
10i: Ar = 2-MeOC₆H₄, 99%

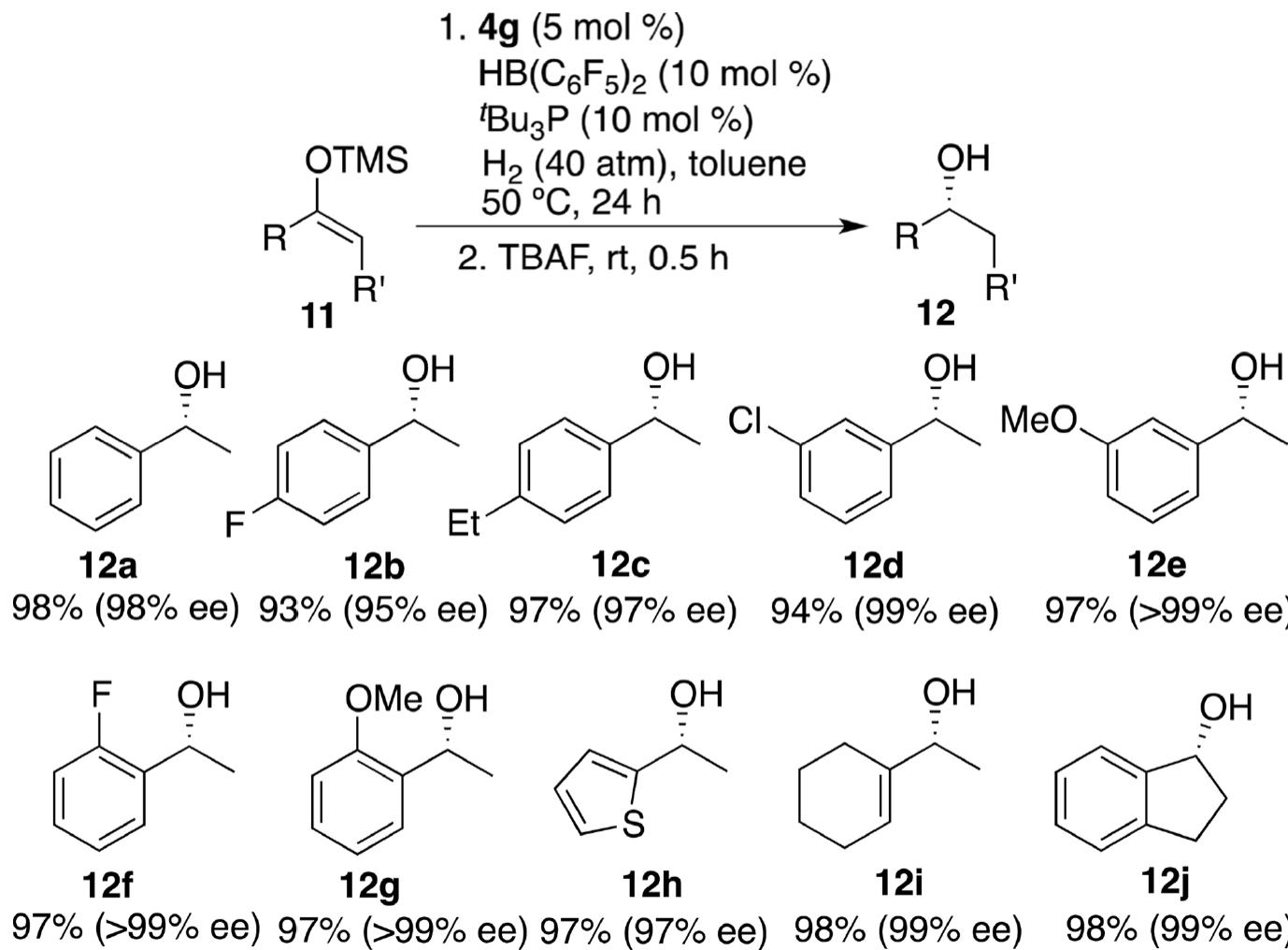


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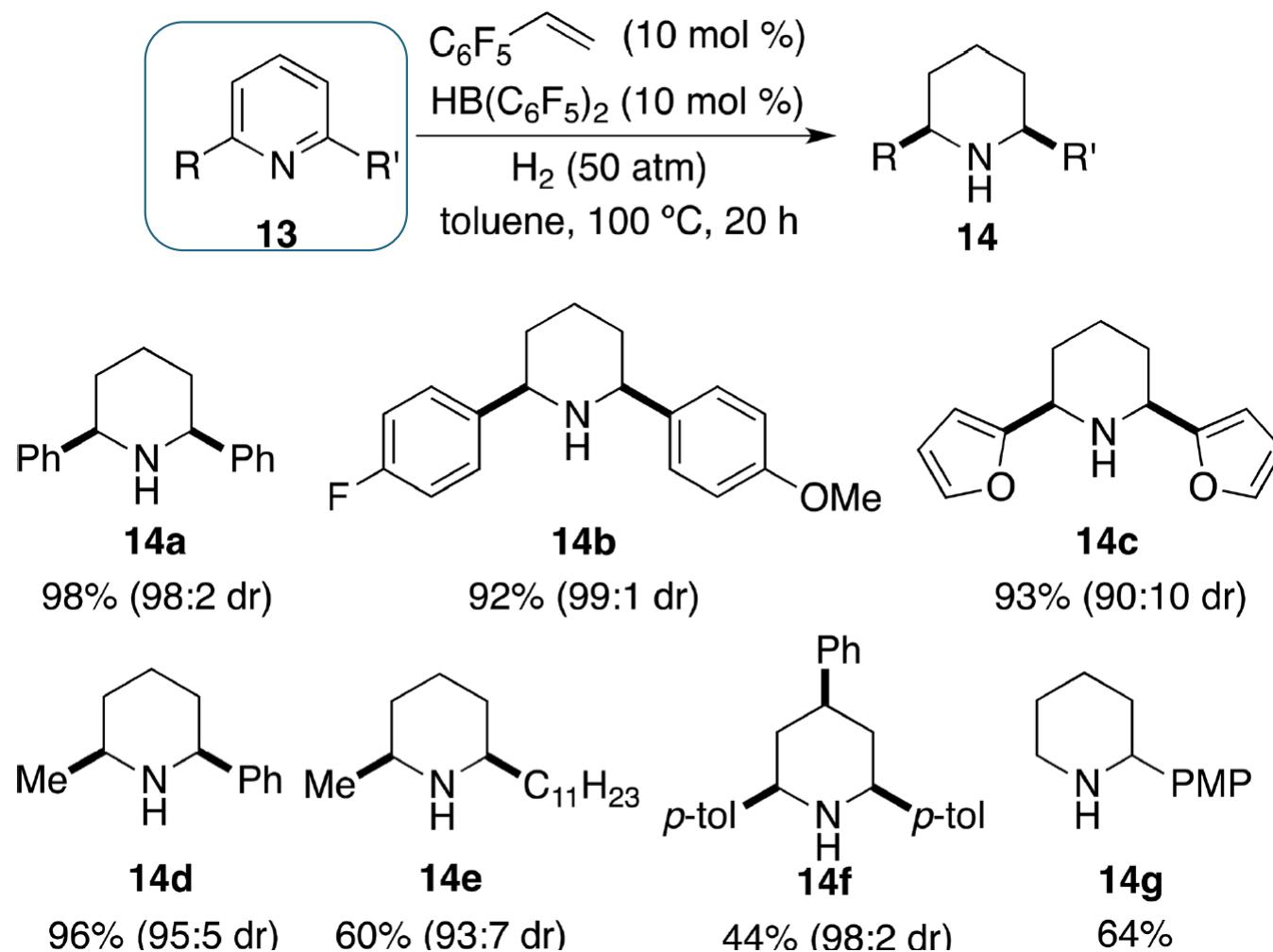


		Lewis base	
	11a	none	no reaction
		Mes ₃ P	no reaction
			97% conv (90% ee)
		Cy ₃ P	90% conv (93% ee)
4g: Ar = 3,5- <i>t</i> Bu ₂ C ₆ H ₃		<i>t</i> Bu ₃ P	>99% conv (98% ee)
4f: Ar = 2,4,6-Me ₃ C ₆ H ₂		<i>t</i> Bu ₃ P	>99% conv (-94% ee)

2.1. Hydrogenation of Imines and Silyl Enol Ethers



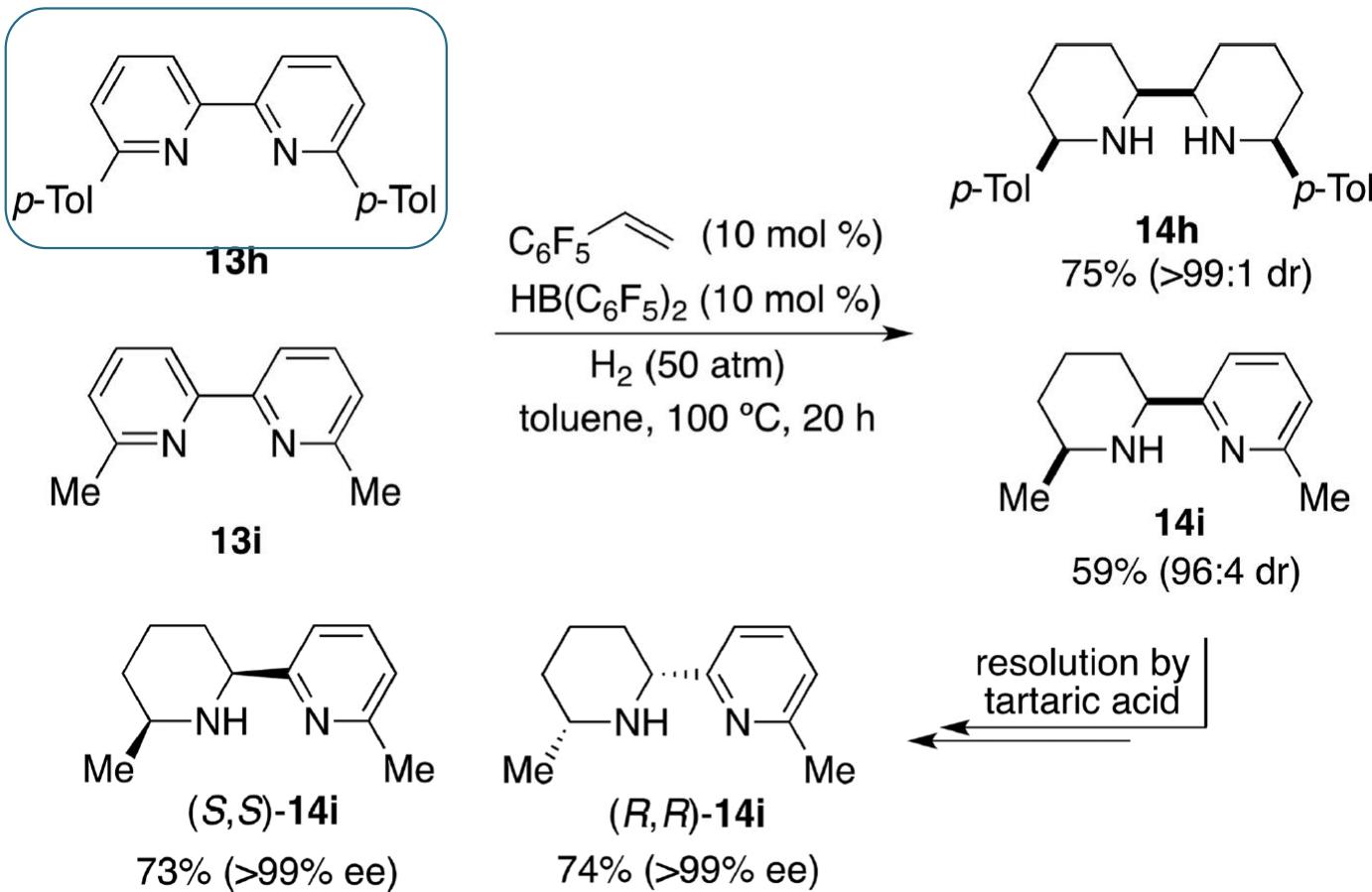
2.2. Hydrogenation of N-Heteroarenes



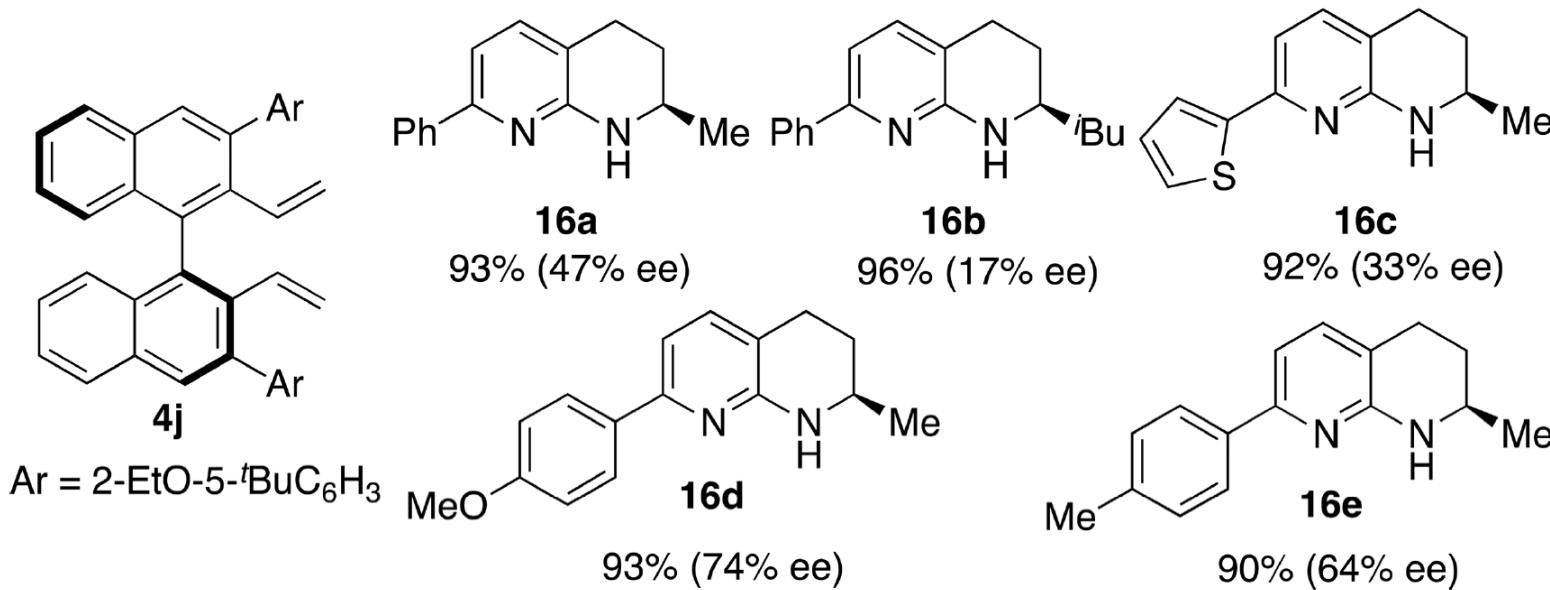
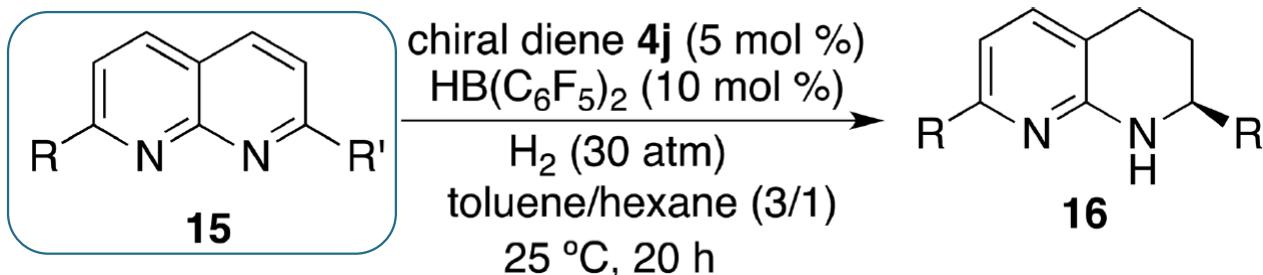
Liu, Y.; Du, H. *J. Am. Chem. Soc.* **2013**, 135, 12968–12971

Zhao, J.; Wang, G.; Li, S. *Dalton Trans.* **2015**, 44, 9200–9208

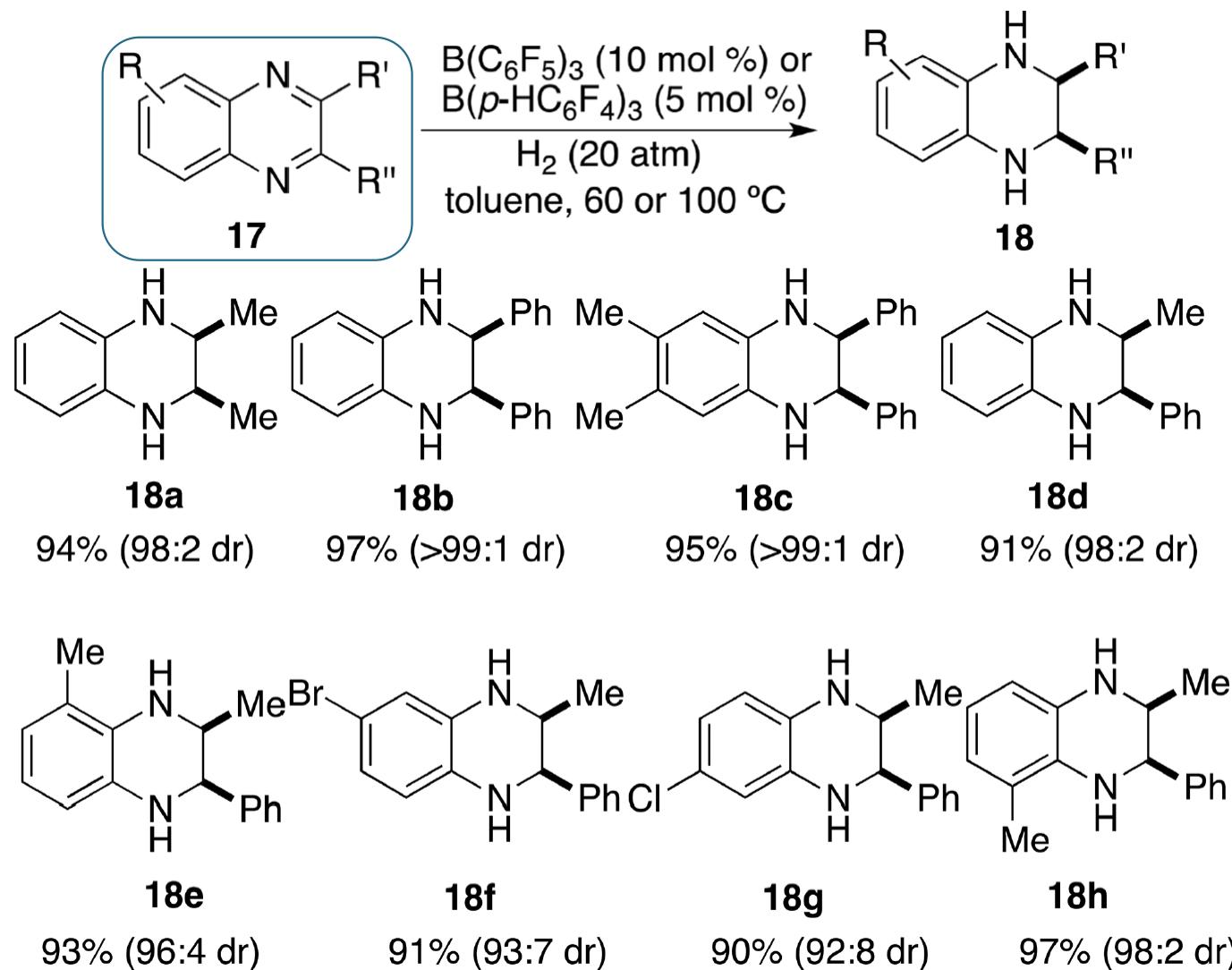
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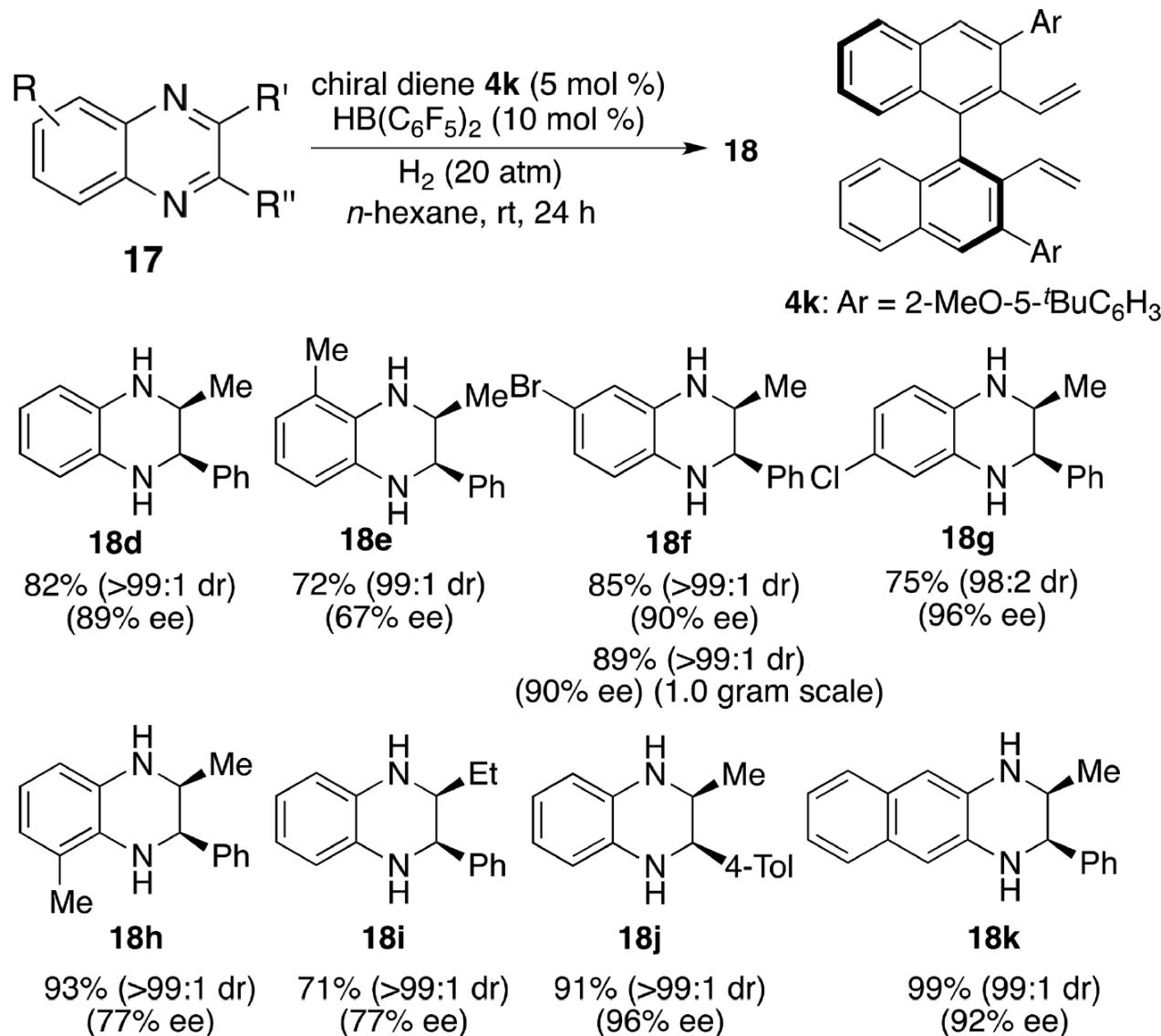
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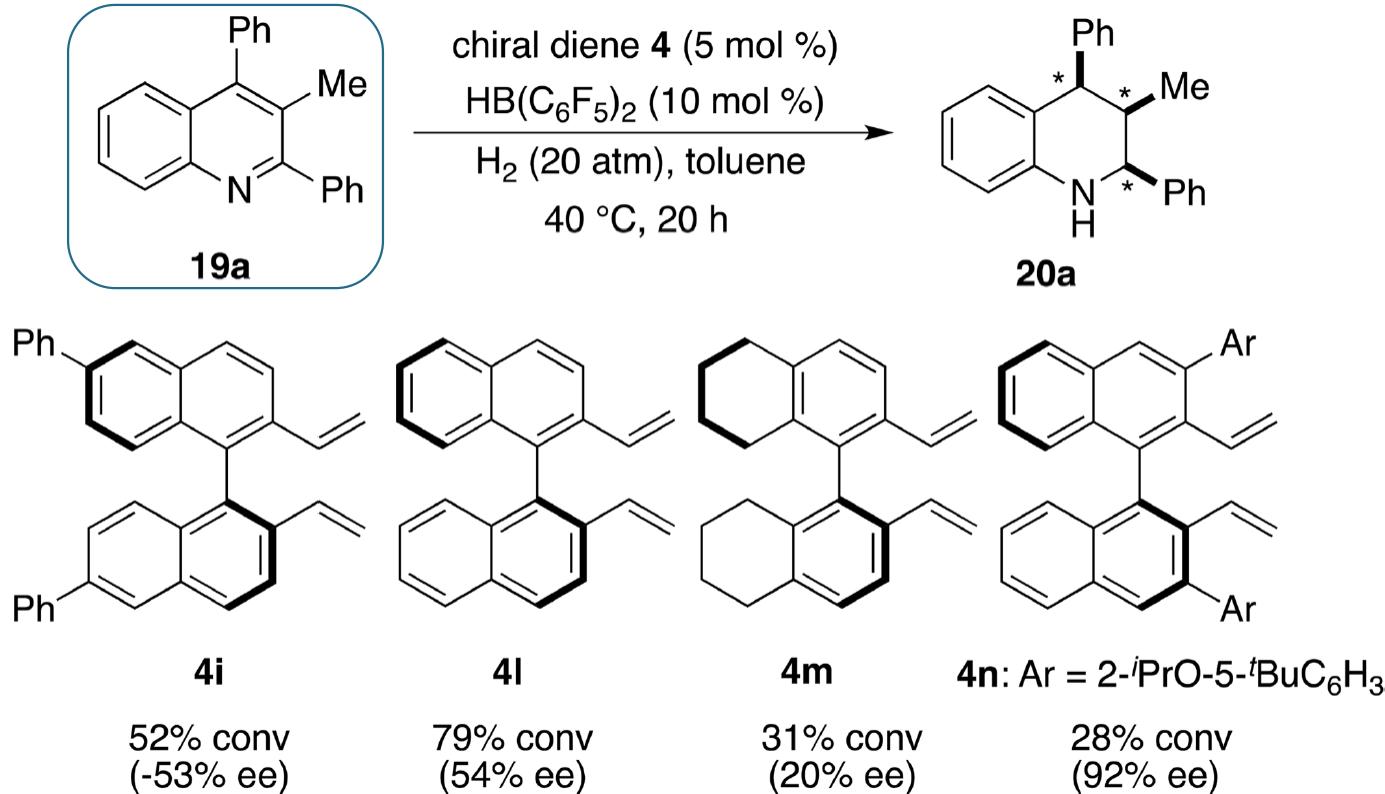
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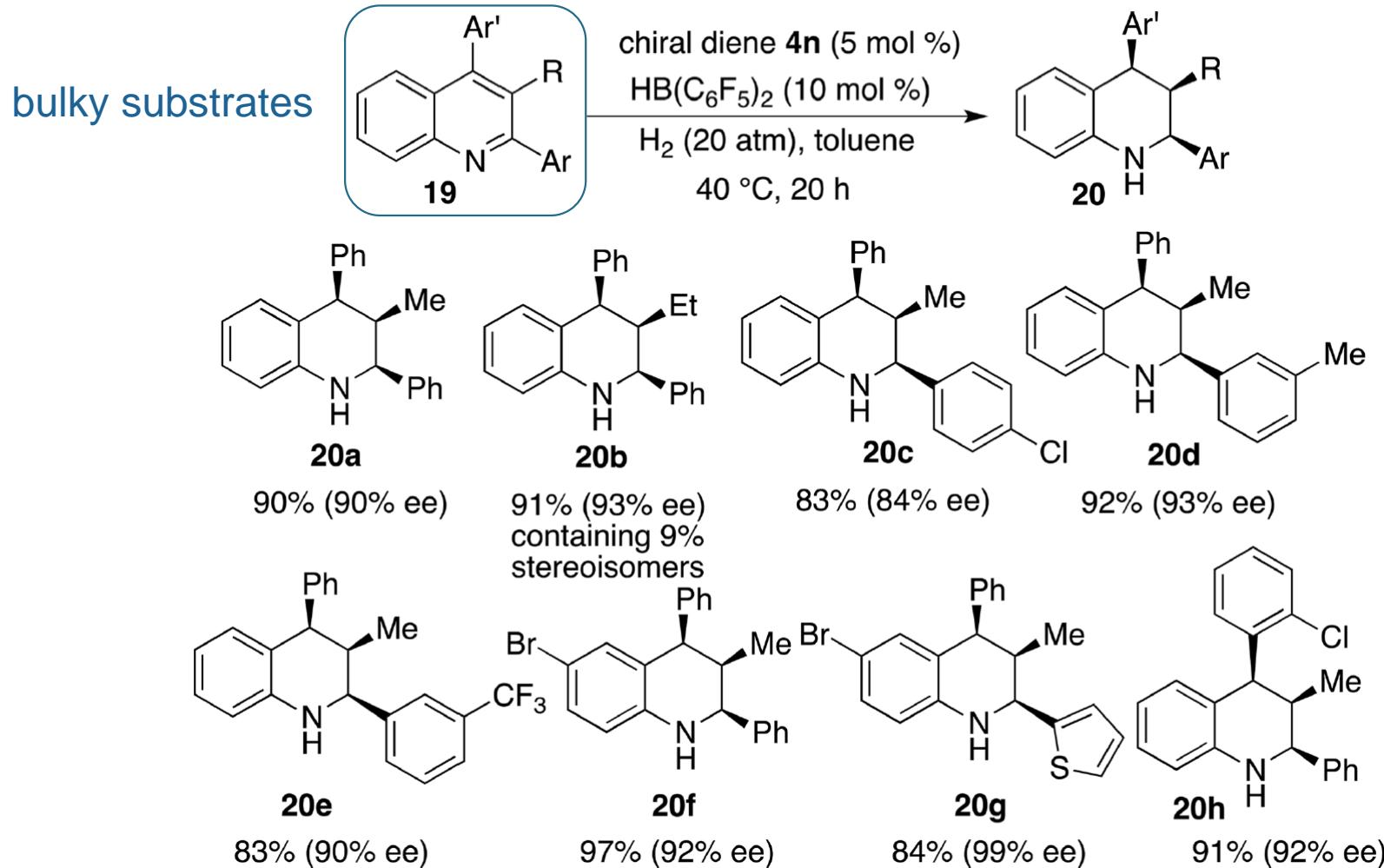
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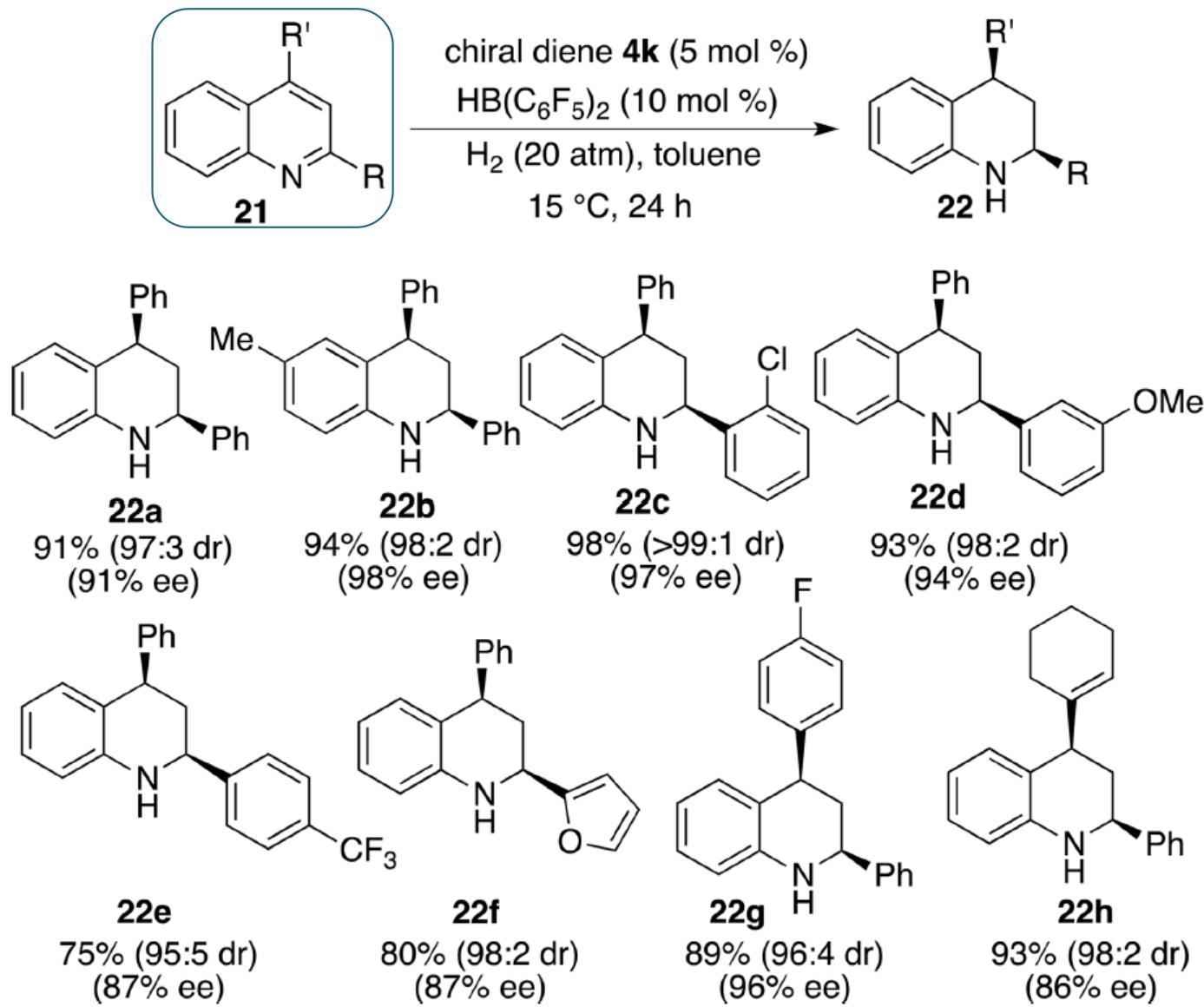
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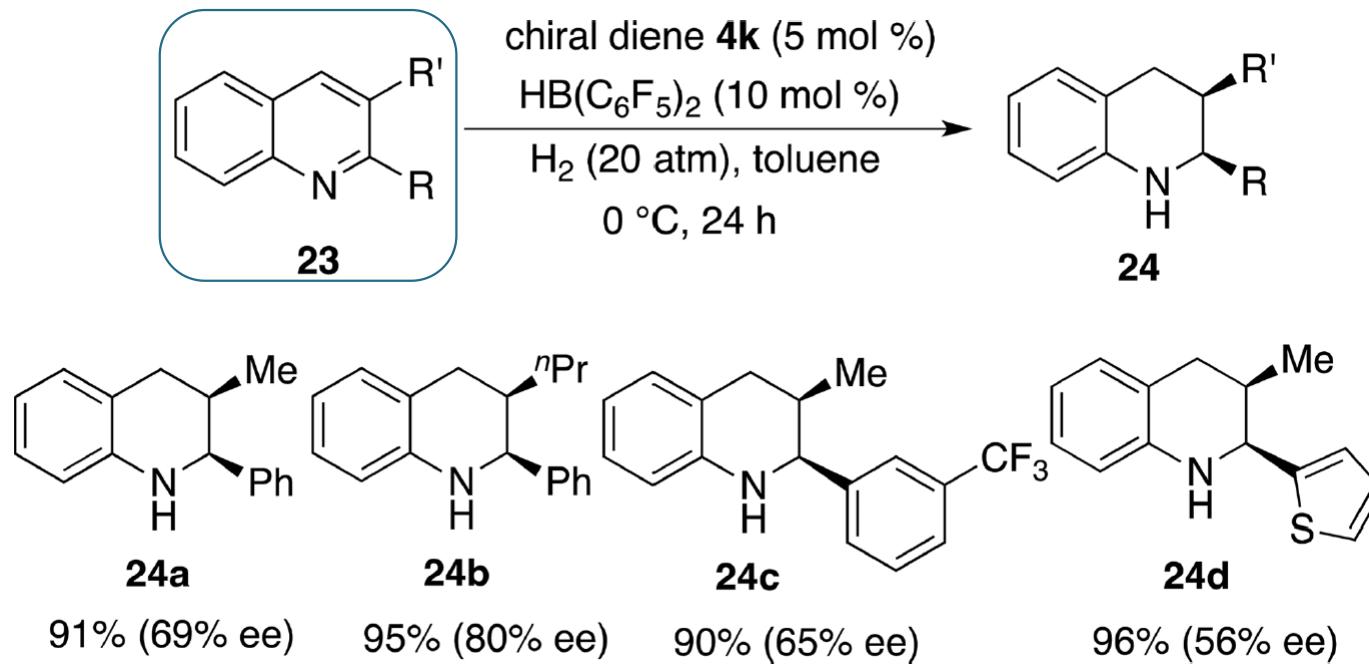
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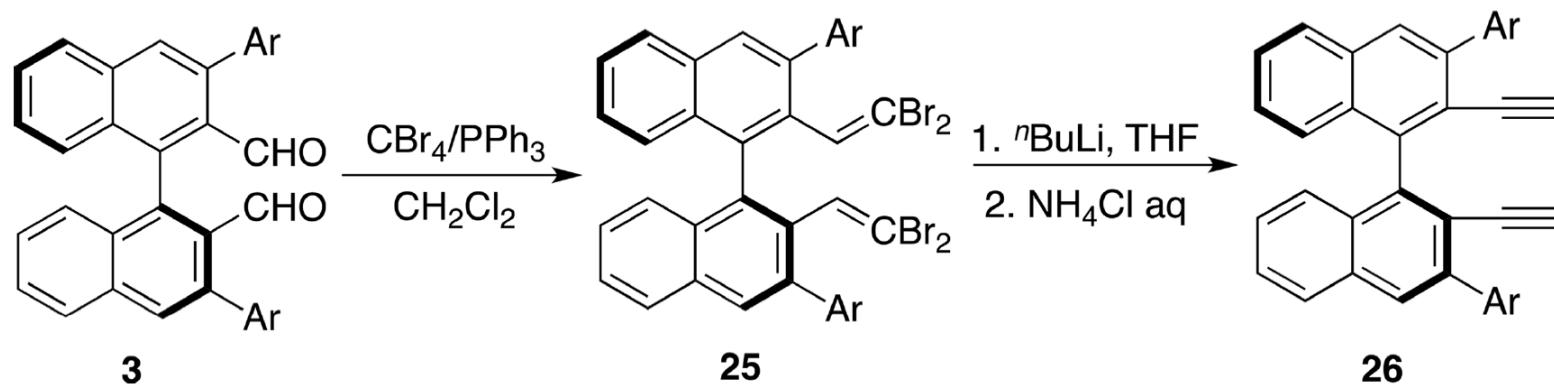
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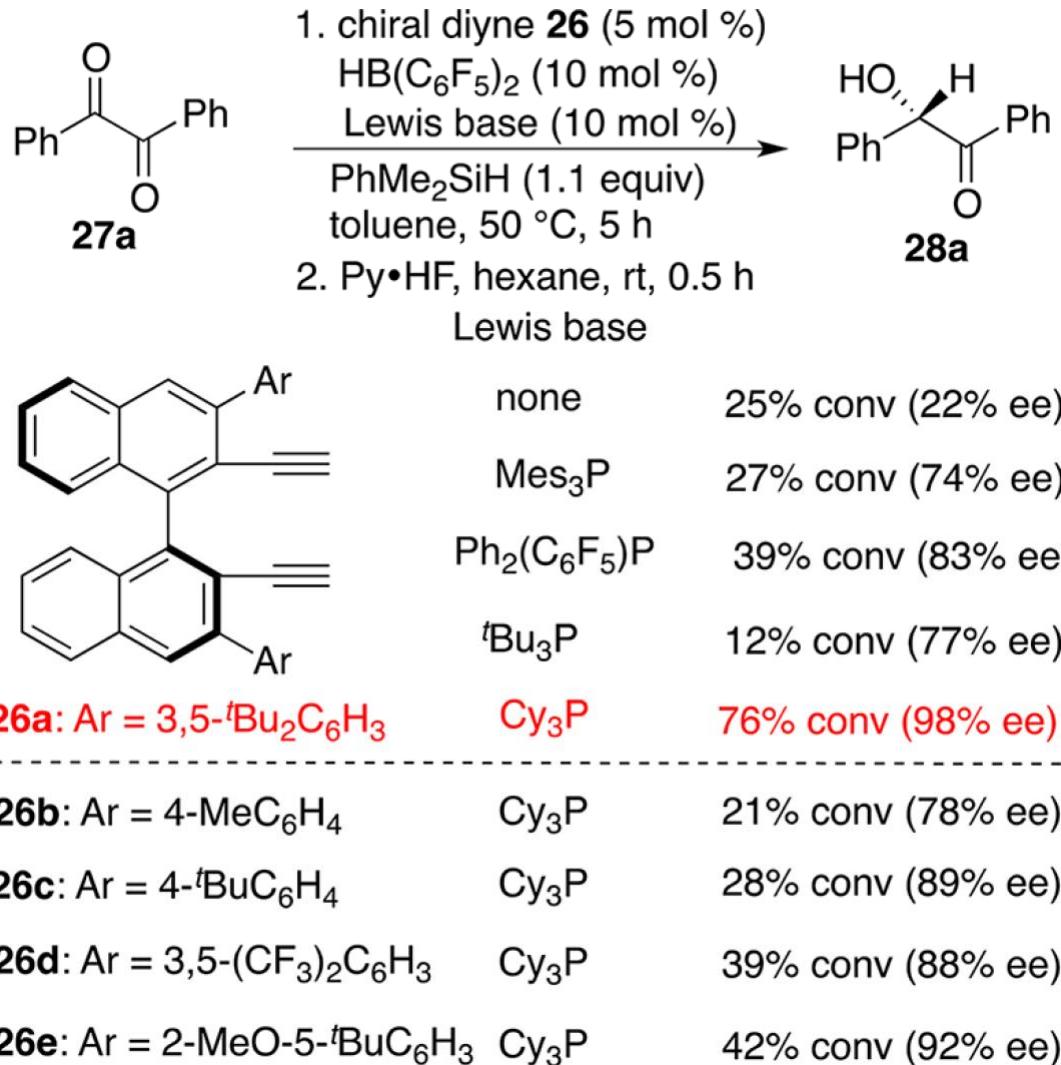
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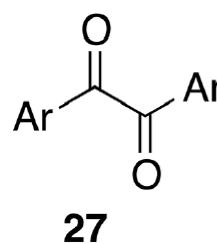
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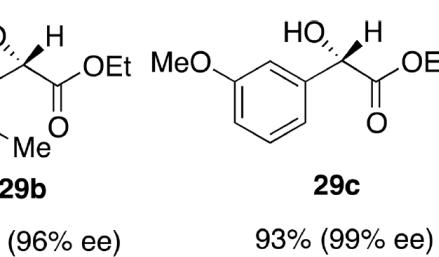
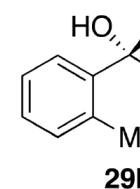
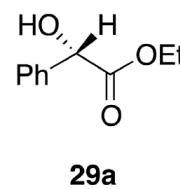
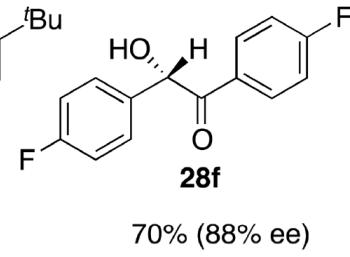
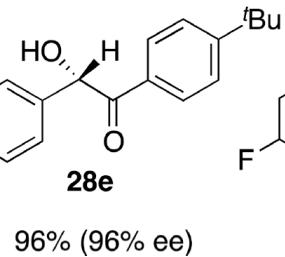
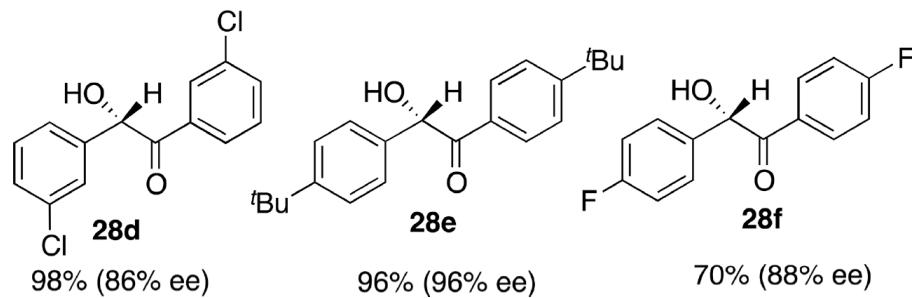
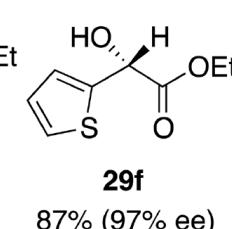
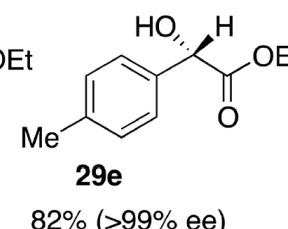
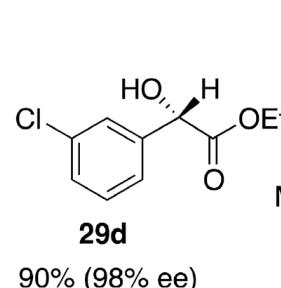
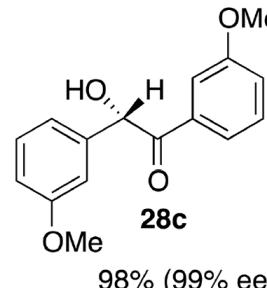
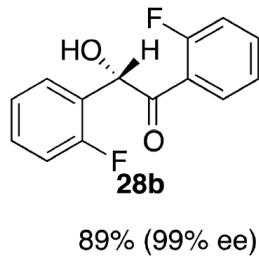
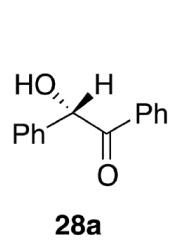
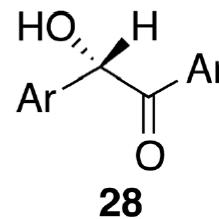
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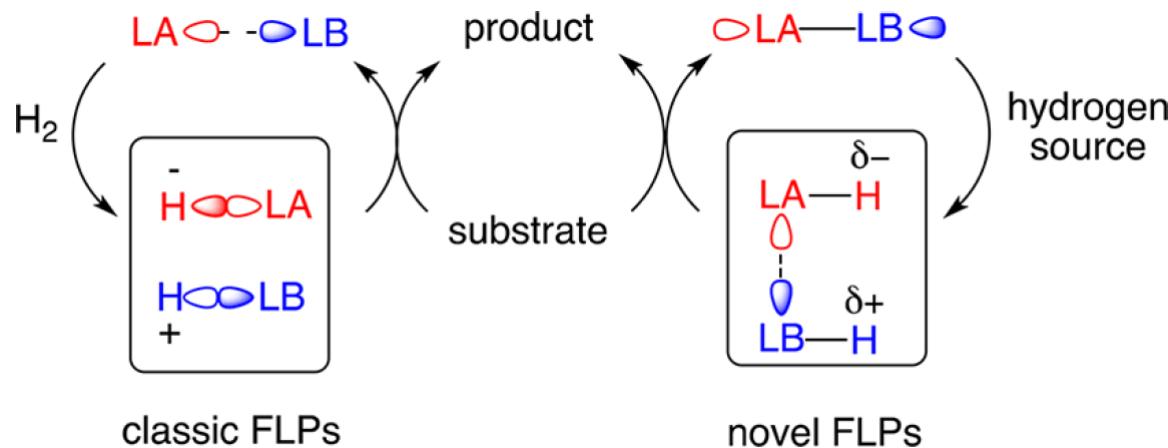
1. chiral diyne **26a** (5 mol %)
HB(C₆F₅)₂ (10 mol %)
Cy₃P (10 mol %)
PhMe₂SiH (3.0 equiv)
toluene, 60 °C, 5 h
2. Py•HF, hexane, rt, 0.5 h



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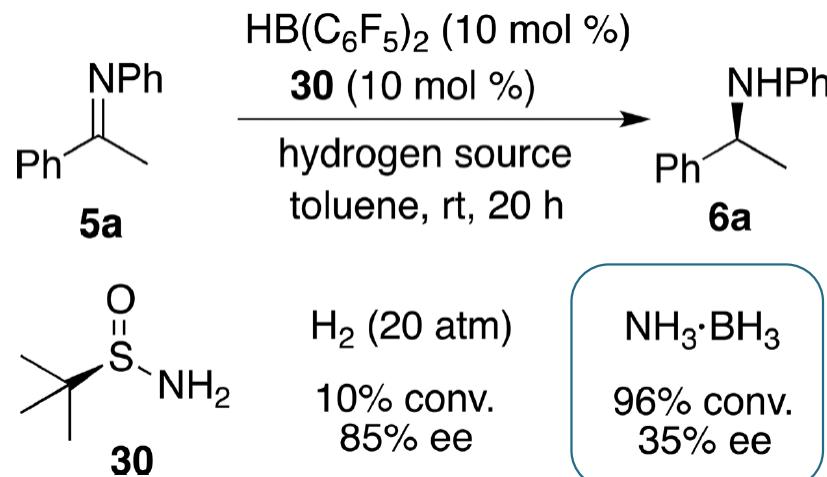
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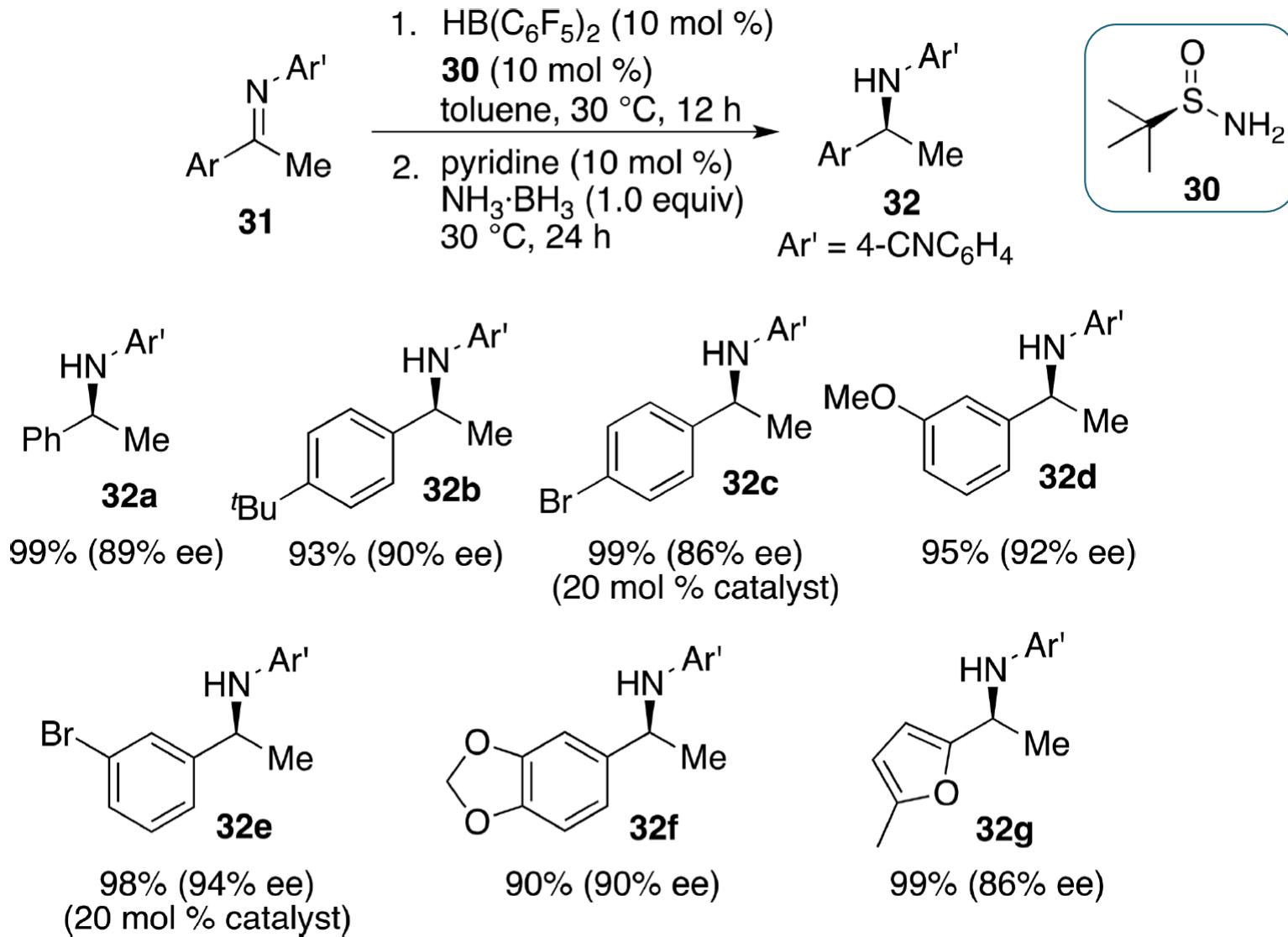
Key Issues

1. The two components of the FLP cannot rapidly release H₂
2. The formed covalent bond must be easy to split
3. The use of chiral bases to control the asymmetric induction

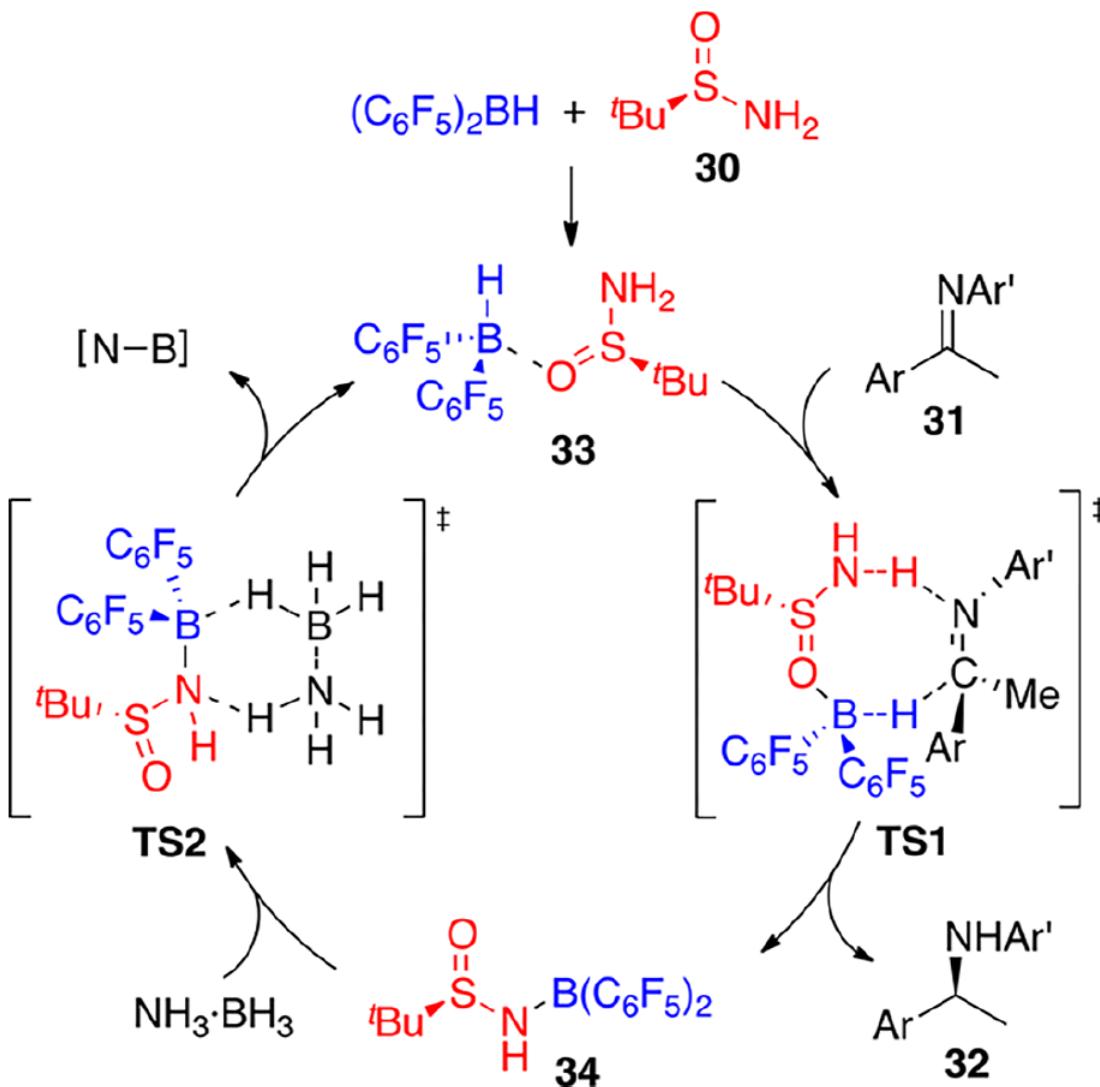
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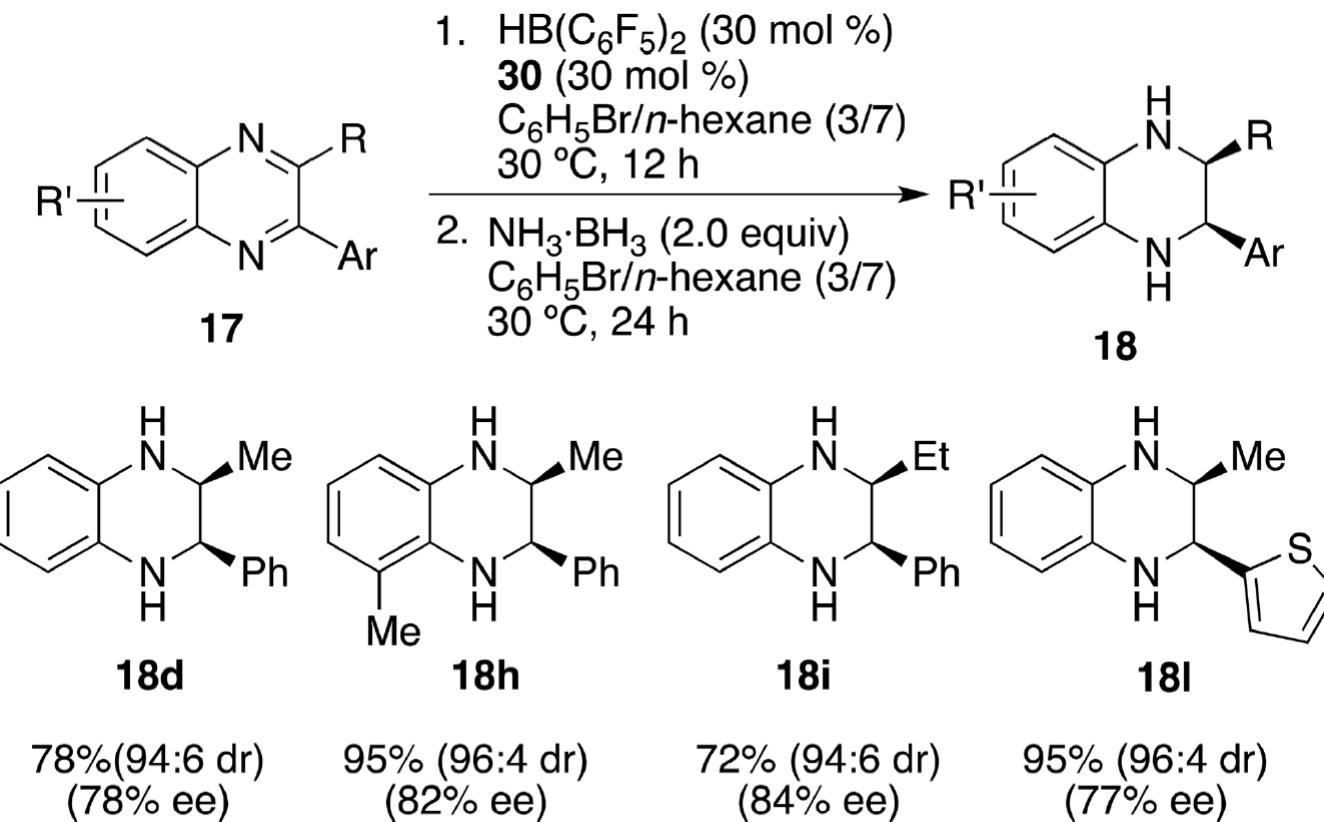
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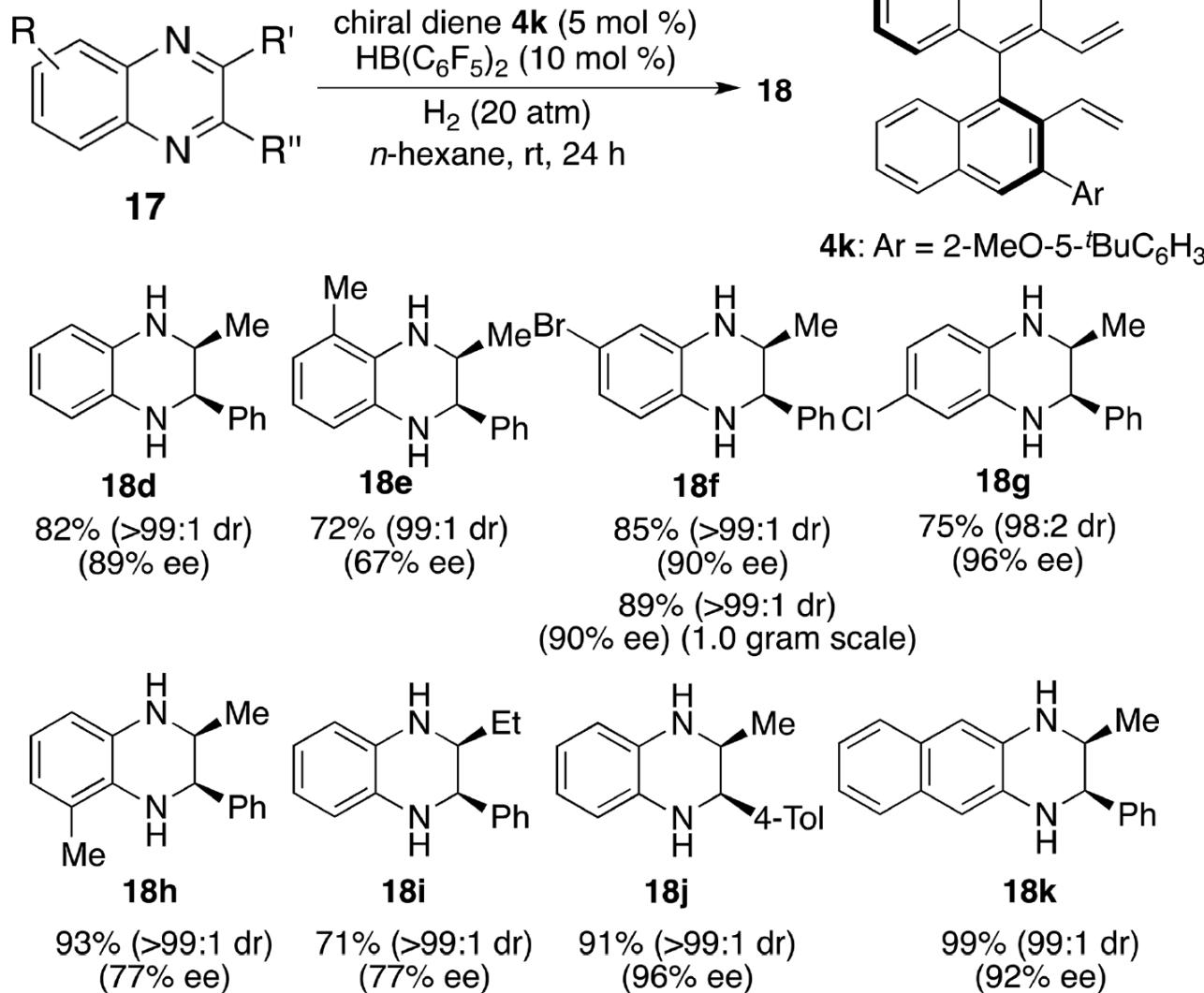


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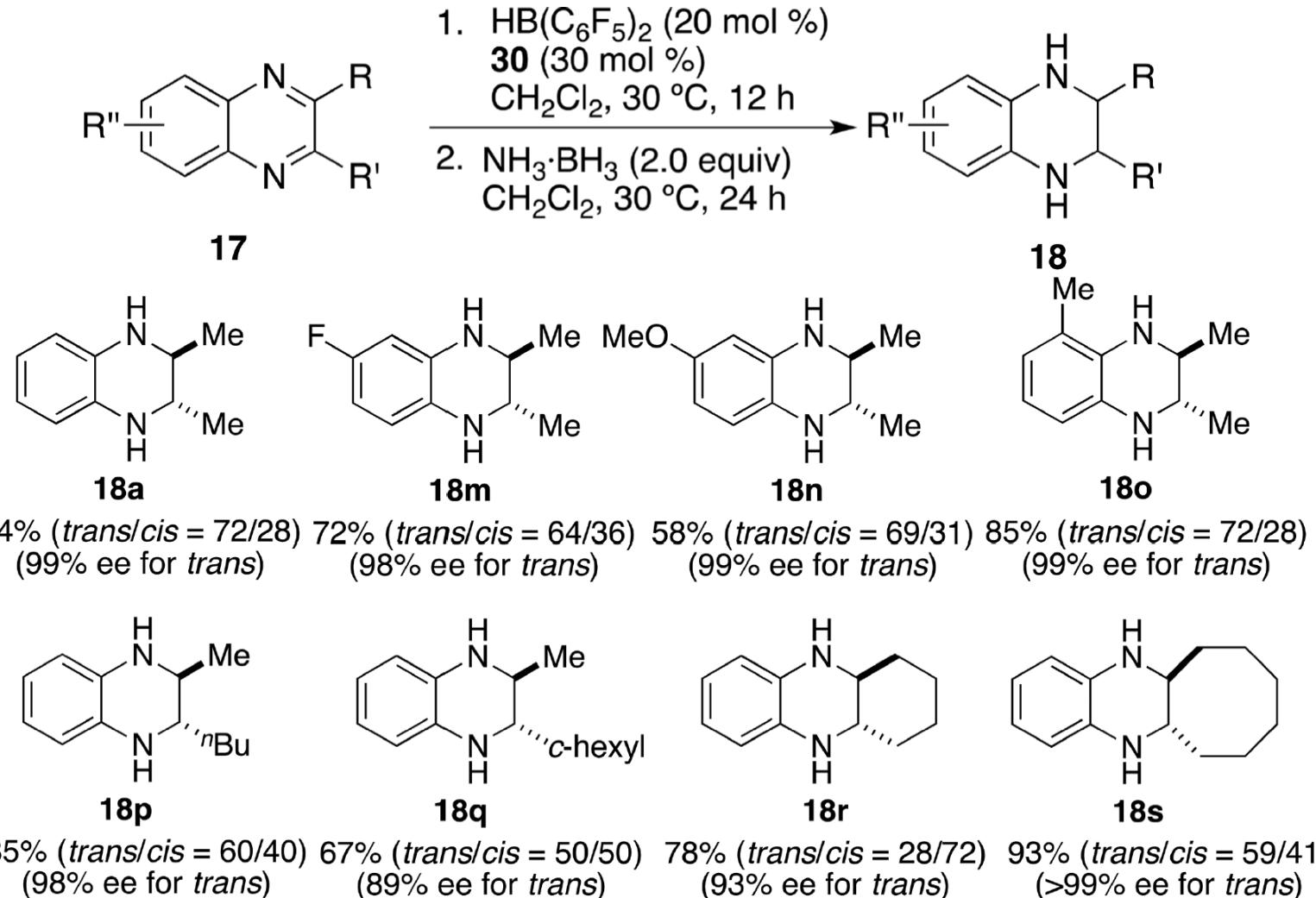
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H₂ as hydrogen source—*cis* products

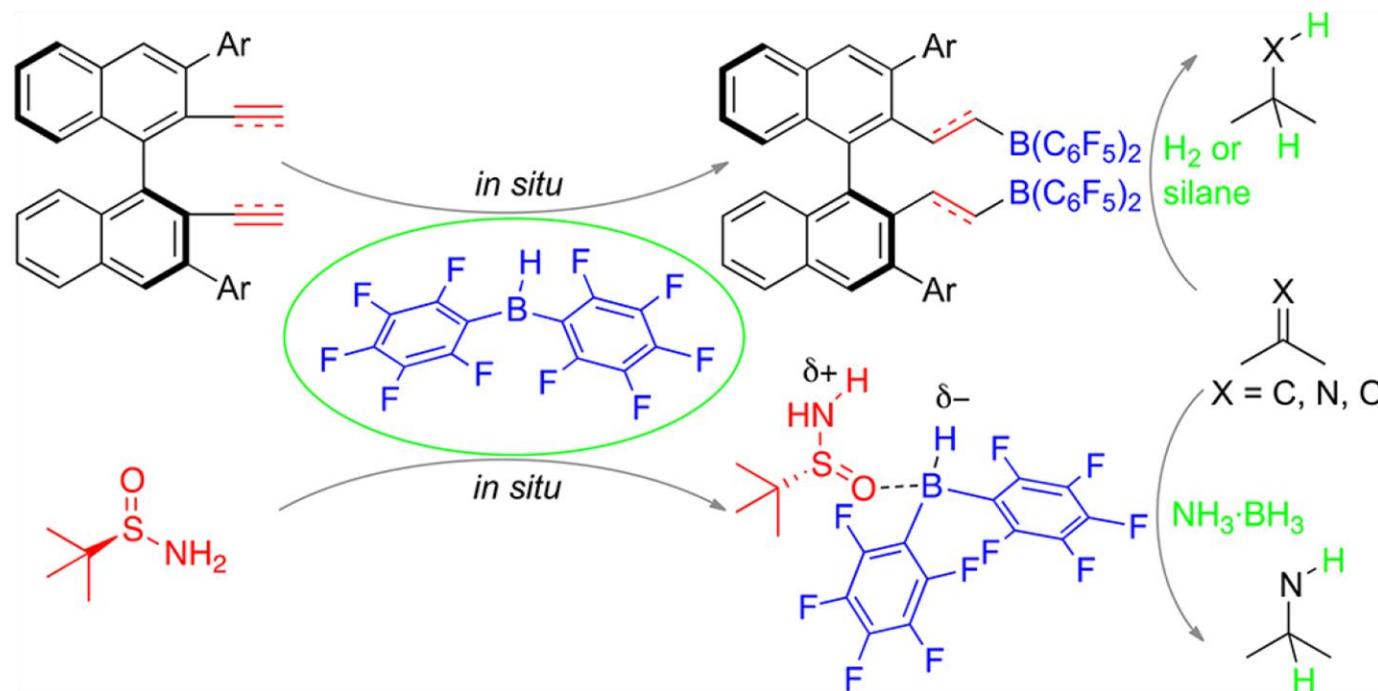


4. A Novel Type of Frustrated Lewis Pairs

$\text{NH}_3 \cdot \text{BH}_3$ as hydrogen source—*trans* products



5. Summary



- The chemistry of FLPs offers new methods of metal-free hydrogenations
- A wide range of compounds were effective for asymmetric hydrogenation
- Novel FLPs: Combination of H($\delta-$) and H($\delta+$) containing Lewis acid and base

Advantages:

- Easily obtained; **b.** Highly enantioselective hydrogenations; **c.** A lot of substrates are well tolerated, including that are challenging for transition-metal catalysts

Thanks for your attention