Supporting Information for

Autoxidation of Heterocyclic Aminals

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Mechanism of Formation of 6a

We varied the reaction conditions in pursuit of increasing the selectivity for the formation of 6a from 1a and 2. While no substantial increase in selectivity for 6a was observed, the experiments shed light into the origin of selectivity. Addition of molecular sieves led to no change in selectivity (Table S1, Entry 2), while addition of water lower the selectivity for 6a (Entry 3). Increasing the loading of Sc(OTf)_3 (Entry 6) and the reaction time (Entry 7) led to no change of selectivity. Changing the catalyst to TfOH (Entry 8) or other Lewis acids (Entries 9,10) led to lower yield or no 6a. These results suggest that the selectivity is kinetically controlled by the Sc(OTf)_3 catalyst. Importantly, addition of a large excess of 1a (5 or 20 equiv, Entries 4,5) has little effect on the selectivity, and the reaction between 4a and 1a yields no 6a. These results suggest that 6a forms by a reaction of 1a with an intermediate on the way to 4a rather than by a reaction with 4a itself. A proposed mechanism is shown in Scheme S1. The selectivity-determining intermediate may be an iminoketone Sc complex with aniline 1a bound, which undergo irreversible ring closure to yield 4a ($k_1$) or interligand aniline addition to ketone followed by formation of 6a ($k_2$). Thus, the 4a/6a selectivity is determined by the relative reaction rates ($k_1/k_2$) and is independent of [1a].

We observed no other organic products in this reaction. The absence of the meso (RS/SR) diastereomer is likely due to steric repulsion between the two isopropyl groups or the two N–Me groups.
Table S1. Optimization of Formation of 6a

| Entry | Variations                  | 4a%a | 6a%a |
|-------|-----------------------------|------|------|
| 1     | No change                   | 94   | 6    |
| 2     | 4A MS                       | 94   | 6    |
| 3     | water (20 equiv)            | 97   | 3    |
| 4     | 1a (5 equiv)                | 93   | 7    |
| 5     | 1a (20 equiv)               | 92   | 8    |
| 6     | Cat.: Sc(OTf)₃ (40 mol.%)   | 94   | 6    |
| 7     | Cat.: Sc(OTf)₃ (40 mol.%), 3 h | 94 | 6 |
| 8     | Cat.: TfOH (50 mol.%)       | 97   | 3    |
| 9     | Cat.: AlCl₃ (2.0 equiv)     | 100  | 0    |
| 10    | Cat.: In(OTf)₃ (20 mol.%)   | 97   | 3    |

aNMR yields. In all runs the diketone 2 was completely consumed.

Scheme S1. Proposed Mechanism for Formation of 6a
Stacked $^1$H NMR Spectra Showing Autoxidation Reactions

**Figure S1.** Stacked $^1$H NMR spectra (expansion of δ 5.0–0.0 region) showing the autoxidation of 4a under O$_2$ (1 atm) in CDCl$_3$ at room temperature to form 7a and 8a.

**Figure S2.** Stacked $^1$H NMR spectra (expansion of δ 3.5–0.5 region) showing the autoxidation of 4a under air in CDCl$_3$ at room temperature to form 8a.
Figure S3. Stacked $^1$H NMR spectra (expansion of δ 5.9–0.0 region) showing the autoxidation of 4b in CD$_2$Cl$_2$/CF$_3$CO$_2$H (100/1) under air at room temperature to form 8b and 9.

Figure S4. Stacked $^1$H NMR spectra (expansion of δ 12–0 region) showing the autoxidation of 5a in CD$_2$Cl$_2$ under O$_2$ at room temperature to form 12 and peracetic acid.
Aerobic Oxidation of 6a in CD₃CN. A J. Young NMR tube was charged with 6a (0.8 mg) and CD₃CN (0.5 mL) under air. The sample was sealed under air and maintained at 80 °C. ¹H NMR spectra were taken periodically to monitor the conversion of 6a to 13. The observed singlet at δ ca. 8.6 corresponds to H₂O₂ in substoichiometric quantity.

**Figure S5.** Stacked ¹H NMR spectra (expansion of δ 8.9–6.4 region) showing the aerobic autooxidation of 6a in CD₃CN at 80 °C to form 13 and H₂O₂. Top: ¹H NMR spectrum of H₂O₂ (30 wt % aq, ca. 0.05 mL) in CD₃CN (0.5 mL). +, 6a; #, 13.
X-ray Crystallography

Data were measured on a Bruker D8 VENTURE with a PHOTON 100 CMOS detector system equipped with a Mo-target X-ray tube ($\lambda = 0.71073 \, \text{Å}$). All atoms were refined with anisotropic thermal parameters. All structures are drawn with thermal ellipsoids at 50% probability. Crystallographic data and details of the data collection and structure refinement are listed in Table S2 for 4a, 6a and 7a and Table S3 for 8a, 9 and 13. Specific details for each compound follow. 4a: Crystals were obtained by diffusion of hexane into a CH$_2$Cl$_2$ solution of 4a under N$_2$ at room temperature. All atoms including disordered oxygen and carbon atoms were refined anisotropically. Hydrogen atoms were included in idealized positions for structure factor calculations except for the one bound to N2, which was located on the difference Fourier map and allowed to be freely refined. The acenaphthene group is disordered over two orientations in 85:15 ratio, and was modeled using geometric restraints and constraints on thermal parameters of carbon atoms. 6a: Crystals were obtained by diffusion of hexane into a CH$_2$Cl$_2$ solution of 6a under N$_2$ at room temperature. All the elements were refined with anisotropic thermal parameters. One $^1$Pr group is disordered over two orientations in 83:17 ratio, and was modeled with the application of soft geometric (SADI) restraints utilizing the non-disordered $^1$Pr group. RIGU and EADP constraints were also used for the disordered atoms. Hydrogen atoms were included in idealized positions for structure factor calculations except for those attached to N atoms, which were located on the difference Fourier map and allowed to be fully refined. The crystal contained many disordered solvent molecules located in large solvent-accessible voids. The diffuse contribution to scattering was treated by application of the program SQUEEZE$^{1,2}$ as implemented in Platon$^3$ using the “fab” file construct. The SQUEEZE algorithm located 3 voids, centered at (0, 0, 0), (1/3, 2/3, 2/3), and (2/3, 1/3, 1/3), with the same volume and the electron count (1187 Å$^3$ / 186). 7a: Crystals
were obtained by diffusion of pentane into a THF solution of 7a under N₂ at room temperature. All atoms were refined with anisotropic thermal parameters. Hydrogen atoms were included in idealized positions for structure factor calculations except the H2 atom attached to the peroxo group, which was located in the difference Fourier map and allowed to be freely refined to give O–H bond length of 0.93(3) Å. The crystal contained many disordered solvent molecules located in large solvent-accessible voids. The diffuse contribution to scattering was treated by application of the program SQUEEZE¹,² as implemented in Platon³ using the “fab” file construct. The SQUEEZE algorithm located 3 voids, centered at (0, 0, −0.025), (0.333, 0.667, 0.141), and (0.667, 0.333, 0.808) with a volume of 1349 Å³ and the electron count of 216. 8a: Crystals were obtained by slow evaporation/oxidation of a CDCl₃ solution of 4a under air at room temperature for 5 d. All elements were refined anisotropically. Hydrogen atoms were included in idealized positions for structure factor calculations except the H atom on N2, which was located on the difference Fourier map and refined with no restraints. 9: Crystals were obtained by diffusion of hexane into a CHCl₃ solution of 9 at room temperature. All atoms were refined with anisotropic thermal parameters. Hydrogen atoms were included in idealized positions for structure factor calculations. 13: Crystals were obtained by slow evaporation of a hexane/CH₂Cl₂ solution of 13 at room temperature. All atoms were refined anisotropically. Hydrogen atoms were included in idealized positions for structure factor calculations.
Table S2. Crystallographic Data for Compounds 4a, 6a and 7a

| Compound | 4a                  | 6a                  | 7a                  |
|----------|---------------------|---------------------|---------------------|
| CCDC Deposition No. | 1535604             | 1535605             | 1535606             |
| Empirical formula | C$_{23}$H$_{20}$N$_2$O$_2$ | C$_{34}$H$_{34}$N$_4$O$_2$ | C$_{23}$H$_{20}$N$_2$O$_2$ |
| Formula weight | 356.41              | 530.65              | 388.41              |
| Temperature/K | 100(2)              | 100(2)              | 100.0               |
| Crystal system | Monoclinic          | Trigonal            | Trigonal            |
| Space group | P2$_1$/c            | R$\overline{3}$      | R$\overline{3}$      |
| a/Å     | 9.2660(11)          | 33.259(3)           | 42.788(3)           |
| b/Å     | 15.0394(17)         | 33.259(3)           | 42.788(3)           |
| c/Å     | 13.5414(16)         | 15.5227(18)         | 7.4202(6)           |
| α/°     | 90                  | 90                  | 90                  |
| β/°     | 104.785(3)          | 90                  | 90                  |
| γ/°     | 90                  | 120                 | 120                 |
| Volume/Å$^3$ | 1824.6(4)          | 14870(3)            | 11765(2)            |
| Z       | 4                   | 18                  | 18                  |
| ρ$_{calc}$/g cm$^{-3}$ | 1.297               | 1.067               | 0.987               |
| μ/mm$^{-1}$ | 0.084               | 0.067               | 0.068               |
| F(000)  | 752                 | 5076.0              | 3672.0              |
| Crystal size/mm$^3$ | 0.27 × 0.15 × 0.060 | 0.38 × 0.19 × 0.13  | 0.28 × 0.16 × 0.14  |
| Radiation | MoKα ($\lambda$=0.71073) | MoKα ($\lambda$=0.71073) | MoKα ($\lambda$=0.71073) |
| 2Θ range for data collection/° | 4.546 to 50.136      | 4.242 to 52.89      | 5.038 to 50.096     |
| Index ranges | −11 ≤ h ≤ 11,      | −41 ≤ h ≤ 41,       | −40 ≤ h ≤ 50,       |
|           | −17 ≤ k ≤ 17,      | −41 ≤ k ≤ 41,       | −50 ≤ k ≤ 49,       |
|           | −16 ≤ l ≤ 16       | −19 ≤ l ≤ 19        | −8 ≤ l ≤ 8          |
| Reflections collected | 21427               | 113664              | 17818               |
| Independent reflections | 3218 [R$_{int}$=0.0706] | 6786 [R$_{int}$=0.0496, R$_{sigma}$=0.0256] | 4528 [R$_{int}$=0.0503] |
| Data/restraints/parameters | 3218/37/290         | 6786/33/384         | 4528/0/269          |
| Goodness-of-fit on F$^2$ | 1.052               | 1.055               | 1.058               |
| Final R indexes [I ≥ 2σ (I)] | R$_1$=0.0591, wR$_2$=0.1177 | R$_1$=0.0529, wR$_2$=0.1308 | R$_1$=0.0504, wR$_2$=0.1260 |
| Final R indexes [all data] | R$_1$=0.1043, wR$_2$=0.1356 | R$_1$=0.0729, wR$_2$=0.1406 | R$_1$=0.0890, wR$_2$=0.1400 |
| Largest diff. peak/hole /e Å$^{-3}$ | 0.193/−0.370       | 0.52/−0.44          | 0.33/−0.29          |
Table S3. Crystallographic Data for Compounds 8a, 9 and 13

| Compound | 8a | 9 | 13 |
|----------|----|---|----|
| CCDC Deposition No. | 1535607 | 1535608 | 1535609 |
| Empirical formula | $C_{23}H_{20}N_2O_3$ | $C_{22}H_{16}N_2O_2$ | $C_{34}H_{32}N_4O_2$ |
| Formula weight | 372.41 | 340.37 | 528.63 |
| Temperature/K | 100(2) | 100(2) | 100(2) |
| Crystal system | Triclinic | Orthorhombic | Monoclinic |
| Space group | $P\bar{1}$ | $Pca_{21}$ | $C2/c$ |
| $a$/Å | 7.4731(6) | 22.720(3) | 18.3177(14) |
| $b$/Å | 9.4040(8) | 8.2209(9) | 11.2752(9) |
| $c$/Å | 14.3670(12) | 17.0117(19) | 26.814(2) |
| $\alpha$/° | 93.623(2) | 90 | 90 |
| $\beta$/° | 100.659(2) | 90 | 100.871(3) |
| $\gamma$/° | 111.227(2) | 90 | 90 |
| Volume/Å³ | 915.54(13) | 3177.5(6) | 5438.8(7) |
| $Z$ | 2 | 8 | 8 |
| $\rho_{calc}$/g cm$^{-3}$ | 1.351 | 1.423 | 1.291 |
| $\mu$/mm$^{-1}$ | 0.090 | 0.092 | 0.082 |
| F(000) | 392 | 1424.0 | 2240 |
| Crystal size/mm$^3$ | 0.25 × 0.19 × 0.11 | 0.28 × 0.06 × 0.02 | 0.44 × 0.26 × 0.25 |
| Radiation | MoKα ($\lambda=0.71073$) | MoKα ($\lambda=0.71073$) | MoKα ($\lambda=0.71073$) |
| 2Θ range for data collection/° | 4.694 to 54.298 | 4.312 to 54.908 | 4.528 to 54.378 |
| Index ranges | $-23 \leq h \leq 23$, $-14 \leq k \leq 14$, $-33 \leq l \leq 33$ | $-29 \leq h \leq 26$, $-10 \leq k \leq 10$, $-16 \leq l \leq 21$ | $-23 \leq h \leq 23$, $-14 \leq k \leq 14$, $-33 \leq l \leq 33$ |
| Reflections collected | 12673 | 23365 | 43993 |
| Independent reflections | 4026 [R$_{int}=0.0248$] | 5866 [R$_{int}=0.0532$, R$_{sigma}=0.0601$] | 6023 [R$_{int}=0.0480$] |
| Data/restraints/parameters | 4026/0/260 | 5866/1/473 | 6023/0/367 |
| Goodness-of-fit on F$^2$ | 1.024 | 1.038 | 1.038 |
| Final R indexes [$I \geq 2\sigma$ (I)] | $R_1=0.0443$, wR$_2=0.1062$ | $R_1=0.0439$, wR$_2=0.0834$ | $R_1=0.0427$, wR$_2=0.1036$ |
| Final R indexes [all data] | $R_1=0.0639$, wR$_2=0.1161$ | $R_1=0.0731$, wR$_2=0.0936$ | $R_1=0.0593$, wR$_2=0.1128$ |
| Largest diff. peak/hole /e Å$^{-3}$ | 0.475/−0.303 | 0.24/−0.22 | 0.314/−0.259 |
| Structure | Bond Length / Å | CCDC Entry Code | Ref. |
|-----------|----------------|-----------------|------|
|           | 1.547(3)       | BIXLIE          | 4    |
|           | 1.551(2)       | HUQRIV          | 5    |
|           | 1.5642(18)     | PAFDIM          | 6    |

| Structure | Bond Length / Å | CCDC Entry Code | Ref. |
|-----------|----------------|-----------------|------|
|           | 1.576(5); 1.574(11) | NOFCIV          | 7    |
|           | 1.584(2)       | QIBMIX          | 8    |

| Structure | Bond Length / Å | CCDC Entry Code | Ref. |
|-----------|----------------|-----------------|------|
|           | 1.593(3)       | ACNAQU01        | 9    |
|           | 1.633(2)       | YAMCON          | 10   |
|           | 1.681(2)       | This work       |      |

| Structure | Bond Length / Å | CCDC Entry Code | Ref. |
|-----------|----------------|-----------------|------|
|           | 1.696(3)       | RADZUS          | 11   |
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NMR Spectra of Compounds

(a) 

$^1$H NMR (DMSO-$d_6$, 500 MHz)

(b) 

$^{13}$C($^1$H) NMR (DMSO-$d_6$, 126 MHz)

Figure S6. NMR spectra of 1b.
Figure S7. NMR spectra of 4a.
Figure S8. NMR spectra of 4b.
Figure S9. NMR spectra of 5a.
Figure S10. NMR spectra of 6a.
Figure S11. NMR spectra of 7a.
(c) NOESY (expansion of $\delta$ 9.3–0.6/9.3–0.6 region)

Figure S11, continued. NMR spectra of 7a.
(d) NOESY (expansion of δ 9.0–6.8/3.4–0.8 region)

Figure S11, continued. NMR spectra of 7a.
(e) HMBC (expansion of δ 3.5-1.0/170–90 region)

Figure S11, continued. NMR spectra of 7a.
Figure S12. NMR spectra of 8a.
Figure S13. NMR spectra of 8b.
Figure S14. NMR spectra of 9.
Figure S15. NMR spectra of 11.
Figure S16. NMR spectra of 12.
Figure S17. NMR spectra of peracetic acid.
Figure S18. NMR spectra of 13.