Supporting Information

Highly Enantioselective Aza-Henry Reaction of *N*-Tosyl Imines Catalyzed by *N,N'*-Dioxide-Cu(I) Complexes

Hui Zhou,[†] Dan Peng,[†] Bo Qin,[†] Zongrui Hou,[†] Xiaohua Liu,[†] Xiaoming Feng[†,‡]

[†]*Key Laboratory of Green Chemistry & Technology (Sichuan University), Ministry of Education, College of Chemistry, Sichuan University, Chengdu 610064, China*

[‡]*State Key Laboratory of Oral Diseases, Sichuan University, Chengdu 610041, China*

xmfeng@scu.edu.cn

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1. General Information.

^{1}H NMR spectra were recorded on commercial instruments (400 MHz). Chemical shifts were reported in ppm from tetramethylsilane with the solvent resonance as the internal standard ($CDCl_3$, δ = 7.26). Spectra are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants (Hz), integration, and assignment. ^{13}C NMR spectra were collected on commercial instruments (100 MHz) with complete proton decoupling. Chemical shifts are reported in ppm from the tetramethylsilane with the solvent resonance as internal standard ($CDCl_3$, δ = 77.0). The enantiomeric excesses were determined by HPLC analysis on chiral DAICEL CHIRALCEL OD-H or CHIRALPAK AD-H, IA column at 215 nm. Optical rotations are measured on a commercial polarimeter and are reported as follows: $[\alpha]_D^T$ (c = g/100 mL, solvent).

2. General procedures for the preparation of *N*-Ts imines.

Imines **5a-j** were prepared according to the literature.[1]

3. General procedures for the preparation of chiral ligands.

Chiral ligands (**1a-g**, **2-4**) were prepared according to the methods reported in the literature.[2] For the characterization of the ligands, see literature.[2]

4. Typical experimental procedure for the aza-Henry reaction

Typical experimental procedure: The mixture of ligand **1a** (4.7 mg, 0.01 mmol), $CuOTf{\cdot}0.5C_7H_8$ (2.6 mg, 0.01 mmol) and 4 Å MS (5 mg) was stirred in the mixture of THF/CH_3NO_2 (THF : CH_3NO_2 = 2:1, V/V, 0.3 mL) at room temperature under air atmosphere for 10 min to generate the catalyst. The reaction mixture was cooled to -45 ^{o}C followed by the addition of imine **5a** (0.05 mmol) and the mixture of THF/CH_3NO_2 (THF : CH_3NO_2 = 2:1, V/V, 0.2 mL), then *i*Pr_2NEt (50 μL, c = 0.05 mol/L in THF, 5 mol%) was added to the mixture. The stirring was continued for indicated time in Table 3 at -45 ^{o}C. The reaction mixture was directly purified by silica gel flash column chromatography (AcOEt : petroleum ether, 1:4) to afford the corresponding product **6a** as a white solid.

5. Determination of the absolute configuration of 6a.

To a solution of **6a** (31.6 mg, 0.1 mmol) in methanol (5 mL) was added activated Pd(C) (10%, 3.2 mg) and the mixture was kept under hydrogen atmosphere at RT until the starting material disappeared. The resulting suspension was filtered through a short pad of celite, and the solution concentrated under reduced pressure. The crude

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(1) (a) Jennings, W. B.; Lovely, C. J. *Tetrahedron* **1991**, *47*, 5561. (b) Chemla, F.; Hebbe, V.; Normant, J. F. *Synthesis* **2000**, 75. (c) Ooi, T.; Uematsu, Y.; Maruoka, K. *J. Am. Chem. Soc.* **2006**, *128*, 2548.
(2) (a) Wen, Y. H.; Huang, X.; Huang, J. L.; Xiong, Y.; Qin, B.; Feng, X. M. *Synlett* **2005**, 2445. (b) Huang, J. L.; Liu, X. H.; Wen, Y. H.; Qin, B.; Feng, X. M. *J. Org. Chem.* **2007**, *72*, 204. (c) Zhang, X.; Chen, D. H.; Liu, X. H.; Feng, X. M. *J. Org. Chem.* **2007**, *72*, 5227. (d) Qin, B.; Liu, X. H.; Shi, J.; Zheng, K.; Zhao, H. T.; Feng, X. M. *J. Org. Chem.* **2007**, *72*, 2374. (d) Zheng, K.; Qin, B.; Liu, X. H.; Feng, X. M. *J. Org. Chem.* **2007**, *72*, 8478.

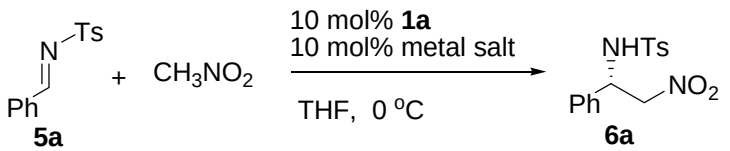
product was purified by flash column chromatography using ethyl acetate as the eluant to give **7** as a white solid (24.1 mg, 83%); $[\alpha]_D^{29}$ = 85 (*c* = 0.1, $CHCl_3$), [Lit.[3] $[\alpha]_D^{20}$ = -62 (*c* = 0.85, $CHCl_3$), *R*]. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.0 Hz, 2H), 7.18-7.08 (m, 7H), 4.31 (t, *J* = 6.0 Hz, 1H), 2.93 (m, 2H), 2.35 (s, 3H), 2.05 (s, 1H), 1.26 (s, 1H). The absolute configuration of **7** was determined as *S*, so the absolute configuration of **6a** should be *S*.

6. Optimizations of aza-Henry reaction.

(1) Metal effects:

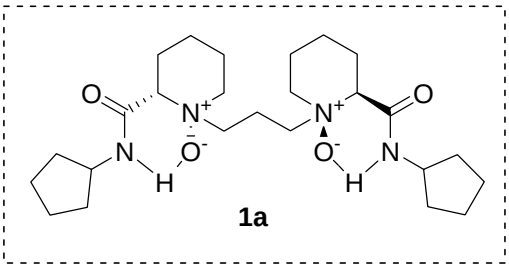
The results of metal screening were summarized in Table S1. When $Cu(OTf)_2$, $Zn(OTf)_2$, $In(OTf)_3$, or $Sc(OTf)_3$ was used instead of CuOTf, the reaction hardly proceeded. Cu(I) gave the best result.

Table S1. Metal effects



Entry[a]	Metal salt	Yield[b] (%)	Ee[c] (%)
1	$Cu(OTf)_2$	trace	-
2	$Zn(OTf)_2$	trace	-
3	$In(OTf)_3$	trace	-
4	$Sc(OTf)_3$	trace	-
5	$CuOTf \cdot 0.5C_7H_8$	52	68

[a] Reaction was conducted with **5a** (0.1 mmol) and CH_3NO_2 (10 eq.) in THF (1.0 mL) with 10 mol% metal salt and 10 mol% **1a** at 0 °C. [b] Isolated yields. [c] Determined by HPLC on a Chiralcel OD-H column.



(2) Solvent effects:

As shown in Table S2, various solvents were screened in the presence of 10 mol% CuOTf and 10 mol% **1a**. The enantioselectivity was scarcely affected by the variety of the solvents while the reactivity was deeply dependent on it. When the reaction was performed in DMF, no corresponding product was obtained (entry 8). CH_3NO_2 was found to be the best solvent in terms of the reactivity and enantioselectivity (entry 6). In addition, THF was the best solvent except CH_3NO_2 (entry 1).

Table S2. Solvent effects

Entry[a]	solvent	Yield[b] (%)	Ee[c] (%)
1	THF	52	68
2	Toluene	34	60

(3) Hayes, A.; Clarkson, G.; Nills, M. *Tetrahedron: Asymmetry* **2004**, *15*, 2079.

3	CH_2Cl_2	8	72
4	Et_2O	37	68
5	CH_3OH	20	11
6	CH_3NO_2	76	71
7	CH_3CN	23	70
8	DMF	N.D.[d]	-

[a] Reaction was conducted with **5a** (0.1 mmol) and CH_3NO_2 (10 eq.) in a certain solvent (1.0 mL) with 10 mol% CuOTf · $0.5C_7H_8$ and 10 mol% **1a** at 0 °C. [b] Isolated yields. [c] Determined by HPLC on a Chiralcel OD-H column. [d] N.D. = Not detected.

(3) The effects of concentration of imine:

The reactivity was improved with the increasing of the concentration of the imine, while the enantioselectivity was hardly affected. We selected the concentration of 0.1 M to further optimize the reaction.

Table S3. The effects of concentration of imine

Entry[a]	The concentration of imine (M)	Time (h)	Yield[b] (%)	Ee[c] (%)
1	0.05	39	63	72
2	0.2	18	91	70
3	0.1	17	76	71

[a] Reaction was conducted with **5a** (x mmol) in CH_3NO_2 (1.0 mL) with 10 mol% CuOTf · $0.5C_7H_8$ and 10 mol% **1a** at 0 °C. [b] Isolated yields. [c] Determined by HPLC on a Chiralcel OD-H column.

(4) Additive effects:

To increase the reactivity, some additives were examined. The yields of nitro amines were improved when 3 Å or 4 Å MS (molecular sieve) was added in the reaction while 5 Å MS had no effect on the reaction (entries 1-3). However, the acidic additive like 4-*tert*-butylphenol had negative effect on the reactivity (entry 4). The *tert*-amine could enhance the reactivity with the enantioselectivity maintained. *i*Pr_2NEt was superior to *N*-methylmorpholine for the stronger organic alkalescence (entries 5 and 6).

Table S4. Additive effects

entry[a]	T (°C)	Additive (amount)	Yield[b] (%)	Ee[c] (%)
1	-20	3 Å MS (10 mg)	78	81
2	-20	4 Å MS (10 mg)	76	82
3	-20	5 Å MS (10 mg)	69	79
4	-20	4-*tert*-butylphenol	56	82
5[d]	-45	4 Å MS (10 mg) *i*Pr_2NEt (5 mol%)	90	91
6[d]	-45	4 Å MS (10 mg) *N*-methylmorpholine (5 mol%)	35	90

[a] Reaction was conducted with **5a** (0.1 mmol) in CH_3NO_2 (1.0 mL) with 20 mol% CuOTf · $0.5C_7H_8$ and 20 mol% **1a**, unless otherwise indicated. [b] Isolated yields. [c] Determined by HPLC on a Chiralcel OD-H column. [d] The solvent was the mixture of THF and CH_3NO_2 (THF : CH_3NO_2 = 2 : 1, V/V).

(5) Effects of the volume ratio of THF to CH_3NO_2:

As the relatively high melting point of CH_3NO_2, THF was selected to mix with CH_3NO_2 as the solvent at -45 ^oC. The volume ratio of THF to CH_3NO_2 was examined and the results were summarized in Table S5. The best volume ratio was THF : CH_3NO_2 = 2 : 1 (Table S5, entry 2).

Table S5: Effects of the volume ratio of THF to CH_3NO_2

Entry[a]	THF : CH_3NO_2 (V/V)	Yield[b] (%)	Ee[c] (%)
1	3 : 1	37	91
2	2 : 1	76	92
3	1 : 1	50	91
4	1 : 2	84	88

[a] Reaction was conducted with **5a** (0.05 mmol) in the mixture of THF and CH_3NO_2 (0.5 mL) with 20 mol% CuOTf · $0.5C_7H_8$ and 20 mol% **1a**, with 5 mg 4 Å MS and 5 mol% *i*Pr_2NEt at -45 ^oC. [b] Isolated yields. [c] Determined by HPLC on a Chiralcel OD-H column.

(6) Effects of *i*Pr_2NEt amount:

The amount of *i*Pr_2NEt affected the reactivity and enantioselectivity. As shown in Table S6, when the amount increased, the enantioselectivity decreased gradually (entries 1-3). When the amount reduced to 3 mol%, the reactivity deeply dropped (entry 4). The best amount of *i*Pr_2NEt was 5 mol%.

Table S6: Effects of *i*Pr_2NEt amount

entry[a]	amount	Yield[b] (%)	Ee[c] (%)
1	20 mol%	77	87
2	10 mol%	80	89
3	5 mol%	76	91
4	3 mol%	23	92

[a] Reaction was conducted with **5a** (0.05 mmol) in the mixture of THF and CH_3NO_2 (THF : CH_3NO_2 = 2 : 1, V/V) (0.5 mL) with 20 mol% CuOTf · $0.5C_7H_8$ and 20 mol% **1a**, with 5 mg 4 Å MS and x mol% *i*Pr_2NEt at -45 ^oC. [b] Isolated yields. [c] Determined by HPLC on a Chiralcel OD-H column.

7. Miscellaneous analyses of CuOTf-1a

(1) ESI-HRMS analysis of CuOTf-1a:

Sample preparation: The mixture of ligand **1a** (4.7 mg, 0.01 mmol) and CuOTf·$0.5C_7H_8$ (2.6 mg, 0.01 mmol) was stirred in the mixture of THF (0.5 mL) at room temperature under air atmosphere for 10 min. The resulting solution was injected for analysis. ESI-HRMS chart was shown in Figure S1.

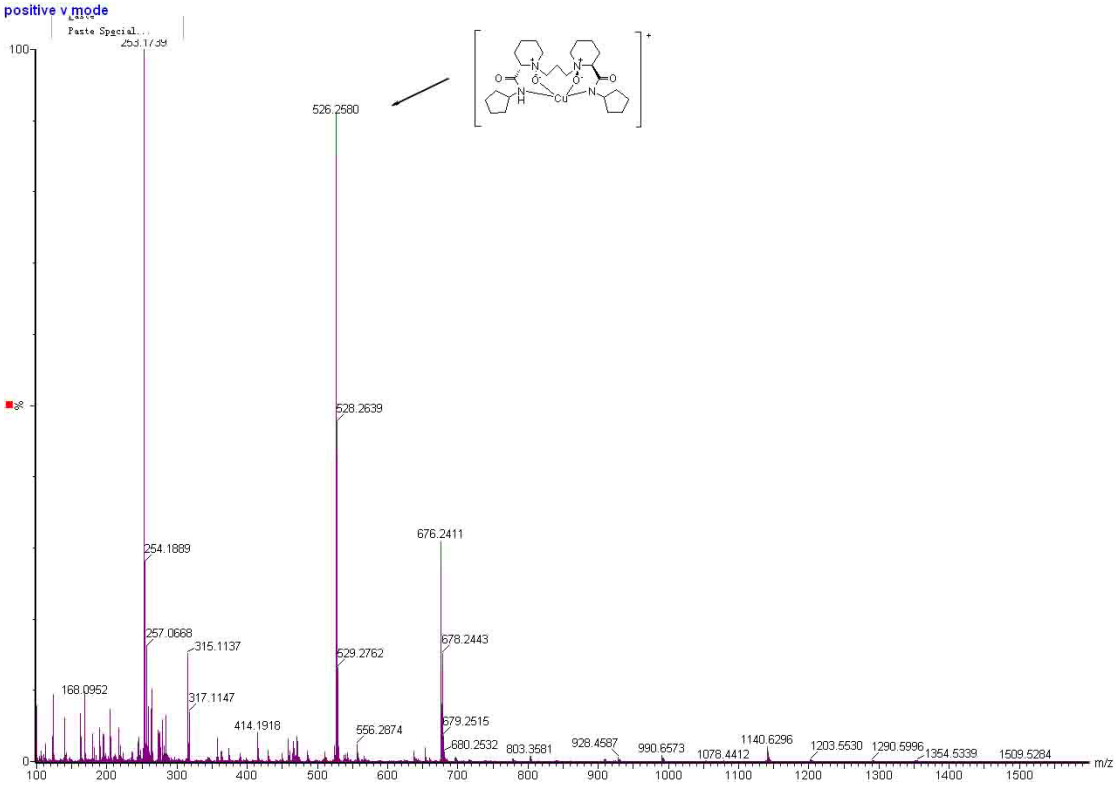


Figure S1. ESI-HRMS of CuOTf/**1a** = 1:1 mixture.

(2) ^{1}H NMR analysis of CuOTf-1a:

Sample preparation: The mixture of ligand **1a** (9.4 mg, 0.02 mmol), and CuOTf·0.5C_7H_8 (5.2 mg, 0.02 mmol) was stirred in the mixture of THF (1.0 mL) at room temperature under air atmosphere for 10 min. The resulting solution was concentrated under reduced pressure and resolved in DMSO-*d6* for analysis. The ^{1}H NMR spectra of **1a** and Cu-**1a** were shown in page S15.

(3) MM2 analysis of Cu-1a:

Based on the studies of ESI-HRMS and ^{1}H NMR, the catalyst model was investigated by the Chem3D 9.0 program package. The geometry of the catalyst was optimized at MM2 level (Figure S2).

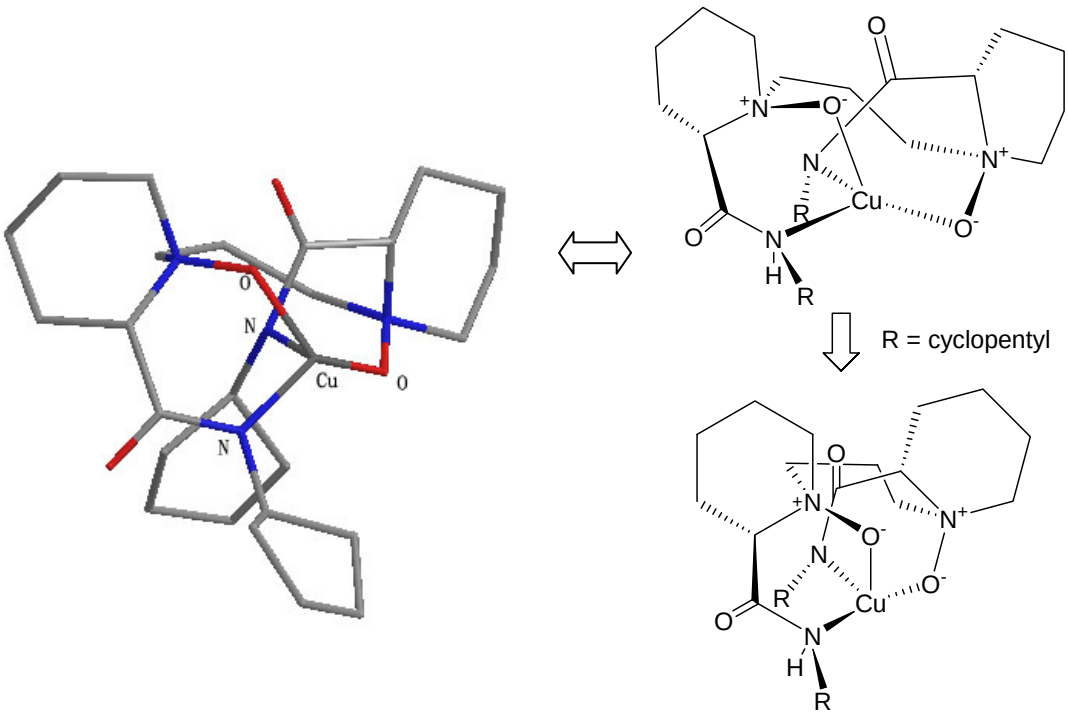


Figure S2. MM2 optimized geometry for *N,N'*-dioxide **1a**-Cu(I) complex

8. Discussion and speculative reaction mechanism

Part I: Discussion on the coordination and the geometry of the Cu-1a

(1). In the present reaction, the bis-*N*-oxide, the linker of a three carbon chain of the ligand as well as the 1:1 ratio of Cu(I) to ligand were essential to good enantioselectivity.

In the ESI-HRMS chart of Cu(I)/**1a** = 1:1 mixture (Figure S1), a peak corresponding to monomeric Cu(I)/**1a** = 1:1 mixture was observed (calcd. For $C_{25}H_{43}CuN_4O_4^+$: 526.2580; found 526.2580). The peak of poly-complex was not found.

By the analysis of the experimental results and the ESI-HRMS, we speculated that a monomeric Cu(I)/**1a** = 1:1 complex without OTf moiety could be the active species for the aza-Henry reaction.

(2). ^{1}H NMR spectroscopy of *N,N'*-dioxide **1a** was studied to get a preliminary insight into the function of NH moiety. The NH proton showed strong deshielding effect at 10.91 ppm, which assigned to strong intramolecular hydrogen bonding between *N*-oxide and the NH proton. However, when equal equivalent of CuOTf was mixed with the ligand **1a**, the signal of NH proton disappeared. It showed that the hydrogen bond was broken entirely, which was caused by the coordination of *N,N'*-dioxide ligand **1a** with Cu(I).

In reference 14d,[4] the authors reported the complex of Cu(II) and a pyridine *N*-oxide containing the amide moiety. According to the X-ray crystal structure study, a dimeric structure was established. The ligand coordinates as a distorted square-planar N_2O_2 donor via the depronated amide nitrogens and the *N*-oxide oxygens. The copper(II) nitrate complex $[CuL_2(NO_3)_2]_2$ (L = pyridine *N*-oxide or 4-methoxypyridine *N*-oxide) also have tetragonal pyramidal coordination, but one bridging Cu-O bond occupies an apical out-of-plane position. At the same time, in references 14b and 14c, the authors introduced some metal complexes of the ligands containing the amide moiety. In reference 14a, the authors discussed the hard and soft acids and bases which gave us much information about the coordination of the ligands to metals.

Based on the ^{1}H NMR spectra and the previous work, we speculated that the *N*,*N*'-dioxide **1a** coordinates to the copper via the amide nitrogens and the *N*-oxide oxygens.

(3). There were some difference between **1a** and the ligand utilized in reference 14d: (a) In **1a**, the *N*-oxide was derived from *tert*-amine while the *N*-oxide was derived from pyridine in the ligand utilized in reference 14d; (b) The linker was a three carbon chain in **1a** while the linker was a amide moiety in the ligand utilized in reference 14d. These obviously made some difference on the geometry of the complexes between Cu-**1a** and the complex in reference 14d. But the attempt to obtain the crystal of Cu-**1a** was failed. We tried to get insight into the configuration of the Cu-**1a** by the MM2 calculation. The catalyst model was investigated by the Chem3D program package. The geometry of the catalyst was optimized at MM2 level (Figure S2). The MM2 calculation illustrated that the *N,N'*-dioxide **1a** coordinated as a tetrahedral N_2O_2 donor via the amide nitrogens and the *N*-oxide oxygens. A *N*-oxide oxygen, the amide nitrogens and the copper were in a distorted plane (the N_2O plane), while another *N*-oxide oxygen was almost perpendicular to the N_2O plane.

In summary, based on the previous work, the experimental results and miscellaneous analyses of **1a**-Cu(I) complex including ESI-HRMS, ^{1}H NMR and MM2 calculations, we concluded: (a) A monomeric Cu(I)/**1a** = 1:1 complex without OTf moiety could be the active species for the aza-Henry reaction; (b) The *N*,*N*'-dioxide **1a** should coordinate to the copper via the amide nitrogens and the *N*-oxide oxygens; (c) The geometry of the **1a**-Cu(I) complex was shown in Figure S2 by the optimization of MM2 calculations.

Part II: Discussion on the transition state

The imine and the nitronate would interact with the complex **A** thus generating the complex **B**.[5] The NH of amide moiety was available to act as a hydrogen bond donor to orient the nitronate while the imine was activated by the Lewis acid. The

(4) (14a) Pearson, R. G. *J. Am. Chem. Soc.* **1963**, *85*, 3533-3539; (14b) Balahura, R. J.; Jordan, R. B. *J. Am. Chem. Soc.* **1970**, *92*, 1533-1539; (14c) Fairlie, D. P.; Angus, P. M.; Fenn, M. D.; Jackson, W. G.; *Inorg. Chem.* **1991**, *30*, 1564-1569; (14d) Antolovich, M.; Phillips, D. J.; Rae, A. D. *Inorg. Chim. Acta* **1989**, *156*, 189-193.
(5) (a) Evans, D. A.; Seidel, D.; Rueping, M.; Lam, H. W.; Shaw, J. T.; Downey, C. W. *J Am. Chem. Soc.* **2003**, *125*, 12692; (b) Xu, X.; Furukawa, T.; Okino, T.; Miyabe, H.; Takemoto, Y. *Chem. Eur. J.* **2006**, *12*, 466. (c) Okino, T.; Nakamura, S.; Furukawa, T.; Takemoto, Y. *Org. Lett.* **2004**, *6*, 625. (d) Chang, Y.; Yang, J.; Dang, J.; Xue, Y. *Synlett*, **2007**, 2283.

orientation of the imine **5a** and the nitronate by the binding with the complex **A** indicated that there were four transition states (Figure S3, **B1**, **B2**, **B3** and **B4**). In **B2**, **B3** or **B4**, the *p*-tosyl group or the phenyl group of the imine was repulsing on the cyclopentyl group of the chiral Cu-complex. Our predisposition was to favor **B1** on the basis of both steric and electronic considerations.

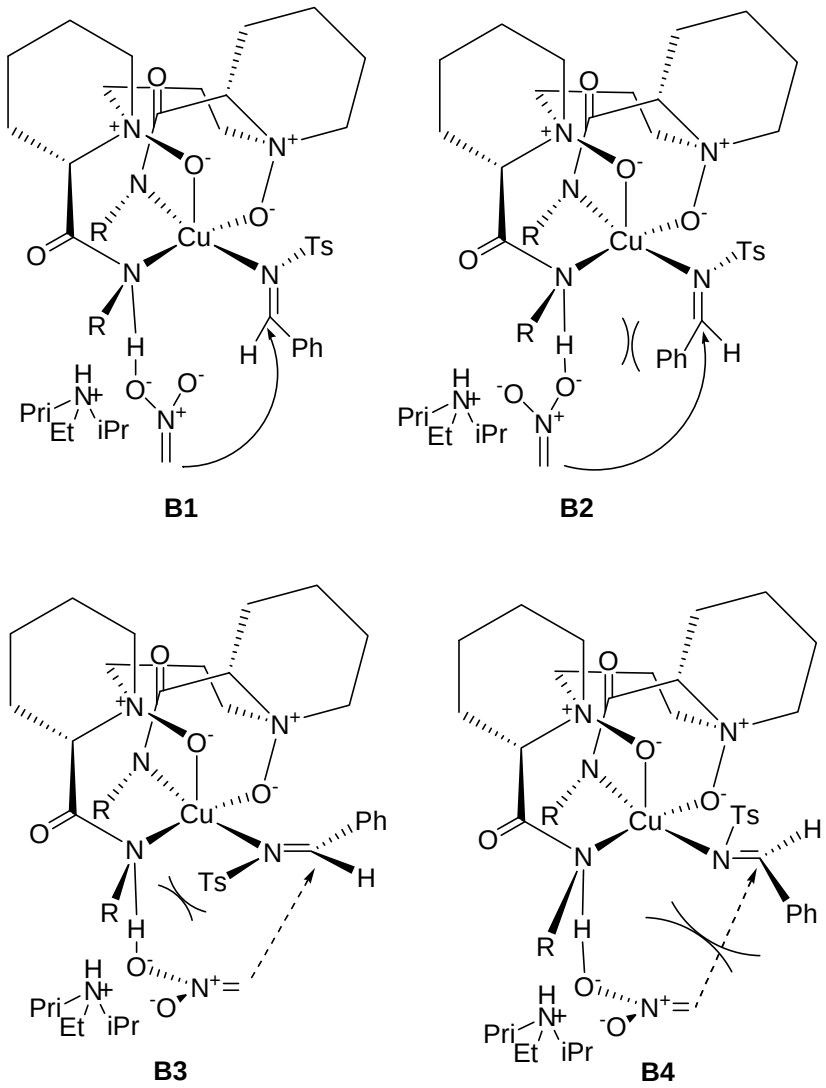
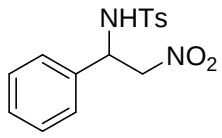


Figure S3. Possible transition states

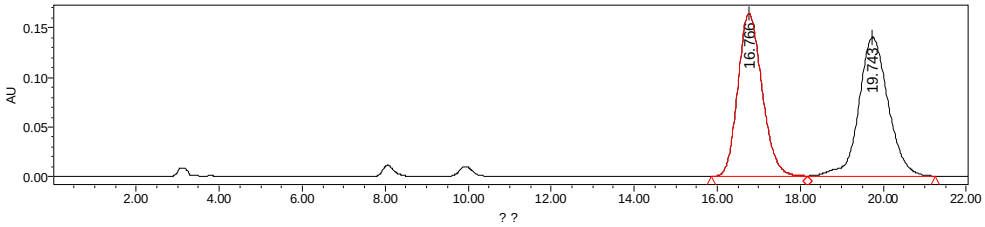
9. Characterization of products

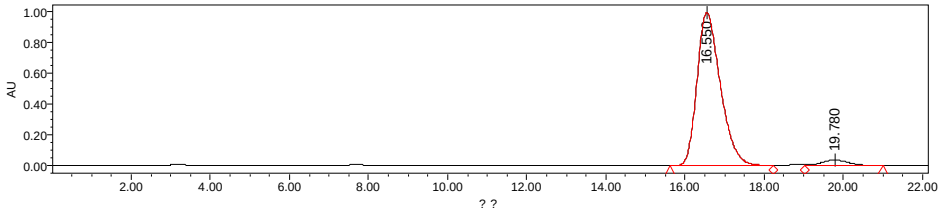
2-Nitro-1-phenyl-*N*-tosylethanamine (6a)



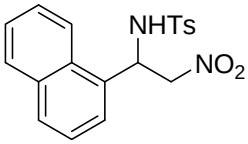
6a

White solid, 91% ee; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.4, 2H), 7.24-7.27 (m, 5H), 7.10-7.08 (m, 2H), 4.98 (t, *J* = 6.6, 1H), 4.84 (q, 1H), 4.69 (q, 1H), 2.40 (s, 3H); $[\alpha]_D^{29}$ 73.5 (*c* 0.10, CH_2Cl_2); HPLC (Chiralcel OD-H column, hexane/2-propanol = 80/20, flow 1.0 mL/min, detection at 215 nm) t_r = 16.6 min (major) and t_r = 19.8 min (minor).



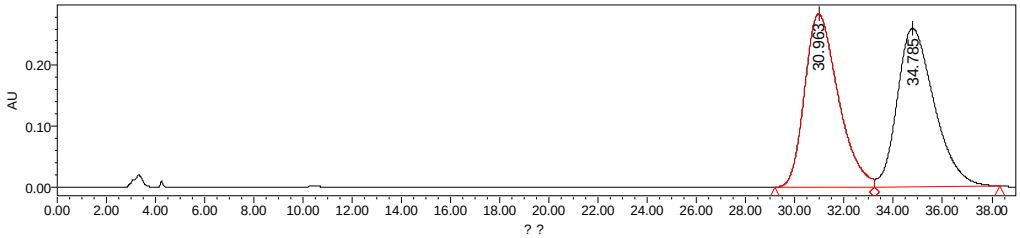


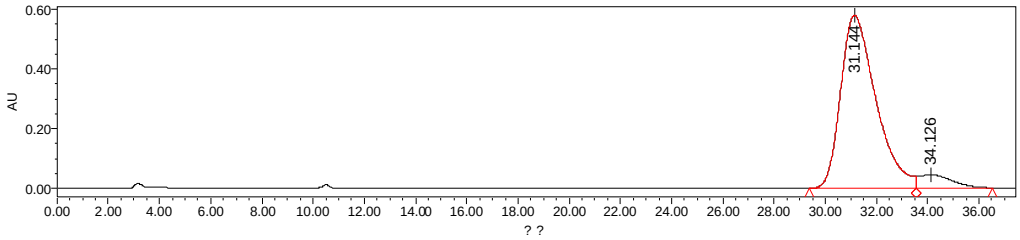
2-Nitro-(1-naphtyl)-*N*-tosylethanamine (6b)



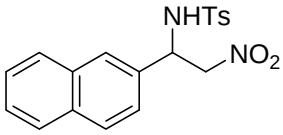
6b

White solid, 86% ee; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83-7.81 (m, 3H), 7.77-7.44 (m, 4H), 7.37-7.31 (m, 2H), 7.09-7.07 (m, 2H), 5.85 (t, *J* = 6.6 Hz, 1H), 5.00-4.93 (m, 1H), 4.90-4.84 (m, 1H), 2.33 (s, 3H); $[\alpha]_D^{26}$ -14.4 (*c* 0.10, CH_2Cl_2); HPLC (Chiralcel OD-H column, hexane/2-propanol = 80/20, flow 1.0 mL/min, detection at 215 nm) t_r = 31.1 min (major) and t_r = 34.1 min (minor).





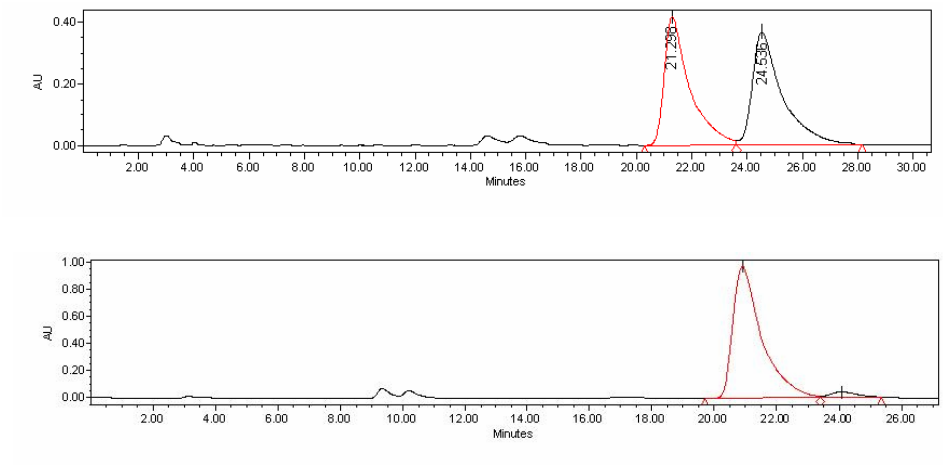
2-Nitro-(2-naphtyl)-*N*-tosylethanamine (6c)



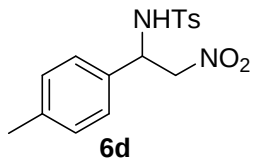
6c

White solid, 93% ee; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72-7.61 (m, 5H), 7.50-7.48 (m, 3H), 7.18-7.10 (m, 3H), 5.16 (t, *J* = 6.6 Hz, 1H), 4.92 (q, 1H), 4.76 (q, 1H), 2.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.0, 136.5, 133.2, 132.9, 132.3, 129.6, 129.3, 128.0, 127.6, 127.1, 126.9, 126.8, 126.4, 123.4, 78.9, 55.7, 21.4; ESI-HRMS calcd. for $C_{19}H_{18}N_2O_4SNa$ $[M+Na]^+$: 393.0879, found 393.0885; $[\alpha]_D^{26}$ 61.5 (*c* 0.10, CH_2Cl_2); HPLC (Chiralpak AD-H column, hexane/2-propanol = 85/15, flow 1.0 mL/min, detection at 215 nm) t_r = 21.3 min

(major) and t_r = 24.5 min (minor).

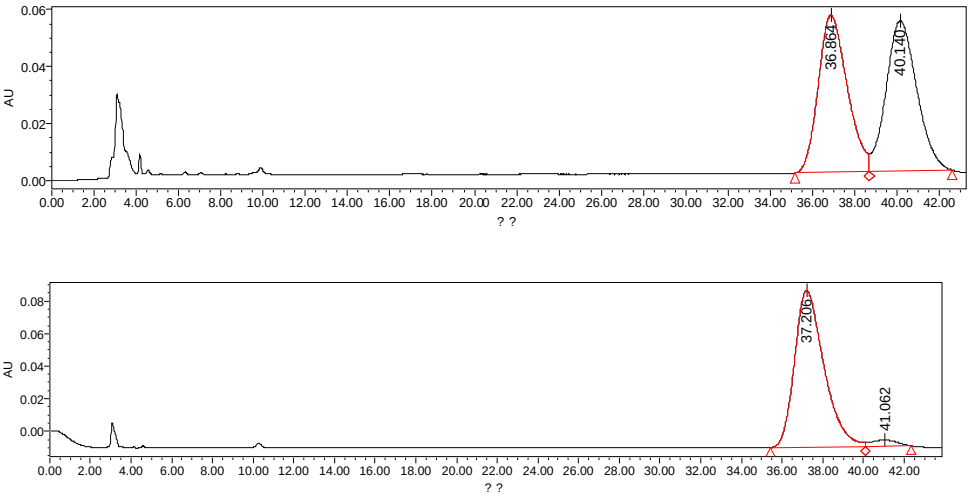


2-Nitro-1-p-tolyl-*N*-tosylethanamine (6d)

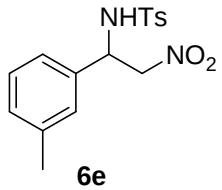


6d

White solid, 93% ee; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, J = 8.0 Hz, 2H), 7.25-7.23 (m, 2H), 7.05 (d, *J* = 8.0 Hz, 2H), 6.96 (d, *J* = 8.4 Hz, 2H), 4.92 (t, *J* = 6.4 Hz, 1H), 4.83 (q, 1H), 4.66 (q, 1H), 2.41 (s, 3H), 2.29 (s, 3H); $[\alpha]_D^{26}$ 50.8 (*c* 0.12, $CHCl_3$); HPLC (Chiralcel OD-H column, hexane/2-propanol = 90/10, flow 1.0 mL/min, detection at 215 nm) t_r = 37.2 min (major) and t_r = 41.1 min (minor).



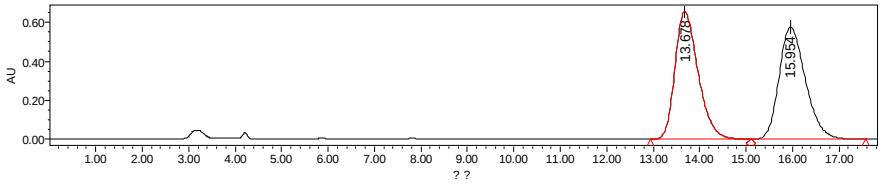
2-Nitro-1-m-tolyl-*N*-tosylethanamine (6e)

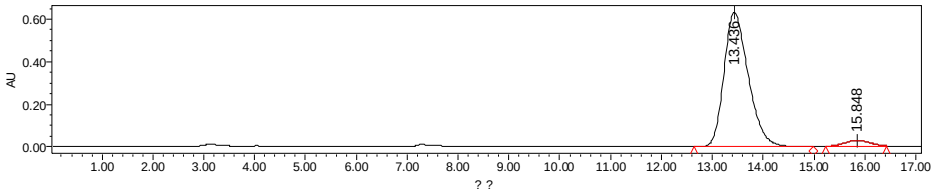


6e

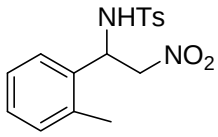
White solid, 92% ee; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, *J* = 8.4 Hz, 2H), 7.22 (d, *J* = 8.4 Hz, 2H), 7.14 (t, *J* = 7.6 Hz, 1H), 7.06 (d, *J* = 7.6 Hz, 1H), 6.88 (d, *J* = 7.6 Hz, 1H), 6.81 (s, 1H), 4.94 (t, *J* = 6.4, 1H), 4.82 (q, 1H), 4.66 (q, 1H), 2.41 (s, 3H), 2.23 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.8, 138.9, 136.6, 135.1, 129.59, 129.57, 129.0, 127.3, 127.2, 123.6, 79.0, 55.7, 21.5, 21.2; ESI-HRMS calcd. for $C_{16}H_{18}N_2O_4SNa$ $[M+Na]^+$: 357.0879, found 357.0885; $[\alpha]_D^{26}$ 53.9 (*c* 0.10, $CHCl_3$); HPLC (Chiralcel OD-H column, hexane/2-propanol = 80/20, flow 1.0 mL/min, detection at 215 nm) t_r

= 13.4 min (major) and t_r = 15.8 min (minor).



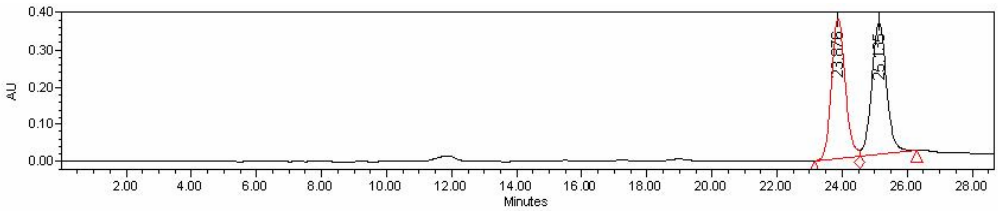


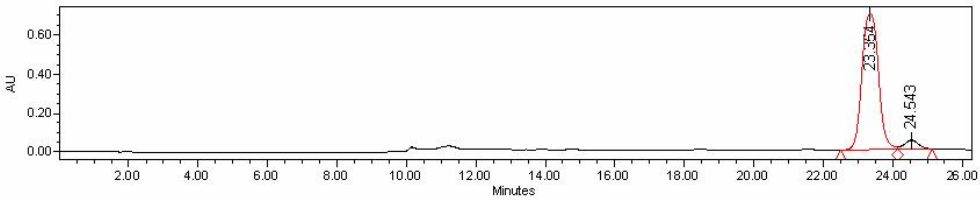
2-Nitro-1-o-tolyl-*N*-tosylethanamine (6f)



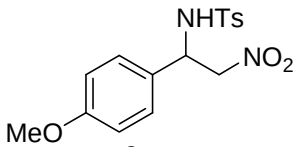
6f

White solid, 89% ee; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, *J* = 8.4, 2H), 7.22 (d, *J* = 8.0Hz, 2H), 7.16-7.13 (m, 3H), 7.06 (d, *J* = 7.2, 1H), 5.24 (t, *J* = 7.0Hz, 1H), 4.87 (q, 1H), 4.67 (q, 1H), 2.40 (s, 3H), 2.09 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.0, 136.4, 135.0, 133.6, 131.1, 129.7, 128.9, 127.2, 125.6, 78.5, 51.4, 21.5, 18.8; ESI-HRMS calcd. for $C_{16}H_{18}N_2O_4SNa$ $[M+Na]^+$: 357.0879, found 357.0885; $[\alpha]_D^{29}$ 43.5 (*c* 0.12, $CHCl_3$); HPLC (Chiralpak AD-H column, hexane/2-propanol = 80/20, flow 0.5 mL/min, detection at 215 nm) t_r = 23.4 min (major) and t_r = 24.5 min (minor).



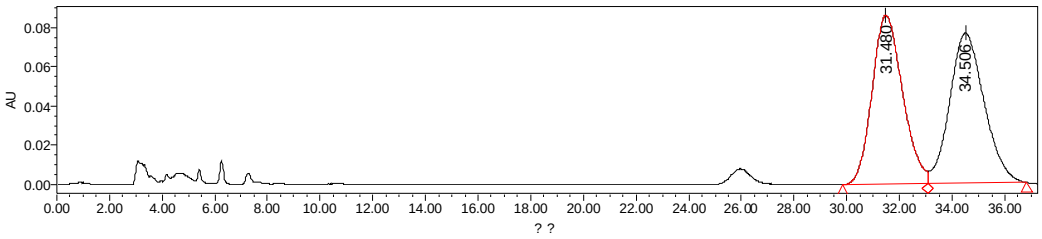


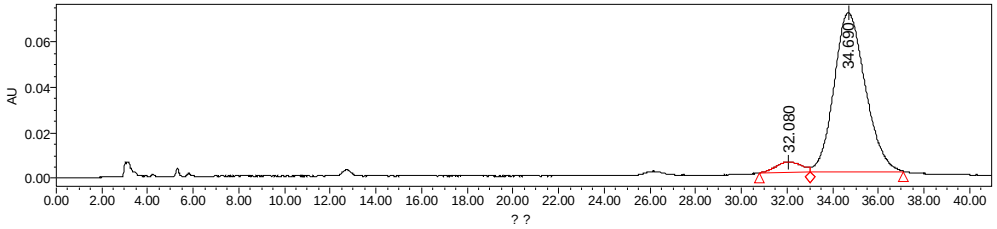
2-Nitro-1-(4'-methoxyphenyl)-*N*-tosylethanamine (6g)



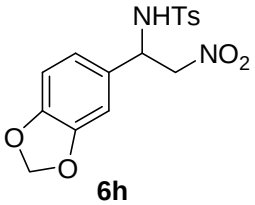
6g

White solid, 90% ee; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.0 Hz, 2H), 7.26-7.24 (m, 2H), 7.01-6.99 (m, 2H), 6.78-6.76 (m, 2H), 4.91 (t, *J* = 6.6, 2H), 4.84 (q, 1H), 4.67 (q, 1H), 3.76 (s, 3H), 2.42 (s, 3H); $[\alpha]_D^{28}$ 68.2 (*c* 0.11, $CHCl_3$); HPLC (Chiralcel OD-H column, hexane/2-propanol = 85/15, flow 1.0 mL/min, detection at 215 nm) t_r = 32.1 min (minor) and t_r =34.7 min (major).



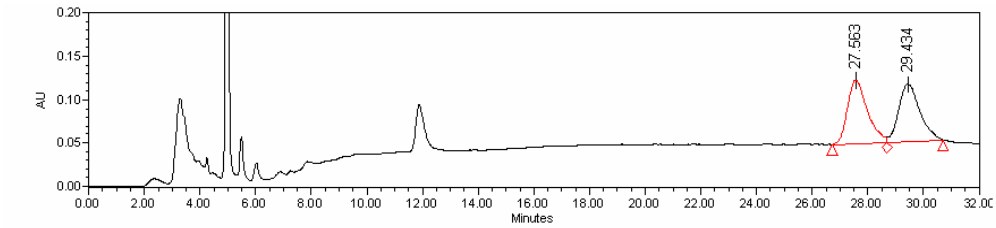


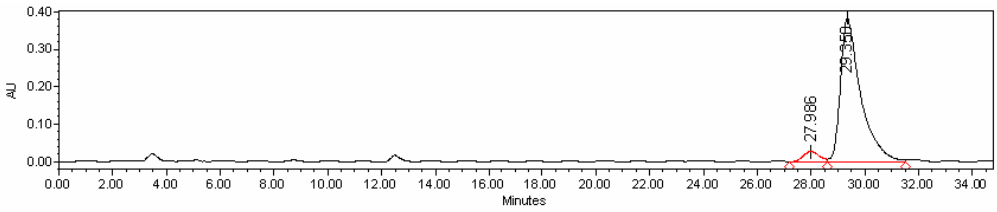
2-Nitro-1-(3',4'-(methylenedioxy)-phenyl)-*N*-tosylethanamine (6h)



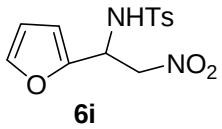
6h

White solid, 89% ee; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.4 Hz, 2H), 7.33-7.27 (m, 2H), 6.67 (d, *J* = 8.0, 1H), 6.58-6.51 (m, 2H), 5.94-5.92 (m, 2H), 4.87 (t, *J* = 6.9, 1H), 4.81 (q, 1H), 4.63 (q, 1H), 2.42 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.2, 148.1, 144.0, 136.5, 129.7, 127.2, 126.4, 120.4, 108.6, 106.9, 101.4, 79.0, 55.4, 21.5; ESI-HRMS calcd. for $C_{16}H_{16}N_2O_6SNa$ $[M+Na]^+$: 387.0621, found 387.0627; $[\alpha]_D^{29}$ 67.5 (*c* 0.11, $CHCl_3$); HPLC (Chiralpak IA column, hexane/2-propanol = 85/15, flow 1.0 mL/min, detection at 215 nm) t_r = 28.0 min (minor) and min t_r = 29.4 (major).





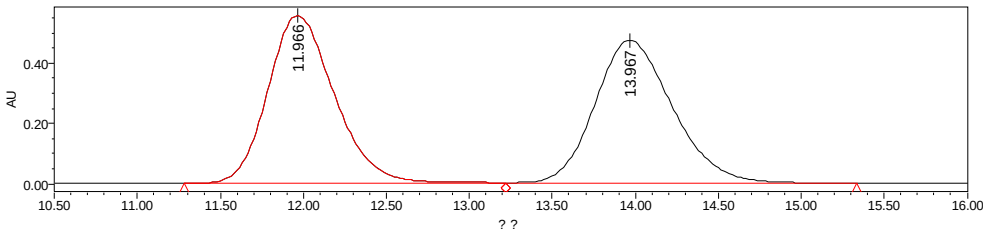
2-Nitro-1-(2-furyl)-*N*-tosylethanamine (6i)

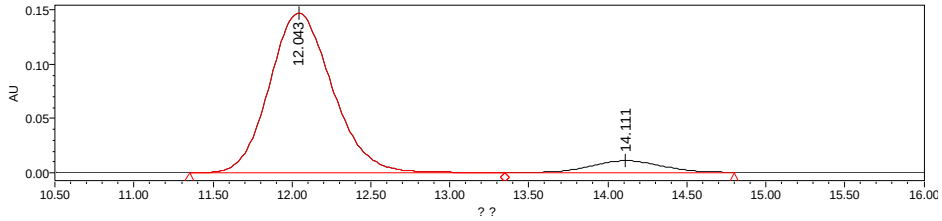


6i

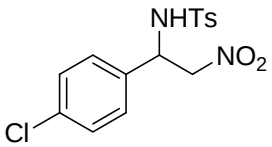
White solid, 84% ee; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, *J* = 8.4 Hz, 2H), 7.29-7.26 (m, 3H), 6.23-6.22 (m, 1H), 6.10 (d, *J* = 3.2 Hz, 1H), 5.11 (t, *J* = 6.0 1H), 4.83 (q, 1H), 4.70 (q, 1H), 2.42 (s, 3H); $[\alpha]_D^{32}$ 26.5 (*c* 0.10, $CHCl_3$); HPLC (Chiralcel OD-H column, hexane/2-propanol

= 80/20, flow 1.0 mL/min, detection at 215 nm) t_r = 12.0 min (major) and t_r = 14.1 min (minor).



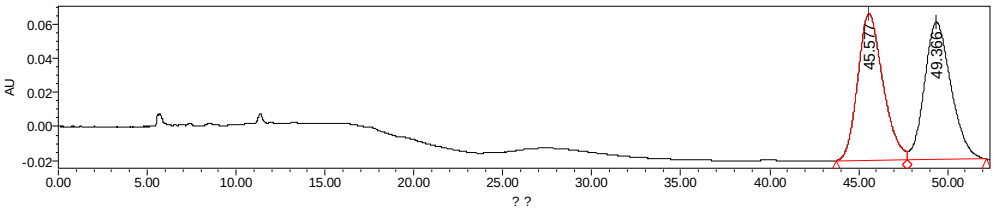


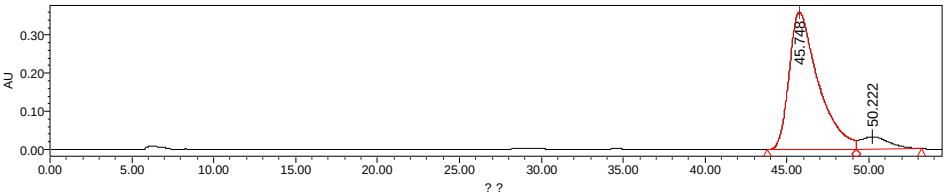
2-Nitro-1-(4'-chlorophenyl)-*N*-tosylethanamine (6j)



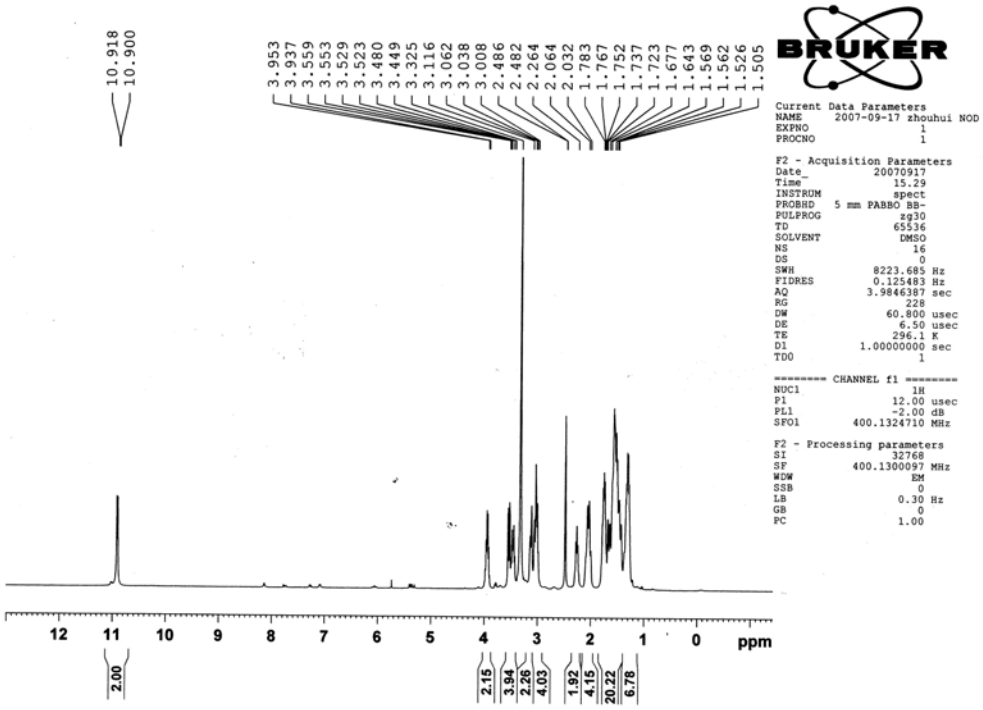
6j

White solid, 84% ee; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62 (d, *J* = 8.0 Hz 2H), 7.24-7.22 (m, 4H), 7.04 (d, *J* = 8.4 Hz, 2H), 5.42 (d, *J* = 6.4 Hz, 1H), 4.96 (m, 1H), 4.80 (q, 1H), 4.60 (q, 1H), 2.42 (s, 3H); $[\alpha]_D^{32}$ 44.6 (*c* 0.11, $CHCl_3$); HPLC (Chiralcel OD-H column, hexane/2-propanol = 85/15, flow 0.5 mL/min, detection at 215 nm) t_r = 45.7 min (major) and t_r = 50.2 min (minor).

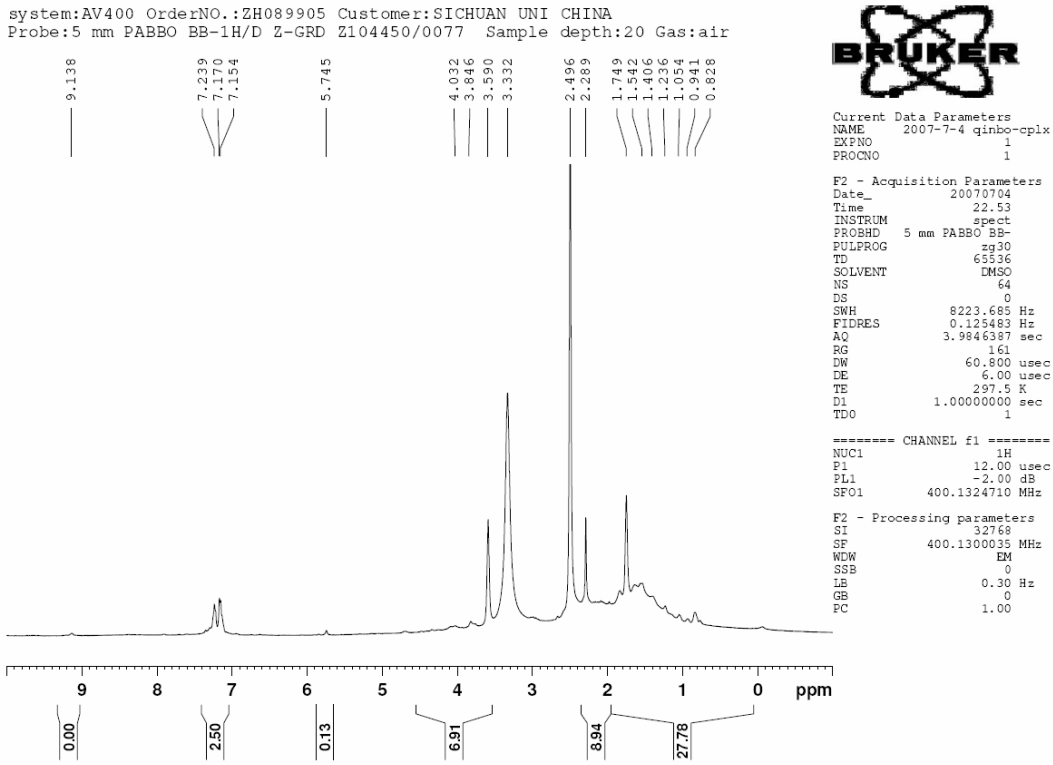




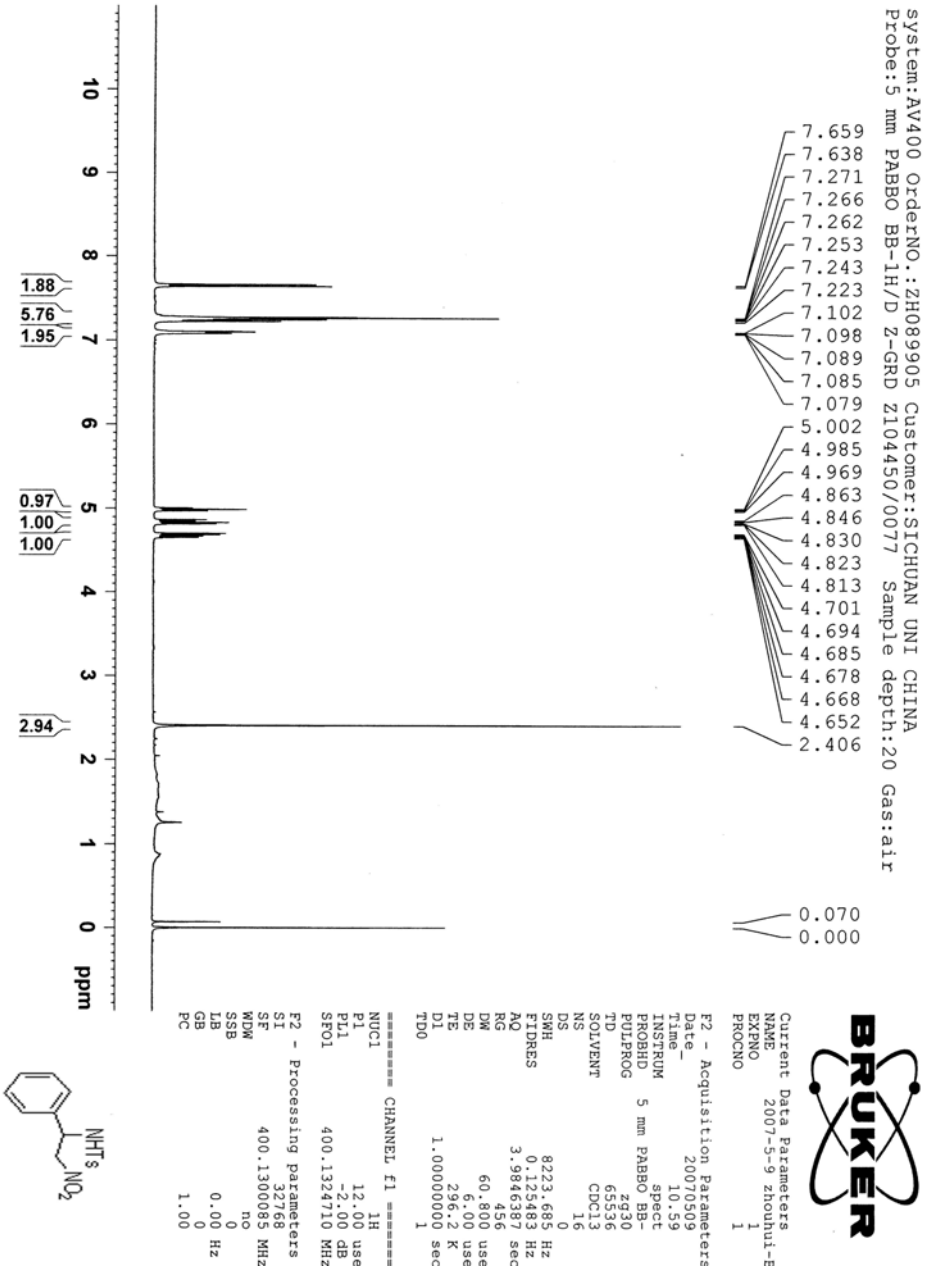
10. **Copy of ^{1}H NMR spectra of 1a**



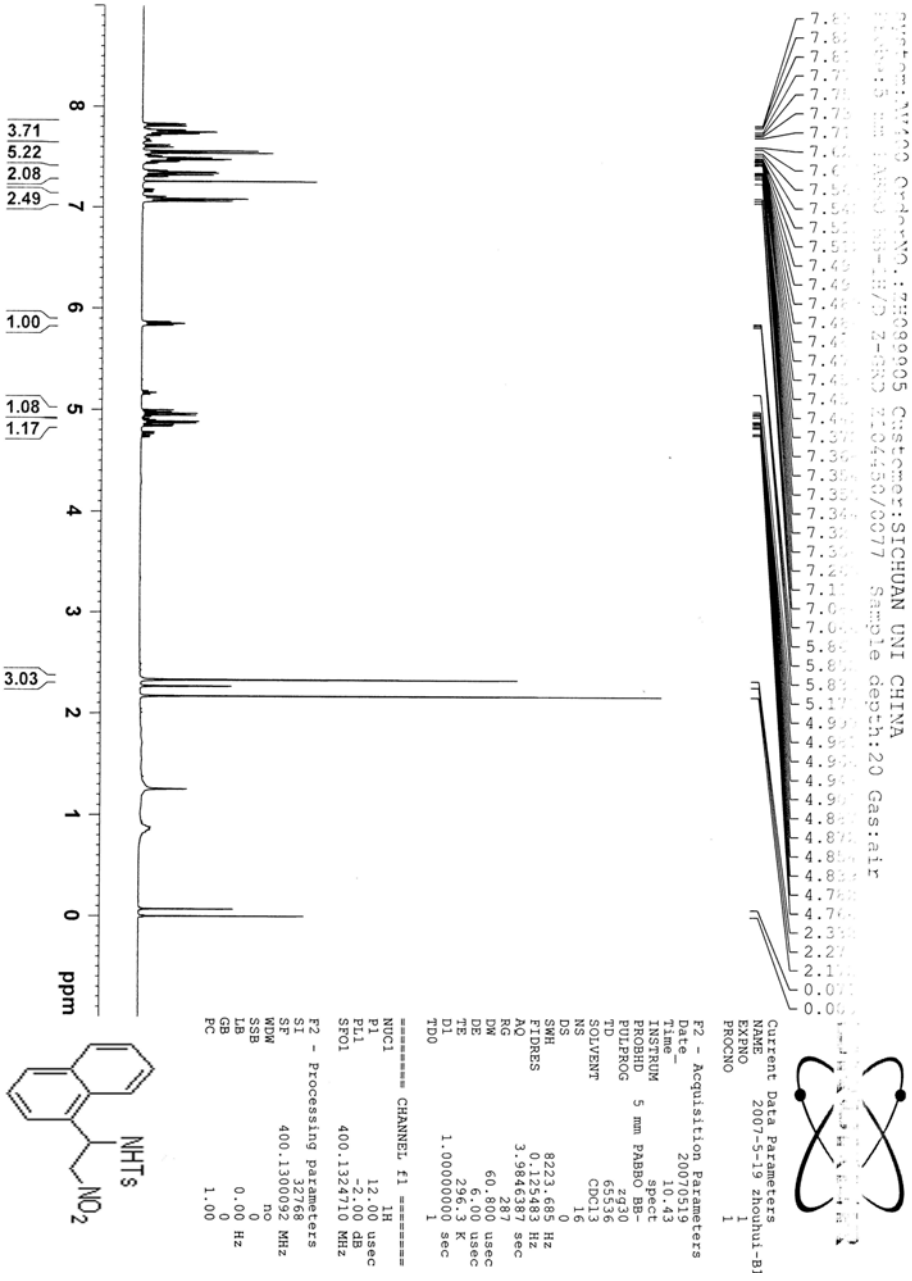
11 **Copy of ^{1}H NMR spectra of CuOTf-1a in the ratio of 1:1**.



12. Copy of NMR spectra of the products



6a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PROCNO 1
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FIDRES 0.125483 Hz
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RG 287
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DE 6.00 usec
TE 296.3 K
D1 1.00000000 sec
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PL1 -2.00 dB
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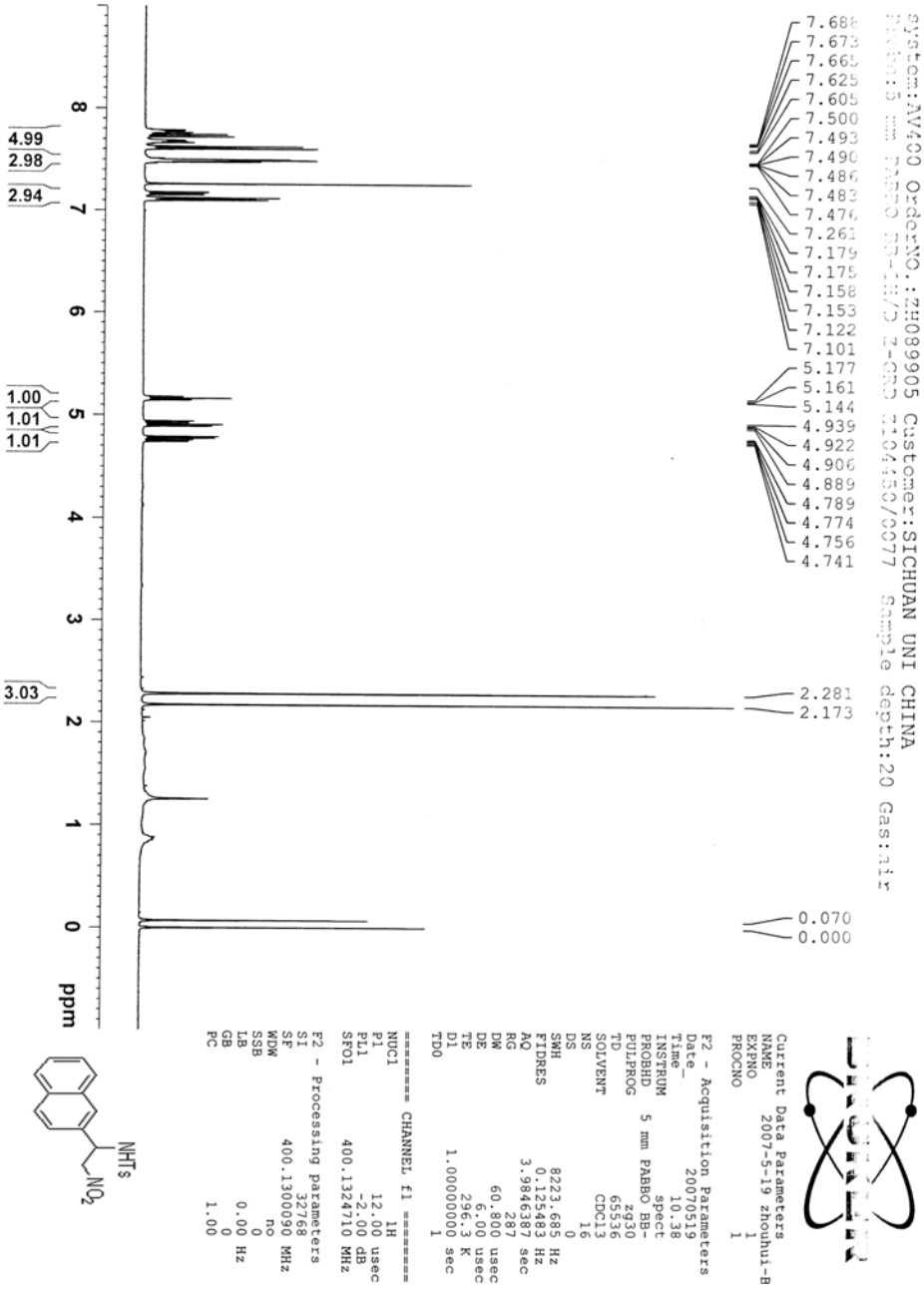
ppm

6b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PROCNO 1
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FIDRES 0.125483 Hz
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RG 287
DW 60.800 usec
DE 6.00 usec
TE 296.3 K
D1 1.00000000 sec
TD0 1
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P1 12.00 usec
PL1 -2.00 dB
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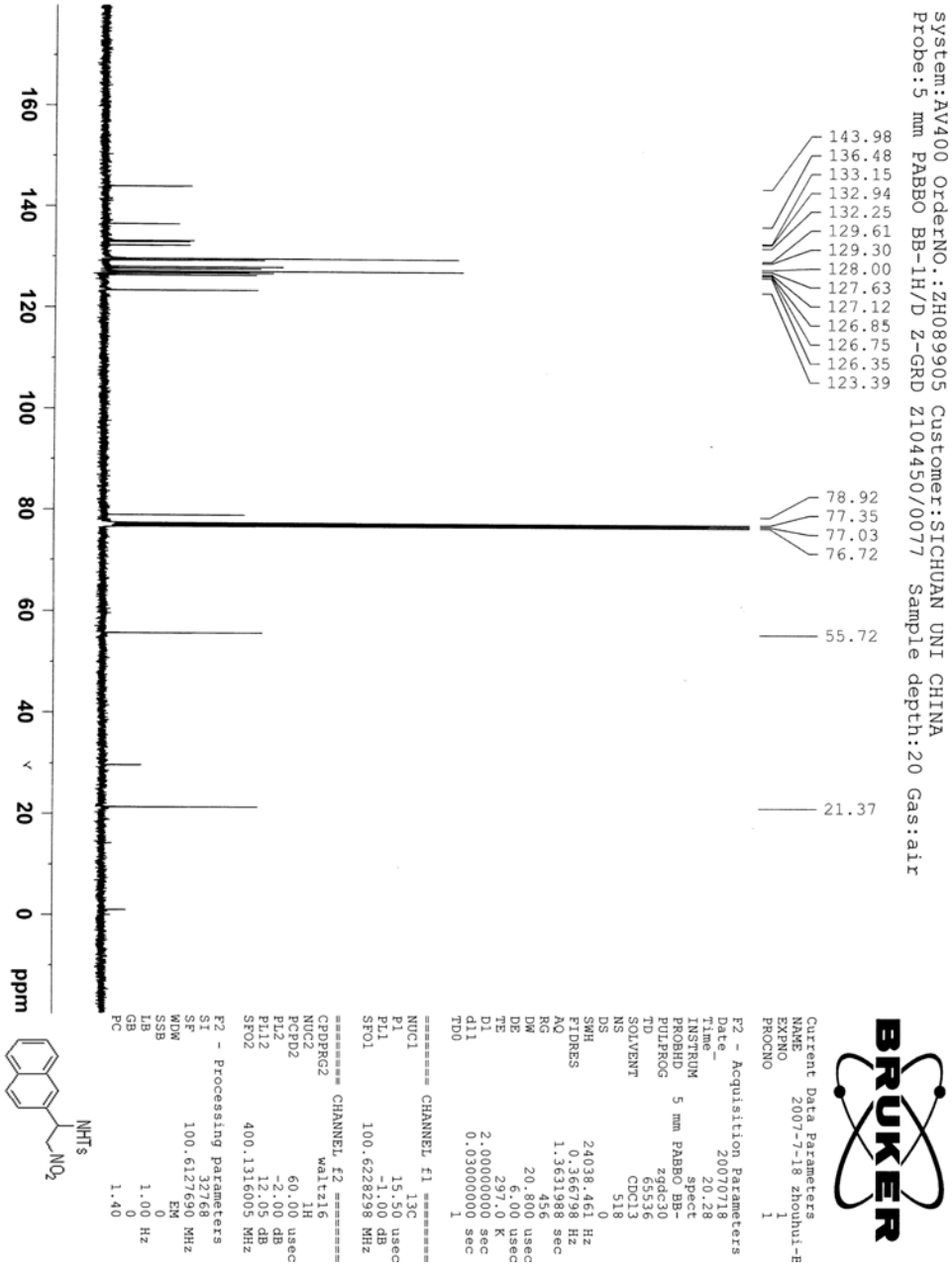
6c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SFO1 100.6228298 MHz
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PL12 12.05 dB
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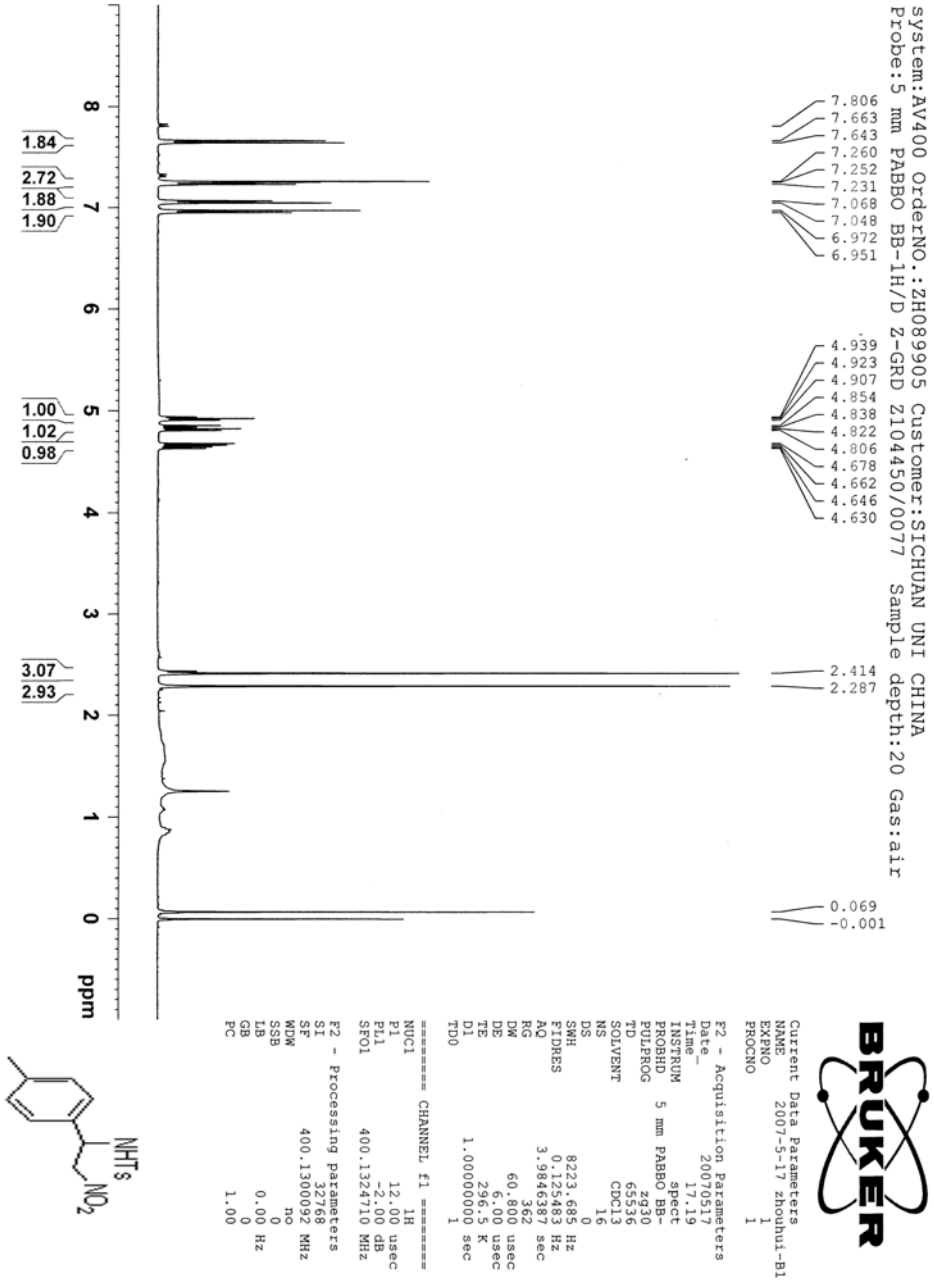
GB 0
PC 1.40
NHTs
NO2

6c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ppm
Current Data Parameters
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PROCNO 1
F2 - Acquisition Parameters
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Time 17.19
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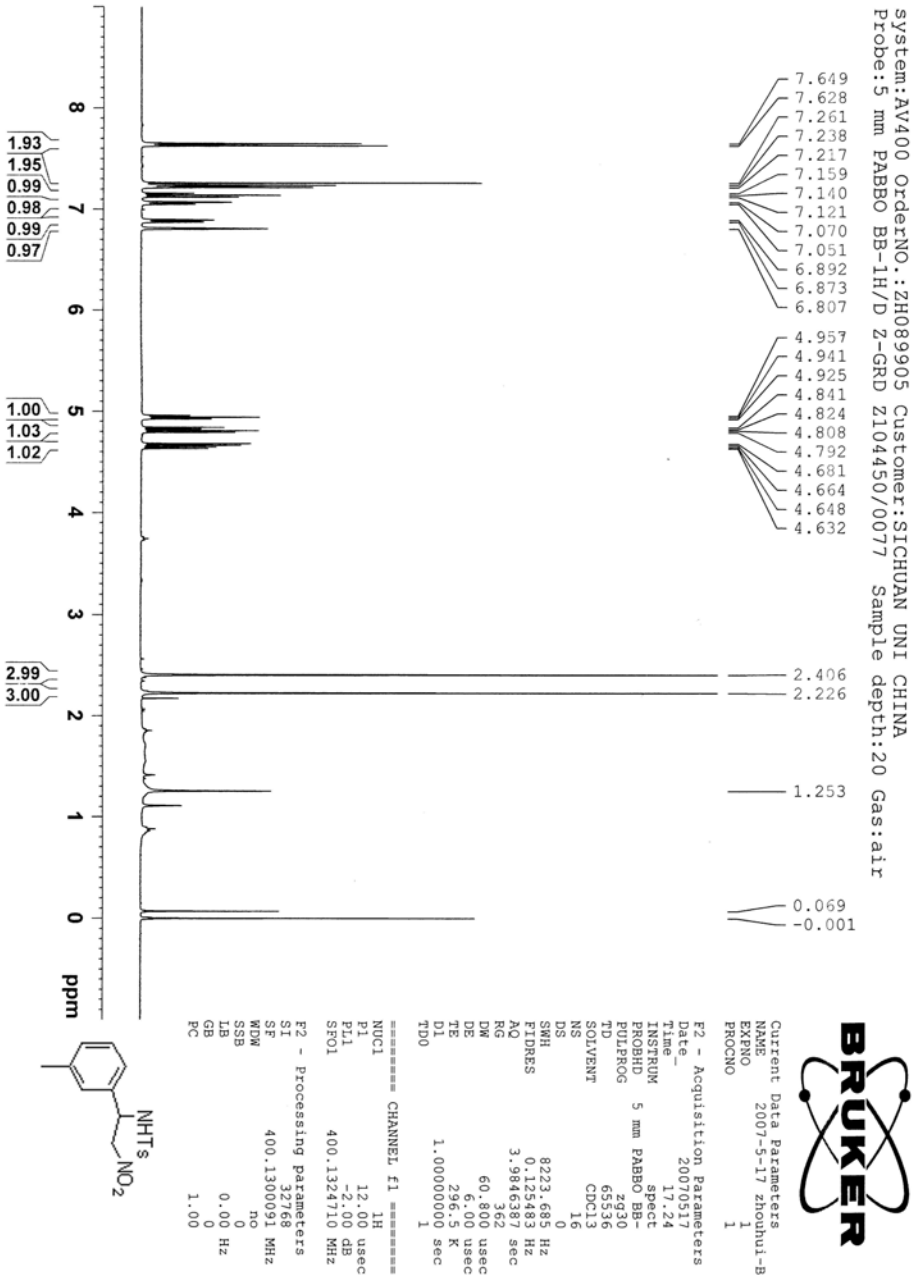
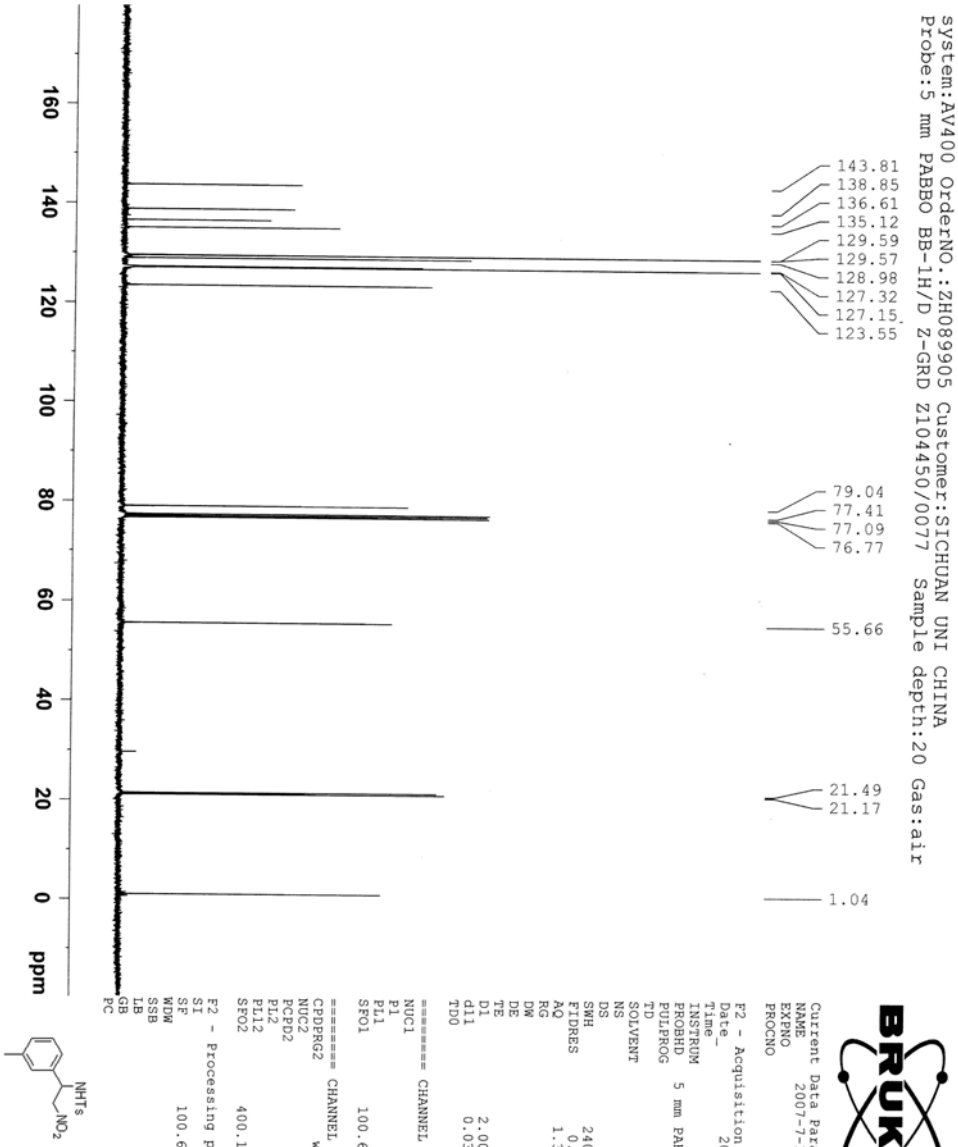
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 0
SWH 8223.685 Hz
FIDRES 0.125483 Hz
AQ 3.9846387 sec
RG 362
DW 60.800 usec
DE 6.00 usec
TE 296.5 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 1H
P1 12.00 usec
PL1 -2.00 dB
SFO1 400.1324710 MHz
F2 - Processing parameters
SI 32768
SF 400.1300092 MHz
WDW no
SSB 0
LB 0.00 Hz
GB 0
PC 1.00
NHTs
NO2

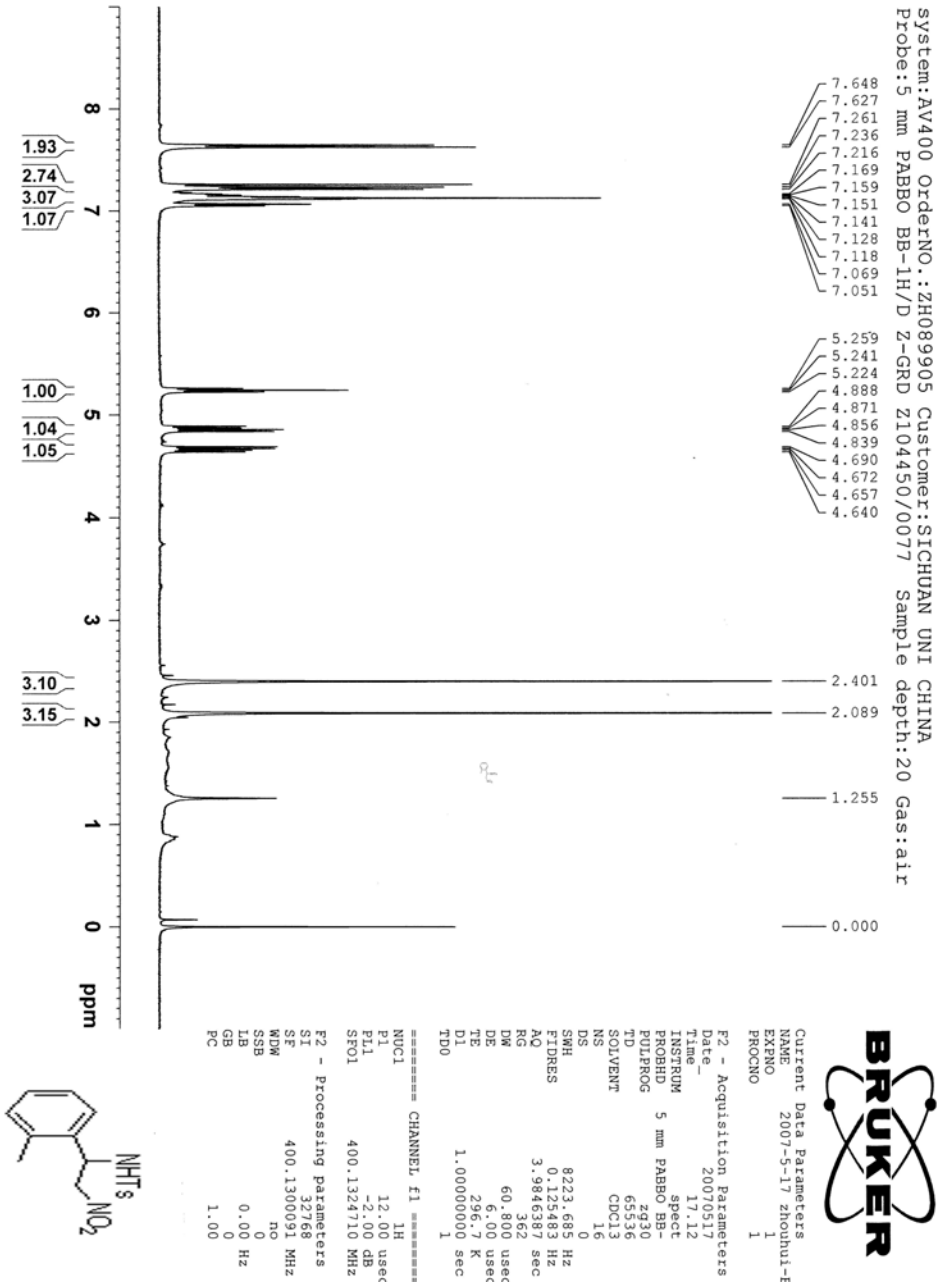
6d


system:AV400 OrderNO.:ZH089905 Customer:SICHUAN UNI CHINA
Probe:5 mm PABBO BB-1H/D Z-GRD Z104450/0077 Sample depth:20 Gas:air
7.649
7.628
7.261
7.238
7.217
7.159
7.140
7.121
7.070
7.051
6.892
6.873
6.807
4.957
4.941
4.925
4.841
4.824
4.808
4.792
4.681
4.664
4.648
4.632
2.406
2.226
1.253
0.069
-0.001
1.93
1.95
0.99
0.98
0.99
0.97
1.00
1.03
1.02
2.99
3.00
ppm
BRUKER
Current Data Parameters
NAME 2007-5-17 zhouhui-B
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20070517
Time 17.24
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 0
SWH 8223.685 Hz
FIDRES 0.125483 Hz
AQ 3.9846387 sec
RG 362
DW 60.800 usec
DE 6.00 usec
TE 296.5 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 1H
P1 12.00 usec
PL1 -2.00 dB
SFO1 400.1324710 MHz
F2 - Processing parameters
SI 32768
SF 400.1300091 MHz
WDW no
SSB 0
LB 0.00 Hz
GB 0
PC 1.00
NHTs
NO2

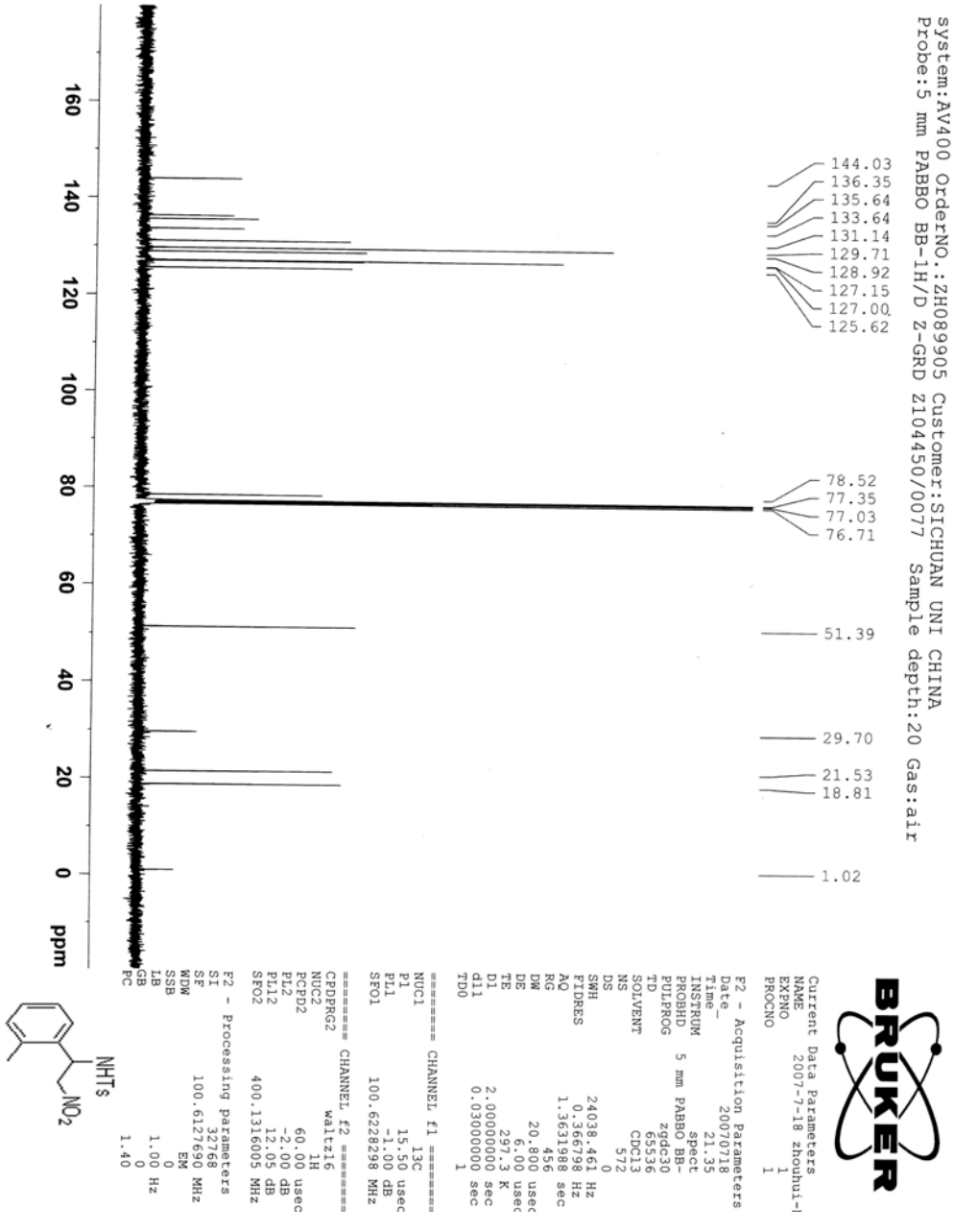
6e


system:AV400 OrderNO.:ZH089905 Customer:SICHUAN UNI CHINA
Probe:5 mm PABBO BB-1H/D Z-GRD Z104450/0077 Sample depth:20 Gas:air
143.81
138.85
136.61
135.12
129.59
129.57
128.98
127.32
127.15
123.55
79.04
77.41
77.09
76.77
55.66
21.49
21.17
1.04
160
140
120
100
80
60
40
20
0
ppm
NHTs
NO2

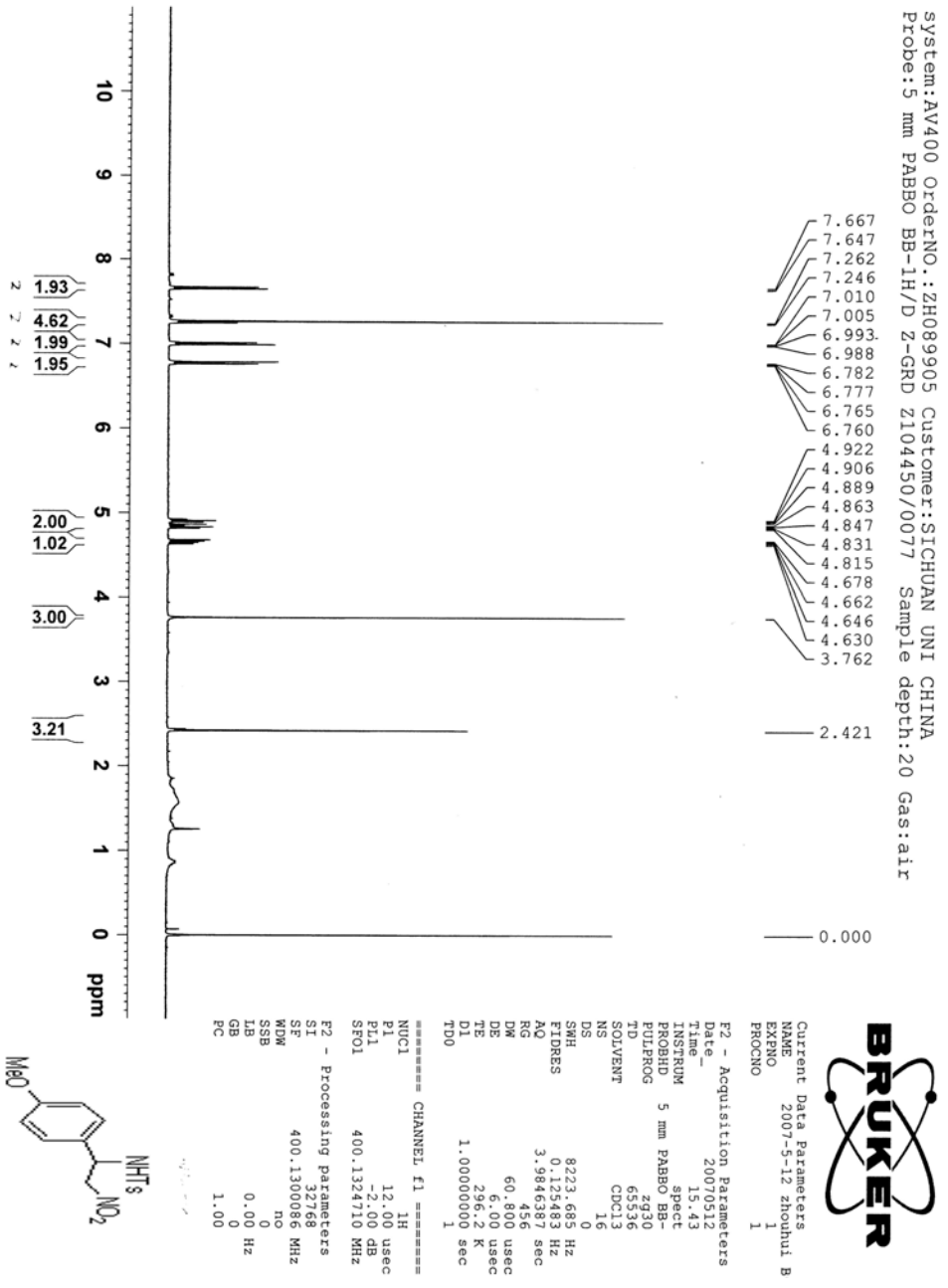
6e


system:AV400 OrderNO.:ZH089905 Customer:SICHUAN UNI CHINA
Probe:5 mm PABBO BB-1H/D Z-GRD 2104450/0077 Sample depth:20 Gas:air
7.648
7.627
7.261
7.236
7.216
7.169
7.159
7.151
7.141
7.128
7.118
7.069
7.051
5.259
5.241
5.224
4.888
4.871
4.856
4.839
4.690
4.672
4.657
4.640
2.401
2.089
1.255
0.000
1.93
2.74
3.07
1.07
1.00
1.04
1.05
3.10
3.15
8
7
6
5
4
3
2
1
0
ppm
BRUKER
Current Data Parameters
NAME 2007-5-17 zhouhui-E
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20070517
Time 17.12
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 0
SWH 8223.685 Hz
FIDRES 0.125483 Hz
AQ 3.9846387 sec
RG 362
DW 60.800 usec
DE 6.00 usec
TE 296.7 K
D1 1.00000000 sec
TD0 1
========== CHANNEL f1 ==========
NUC1 1H
P1 12.00 usec
PL1 -2.00 dB
SFO1 400.1324710 MHz
F2 - Processing parameters
SI 32768
SF 400.1300091 MHz
WDW no
SSB 0
LB 0.00 Hz
GB 0
PC 1.00
NHTs
NO2

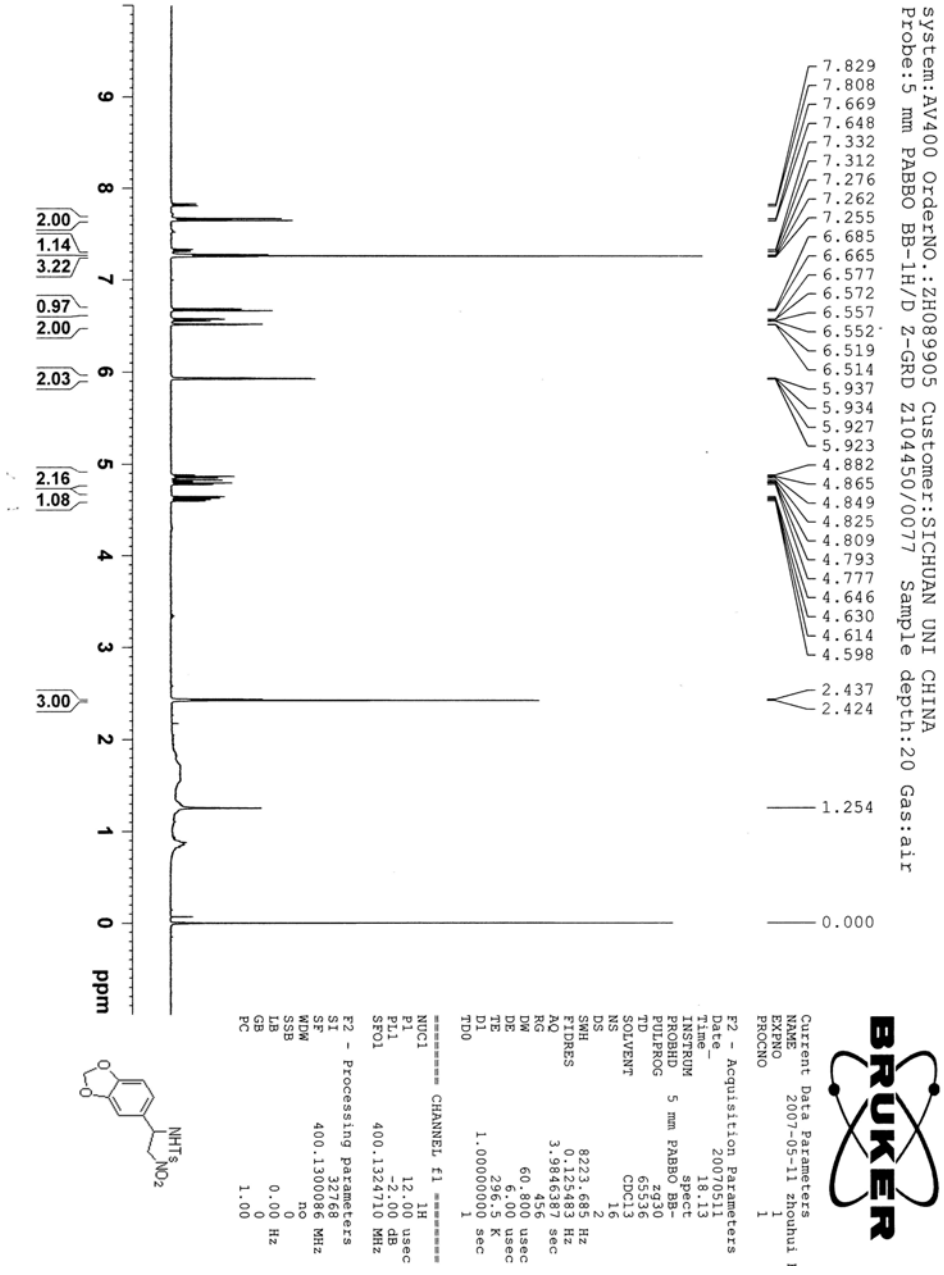
6f


system:AV400 OrderNO.:ZH089905 Customer:SICHUAN UNI CHINA
Probe:5 mm PABBO BB-1H/D Z-GRD Z104450/0077 Sample depth:20 Gas:air
144.03
136.35
135.64
133.64
131.14
129.71
128.92
127.15
127.00
125.62
78.52
77.35
77.03
76.71
51.39
29.70
21.53
18.81
1.02
160
140
120
100
80
60
40
20
0
ppm
BRUKER
Current Data Parameters
NAME 2007-7-18 zhouhui-l
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20070718
Time 21.35
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zgdc30
TD 65536
SOLVENT CDCl3
NS 572
DS 0
SWH 24038.461 Hz
FIDRES 0.366798 Hz
AQ 1.3631988 sec
RG 456
DW 20.800 usec
DE 6.00 usec
TE 297.3 K
D1 2.00000000 sec
d11 0.03000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 13C
P1 15.50 usec
PL1 -1.00 dB
SFO1 100.6228298 MHz
======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 60.00 usec
PL2 -2.00 dB
PL12 12.05 dB
SFO2 400.1316005 MHz
F2 - Processing parameters
SI 32768
SF 100.6127690 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
NHTs
NO2

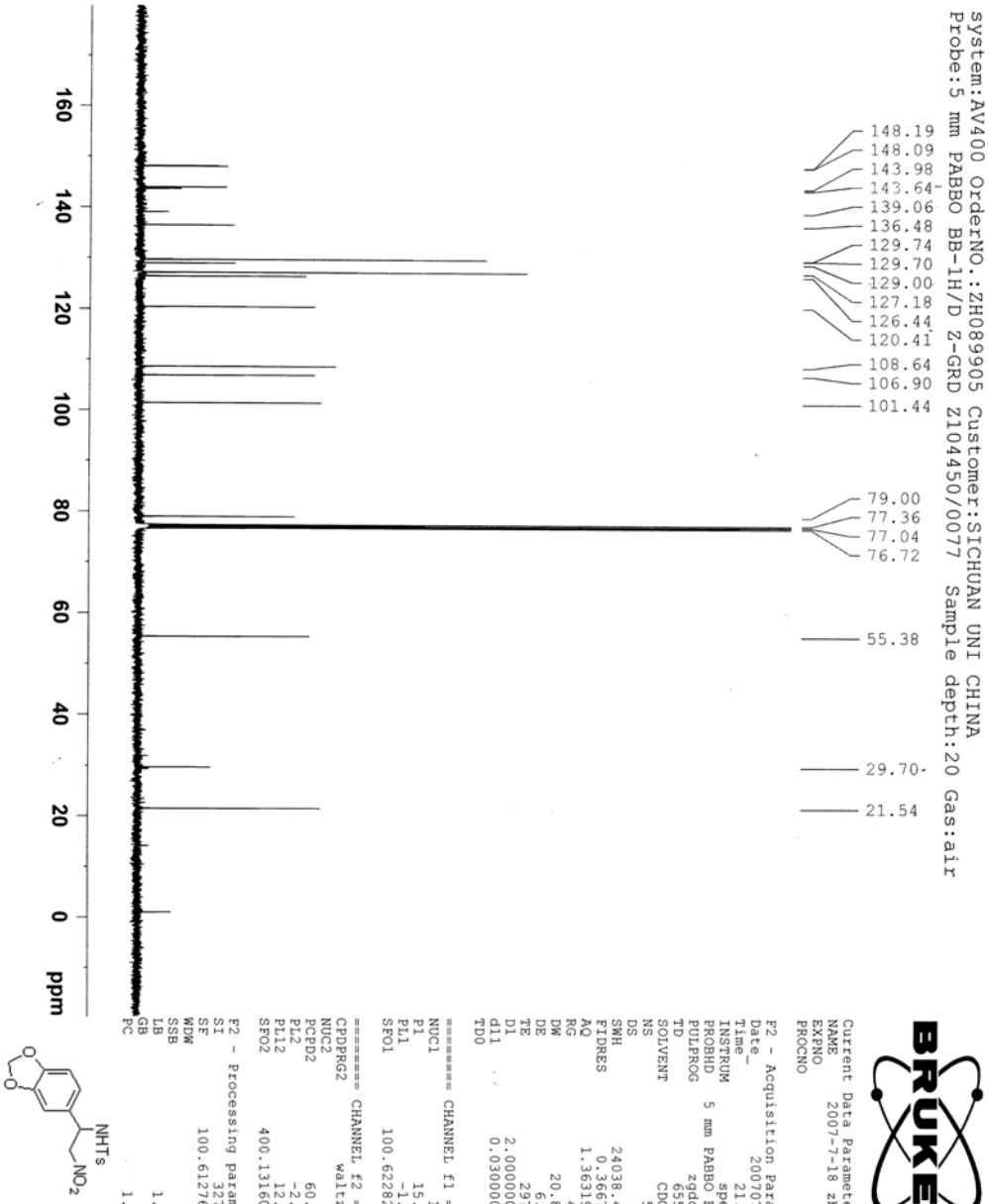
6f

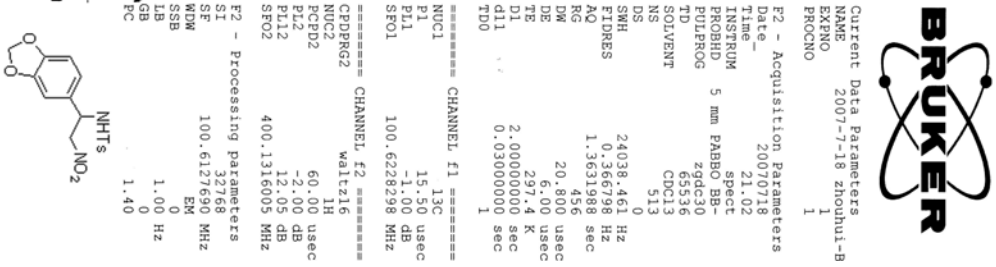

system:AV400 OrderNO.:ZH089905 Customer:SICHUAN UNI CHINA
Probe:5 mm PABBO BB-1H/D Z-GRD Z104450/0077 Sample depth:20 Gas:air
7.667
7.647
7.262
7.246
7.010
7.005
6.993
6.988
6.782
6.777
6.765
6.760
4.922
4.906
4.889
4.863
4.847
4.831
4.815
4.678
4.662
4.646
4.630
3.762
2.421
0.000
Current Data Parameters
NAME 2007-5-12 zhouhui B
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20070512
Time 15.43
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 16
SWH 8223.685 Hz
FIDRES 0.125483 Hz
AQ 3.9846387 sec
RG 456
DW 60.800 usec
DE 6.00 usec
TE 296.2 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 1H
P1 12.00 usec
PL1 -2.00 dB
SFO1 400.1324710 MHz
F2 - Processing parameters
SI 32768
SF 400.1300086 MHz
WDW no
SSB 0
LB 0.00 Hz
GB 0
PC 1.00
1.93
4.62
1.99
1.95
2.00
1.02
3.00
3.21
ppm
MeO
NHTs
NO2

6g

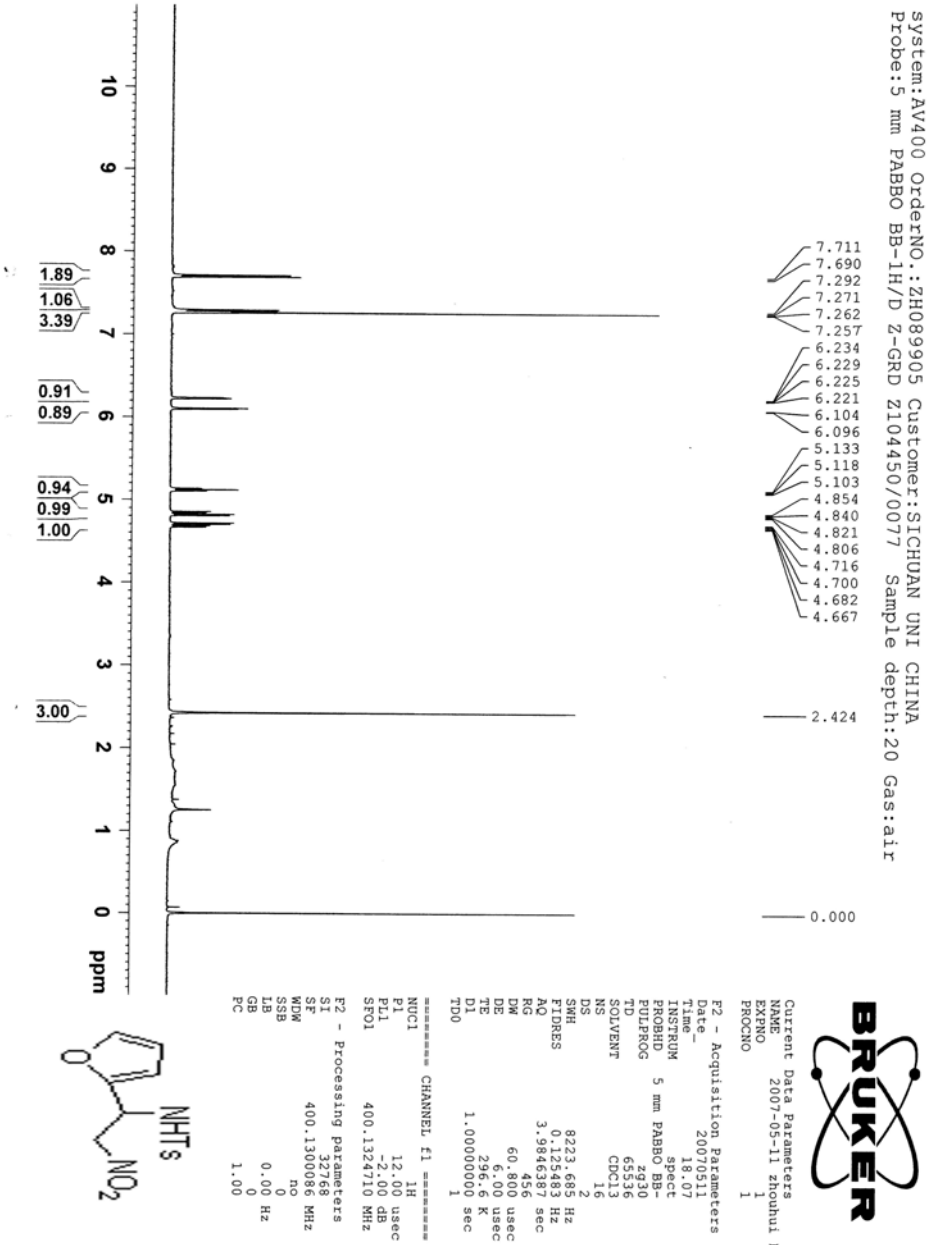

system:AV400 OrderNO.:ZH089905 Customer:SICHUAN UNI CHINA
Probe:5 mm PABBO BB-1H/D Z-GRD Z104450/0077 Sample depth:20 Gas:air
7.829
7.808
7.669
7.648
7.332
7.312
7.276
7.262
7.255
6.685
6.665
6.577
6.572
6.557
6.552
6.519
6.514
5.937
5.934
5.927
5.923
4.882
4.865
4.849
4.825
4.809
4.793
4.777
4.646
4.630
4.614
4.598
2.437
2.424
1.254
0.000
2.00
1.14
3.22
0.97
2.00
2.03
2.16
1.08
3.00
9
8
7
6
5
4
3
2
1
0
ppm
BRUKER
Current Data Parameters
NAME 2007-05-11 zhouhui 1
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20070511
Time 18.13
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8223.685 Hz
FIDRES 0.125483 Hz
AQ 3.9846387 sec
RG 456
DW 60.800 usec
DE 6.00 usec
TE 296.5 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 1H
P1 12.00 usec
PL1 -2.00 dB
SFO1 400.1324710 MHz
F2 - Processing parameters
SI 32768
SF 400.1300086 MHz
WDW no
SSB 0
LB 0.00 Hz
GB 0
PC 1.00
NHTs
NO2

6h

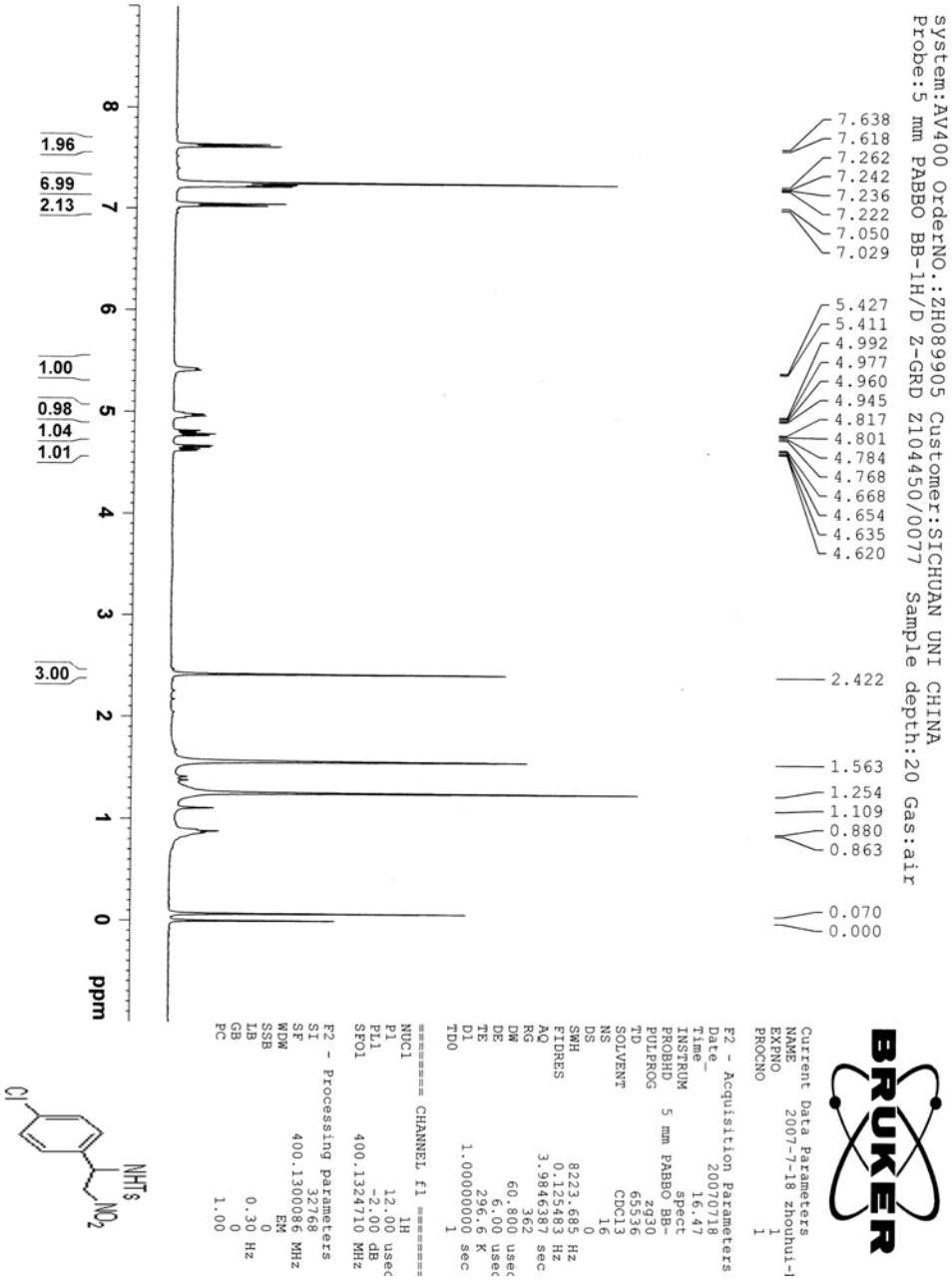

system:AV400 OrderNO.:ZH089905 Customer:SICHUAN UNI CHINA
Probe:5 mm PABBO BB-1H/D Z-GRD Z104450/0077 Sample depth:20 Gas:air
148.19
148.09
143.98
143.64
139.06
136.48
129.74
129.70
129.00
127.18
126.44
120.41
108.64
106.90
101.44
79.00
77.36
77.04
76.72
55.38
29.70
21.54
ppm
160
140
120
100
80
60
40
20
0


BRUKER
Current Data Parameters
NAME 2007-7-18 zhouhui-B
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20070718
Time 21.02
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zgdc30
TD 65536
SOLVENT CDCl3
NS 513
DS 0
SWH 24038.461 Hz
FIDRES 0.366798 Hz
AQ 1.3631988 sec
RG 456
DW 20.800 usec
DE 6.00 usec
TE 297.4 K
D1 2.00000000 sec
d11 0.03000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 13C
P1 15.50 usec
PL1 -1.00 dB
SFO1 100.6228298 MHz
======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 60.00 usec
PL2 -2.00 dB
PL12 12.05 dB
SFO2 400.1316005 MHz
F2 - Processing parameters
SI 32768
SF 100.6127690 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
NHTs
NO2

6h


system:AV400 OrderNO.:ZH089905 Customer:SICHUAN UNI CHINA
Probe:5 mm PABBO BB-1H/D Z-GRD Z104450/0077 Sample depth:20 Gas:air
7.711
7.690
7.292
7.271
7.262
7.257
6.234
6.229
6.225
6.221
6.104
6.096
5.133
5.118
5.103
4.854
4.840
4.821
4.806
4.716
4.700
4.682
4.667
2.424
0.000
1.89
1.06
3.39
0.91
0.89
0.94
0.99
1.00
3.00
10
9
8
7
6
5
4
3
2
1
0
ppm
BRUKER
Current Data Parameters
NAME
EXPNO 2007-05-11 zhouhui
PROCNO 1
F2 - Acquisition Parameters
Date_ 20070511
Time 18.07
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8223.685 Hz
FIDRES 0.125483 Hz
AQ 3.9846387 sec
RG 456
DW 60.800 usec
DE 6.00 usec
TE 296.6 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 1H
P1 12.00 usec
PL1 -2.00 dB
SFO1 400.1324710 MHz
F2 - Processing parameters
SI 32768
SF 400.1300086 MHz
WDW no
SSB 0
LB 0.00 Hz
GB 0
PC 1.00
NHTs
NO2
O

6i


system:AV400 OrderNO.:ZH089905 Customer:SICHUAN UNI CHINA
Probe:5 mm PABBO BB-1H/D Z-GRD Z104450/0077 Sample depth:20 Gas:air
7.638
7.618
7.262
7.242
7.236
7.222
7.050
7.029
5.427
5.411
4.992
4.977
4.960
4.945
4.817
4.801
4.784
4.768
4.668
4.654
4.635
4.620
2.422
1.563
1.254
1.109
0.880
0.863
0.070
0.000
1.96
6.99
2.13
1.00
0.98
1.04
1.01
3.00
ppm
BRUKER
Current Data Parameters
NAME
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20070718
Time 16.47
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 0
SWH 8223.685 Hz
FIDRES 0.125483 Hz
AQ 3.9846387 sec
RG 362
DW 60.800 usec
DE 6.00 usec
TE 296.6 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 1H
P1 12.00 usec
PL1 -2.00 dB
SFO1 400.1324710 MHz
F2 - Processing parameters
SI 32768
SF 400.1300086 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00
NHTs
NO2
Cl

6j