Configuration-Specific Reaction of Nitric Oxide with Aldehyde Arylhydrazones

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Reactions of aldehyde arylhydrazones (**1**) with nitric oxide in the presence of trace oxygen gave exclusively (*E*)-C(1')-nitrohydrazones (**2**) in high yield. The structure of products was confirmed by NMR, IR, MS and X-ray crystallography. The reaction is assumed to be initiated by addition of NO_2 to the imine double.

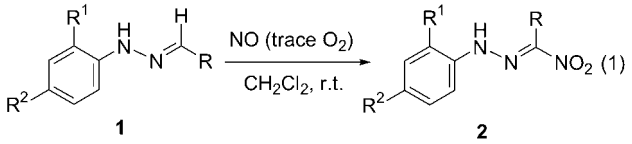
Keywords nitric oxide, hydrazones, electrophilic, addition, configuration-specific

Introduction

Nitric oxide (NO) is a key cell signaling molecule in many biological processes such as vasodilatation, neurotransmission, microbial and tumor-related cell death, tissue damage, and organ-specific autoimmune disorders.[1] Thus, the proper regulation of NO levels is proposed as a desirable target for developing new medicines.[2] In addition, intensive researches have been directed toward reactions of NO with biological molecules[3] and various organic molecules such as amides,[4] oximes,[5] Wittig reagents,[6] Schiff bases,[7] arylhydrazines,[8] ketone hydrazones,[9] chiral (*E*)-(*S*)-2-(benzylideneamino)ethanols,[10] dihydropyrimidinones,[11] 2,3-epoxyphenyl ketones,[12] *N*-tosyl aziridines,[13] enantiopure epoxides,[14] *etc*. The imine double bond of hydrazones was found to be cleaved exclusively in the reaction of ketone hydrazones with NO, giving mono-nitrated azo-compounds.[9]

Arylhydrazones have long been utilized for analyzing carbonyl compounds. In recent years, some of them and their complexes were found to have the anticancer properties.[15] In particular, hydrazones have been used to establish chiral configurations and certain specific skeletons.[16] Moon[17] studied the bromination and chlorination of hydrazones, and obtained the corresponding azo-compounds. The resulting C(1')-halogenated hydrazones were unstable intermediates before they converted into the final products. Guo *et al.*[18] obtained a parallel conclusion that the halogenation of hydrazones was an electrophilic reaction at C(1')-atom and the conversion of halogenated hydrazones to azo-compounds underwent a prototropic reaction.

As part of continuing efforts to explore the role of NO in biochemistry and our ongoing studies on the reaction of NO with arylhydrazones, we have examined the reaction of NO with aldehyde arylhydrazones (**1**) in the presence of trace oxygen in CH_2Cl_2 at room temperature [Eq. (1)]. The unique products, (*E*)-C(1')-nitrohydrazones (**2**), instead of the azo-compounds from ketone arylhydrazones,[9] were obtained in high yield. Their (*Z*)-isomers were not detected. These results indicated that the reaction of NO with **1** occurred in a different mechanism, compared to those of ketone arylhydrazones. We assume that the π-bond of imino-group breaks in the course of reaction, and forms a rotation-free C—N single bond, which afresh constructs a C=N double bond through an elimination reaction.



1 **2**

Experimental

All solvents were distilled prior to use according to standard procedures. Methylene dichloride was dehydrated with CaH_2 by refluxing. (*E*)-Aldehyde hydrazones (**1**) were prepared and purified according to the literature procedure,[19] and characterized by NMR, MS, and IR.

^1H and ^{13}C NMR spectra were recorded on a Bruker Avance 400 (^1H: 400 MHz, ^{13}C: 100 MHz, δ downfield from TMS). IR analysis was performed on a Nicolet NEXUS 670 FT-IR. Mass data were obtained on a

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HP-5988A GC-MS, and HR-ESI-MS data on a Bruker Daltonics APEx II FT-ICR. Melting points were determined with an XT_4-100X micro-melting point apparatus and not corrected.

X-ray analysis on single crystals was carried out at 293(2) K on a Nonius CAD4 automatic diffractometer using Mo Kα radiation (λ=0.71073 Å) graphite monochromation. Structural solutions and full-matrix least-squares refinements based on F^2 were performed with the SHELXS 97 and SHELXL-97 program packages, respectively. All the non-hydrogen atoms were anisotropically positioned. Hydrogen atoms were placed at geometrical positions and constrained to ride on their parent atoms. Analytical expressions of neutral-atom scattering factors were employed, and anomalous dispersion corrections were incorporated. The crystallographic data (excluding structure factors) have been deposited at the Cambridge Crystallographic Data Center.

General procedure for the synthesis of 2a—2j

Compound **1** (0.5 mmol) was dissolved in 100 mL of anhydrous methylene dichloride to give its stock solution. NO was produced by dropwise addition of 1 mol•L^{-1} H_2SO_4 solution to a stirred saturated aqueous solution of $NaNO_2$ under an argon atmosphere. NO gas was purified by passing it through a series of scrubbing bottles containing 4 mol•L^{-1} NaOH, ditilled water, and anhydrous $CaCl_2$ pellets in this order. Bottles were still under an argon atmosphere. The purified NO was bubbled through a stirred stock solution of compound **1**, which was previously degassed by argon for *ca*. 5—10 min and kept at a pressure of up to +10 mm H_2O column over local atmospheric pressure, at ambient temperature for 8—16 h. In the course of reaction, the argon flow rate was controlled by regulating the flow meter at 0.8 L•min^{-1}. The total amount of NO passing through the solution was estimated to be roughly 1000 mmol at the local atmosphere pressure using the ideal gas law. The progress of reaction was monitored by TLC. After the completion of reaction, the mixture was dried over anhydrous $MgSO_4$, concentrated under vacuum, and purified by column chromatography on silica-gel (200—300 mesh, ethyl acetate-hexane: 1∶5, *V*∶*V*), giving the pure product **2** (Table 1).

(*E*)-*N*-(2,4-Dinitrophenyl)-*N*′-(1-nitroethylidene)-hydrazine (2a) Yellow needles, m.p. 143—144 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.66 (s, 3H), 8.17 (d, J=9.2 Hz, 1H), 8.44 (dd, J=2.8, 9.2 Hz, 1H), 9.17 (d, J=2.8 Hz, 1H), 11.11 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 30.8, 117.9, 122.7, 130.5, 132.4, 141.0, 143.3, 150.3; IR (KBr) *v*: 3293 (NH), 3102, 1618, 1599, 1540, 1502, 1430, 1345, 1317, 1283, 1221, 1178, 1134, 1059, 917, 872, 844, 742, 688, 598, 466 cm^{-1}. HR-ESI-MS calcd for $C_8H_7N_5O_6$ (M^+) 269.0391, found 269.0393. EIMS (70 eV) *m*/*z*: 269 (M^+), 181, 135, 78, 63, 51, 43.

(*E*)-*N*-(2,4-Dinitrophenyl)-*N*′-(1-nitrobutylidene)-hydrazine (2b) Yellow needles, m.p. 120 ℃ (decomp.); ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 1.13 (t, J=7.6 Hz, 3H), 1.85 (q, J=7.6 Hz, 2H), 3.03 (t, J=7.6 Hz, 2H), 8.17 (d, J=9.6 Hz, 1H), 8.50 (dd, J=2.8, 9.6 Hz, 1H), 9.16 (d, J=2.8 Hz, 1H), 11.28 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 14.0, 18.8, 27.5, 117.9, 122.8, 130.6, 140.8, 143.4, 154.0; IR (KBr) *v*: 3290 (NH), 3101, 2967, 2874, 1619, 1598, 1532, 1503, 1452, 1427, 1345, 1319, 1274, 1219, 1167, 1133, 912, 848, 739, 610 cm^{-1}. HR-ESI-MS calcd for $C_{10}H_{15}N_6O_6$ ($M+NH_4^+$) 285.1052, found 285.1055. EIMS (70 eV) *m*/*z*: 297 (M^+), 268, 206, 195, 71, 43.

X-ray crystallography data for 2b $C_{10}H_{11}N_5O_6$, M_r=297.24, monocinic, space group $P2(1)/c$ with cell dimension of a=1.2284(2) nm, b=1.7594(3) nm, c=0.61338(7) nm, β=94.67(1)°, V=1.3213(3) nm^3, Z=4, ρ_{calcd}=1.494 g/cm^3, μ=1.26 cm^{-1}. $F(000)$=616, 3.32°≤2θ≤50.98°, −14≤h≤14, −21≤k≤0, 0≤l≤7. 2991 data collected, 2461 unique data (R_{int}=0.0112). 1599 data with $I>2\sigma(I)$, 192 refined parameters, GOF(F^2)=0.954, R_1=0.0594, wR_2=0.0891. The crystallographic data have been deposited at the Cambridge Crystallographic Data Center as Supplementary Publication No. CCDC-212522.

(*E*)-*N*-(2,4-Dinitrophenyl)-*N*′-(3-methyl-1-nitrobutylidene)hydrazine (2c) Yellow needles, m.p. 123

Table 1 Reaction of NO with **1** in CH_2Cl_2

Entry	Hydrazone	R	R^1	R^2	Time[a]/h	Yield of **2**[b]/%
1	**1a**	CH_3	NO_2	NO_2	8	94
2	**1b**	*n*-C_3H_7	NO_2	NO_2	8	96
3	**1c**	*i*-C_4H_9	NO_2	NO_2	8	96
4	**1d**	*i*-C_3H_7	NO_2	NO_2	10	94
5	**1e**	*p*-Methoxyphenyl	NO_2	NO_2	10	95
6	**1f**	Phenyl	NO_2	NO_2	12	93
7	**1g**	*p*-Chlorophenyl	NO_2	NO_2	13	94
8	**1h**	Phenyl	H	NO_2	12	91
9	**1i**	*p*-Nitrophenyl	NO_2	NO_2	16	90
10	**1j**	3,4-Dimethoxyphenyl	NO_2	NO_2	10	94

[a] The reaction time (h). [b] Yield of the isolated product.

—124 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 1.22 (d, J= 7.2 Hz, 6H), 2.25 (m, 1H), 2.95 (d, J=7.2 Hz, 2H), 8.17 (d, J=9.6 Hz, 1H), 8.49 (dd, J=2.8, 9.6 Hz, 1H), 9.18 (d, J=2.8 Hz, 1H), 11.32 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 22.6, 27.0, 34.4, 117.9, 122.8, 130.6, 132.2, 140.8, 143.4, 153.7; IR (KBr) v: 3299 (NH), 3099, 2965, 2930, 2872, 1615, 1596, 1537, 1498, 1449, 1425, 1334, 1220, 1179, 1334, 1061, 918, 849, 740, 688, 599 cm^{-1}. HR-ESI-MS calcd for $C_{11}H_{11}N_5O_6$ (M^+) 300.0865, found 300.0865.

(*E*)-*N*-(2,4-Dinitrophenyl)-*N′*-(2-methyl-1-nitropropylidene)hydrazine (2d) Yellow needles, m.p. 119—121 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 1.35 (d, J=6.8 Hz, 6H), 3.49 (d, J=6.8 Hz, 1H), 8.13 (d, J= 9.6 Hz, 1H), 9.47 (dd, J=2.4, 9.6 Hz, 1H), 9.16 (d, J= 2.4 Hz, 1H), 11.32 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 20.2 (×2), 30.7, 117.2, 122.9, 130.1, 132.4, 140.9, 143.4, 146.2; IR (KBr) v: 3243 (NH), 3117, 3092, 2991, 2876, 1611, 1589, 1548, 1492, 1411, 1333, 1299, 1253, 1164, 1132, 1083, 1049, 916, 880, 692 cm^{-1}. HR-ESI-MS calcd for $C_{10}H_{15}N_6O_6$ ($M+NH_4^+$) 285.1052, found 285.1060. EIMS (70 eV) m/z: 297 (M^+), 190, 181, 77, 75, 71, 63, 43, 41, 39.

(*E*)-*N*-(2,4-Dinitrophenyl)-*N′*-[(4-methoxyphenyl)-nitromethylene]hydrazine (2e) Red needles, m.p. 115—116 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 3.94 (s, 3H), 7.18 (d, J=9.6 Hz, 2H), 7.44 (d, J=9.6 Hz, 2H), 8.24 (d, J=9.6 Hz, 1H), 8.48 (d, J=2.4, 9.6 Hz, 1H), 9.11 (d, J=2.4 Hz, 1H), 11.38 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 55.6, 115.0, 115.6, 115.9, 122.7, 130.4, 130.5, 132.2, 140.7, 143.2, 151.3, 162.7; IR (KBr) v: 3253 (NH), 3101, 2975, 2929, 1615, 1598, 1541, 1505, 1429, 1352, 1312, 1265, 1228, 1172, 1136, 1113, 1018, 996, 830 cm^{-1}. HR-ESI-MS calcd for $C_{14}H_{15}N_6O_7$ ($M+NH_4^+$) 379.0997, found 379.1006. EIMS (70 eV) m/z: 361 (M^+), 298, 282, 269, 252, 223, 135.

X-ray crystallography data for 2e $C_{14}H_{11}N_5O_7$, M_r=361.28, monocinic, space group $P2(1)/c$ with cell dimension of a=1.5075(2) nm, b=1.7683(3) nm, c= 0.6099(3) nm, β=100.43(1)°, V=1.5990(4) nm^3, Z=4, ρ_{calcd}=1.501 g/cm^3, μ=1.23 cm^{-1}. $F(000)$=744, 2.74° ≤2θ≤50.50°, −18≤h≤17, −21≤k≤0, 0≤l≤7. 3199 data collected, 2898 unique data (R_{int}=0.0118), 1578 data with $I>2\sigma(I)$, 237 refined parameters, GOF(F^2)=1.027, R_1=0.0547, wR_2=0.1626. The crystallographic data have been deposited at the Cambridge Crystallographic Data Center as Supplementary Publication No. CCDC-224158.

(*E*)-*N*-(2,4-Dinitrophenyl)-*N′*-(nitro-phenyl-methylene)hydrazine (2f) Yellow needles, m.p. 125—126 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 7.53—7.73 (m, 5H), 8.24 (d, J=8.8 Hz, 1H), 8.51 (dd, J=8.8, 1.6 Hz, 1H), 9.11 (d, J=1.6 Hz, 1H), 11.32 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 117.9, 122.7, 123.6, 128.6, 130.1, 130.4, 132.4, 132.7, 141.0, 143.0; IR (KBr) v: 3269, 3100, 1616, 1596, 1541, 1497, 1430, 1345, 1318, 1215, 1136, 1004, 918, 850, 817, 740, 698 cm^{-1}. HR-ESI-MS calcd for $C_{13}H_9N_5O_6Na$ ($M+Na^+$) 354.0445, found 354.0448. EIMS (70 eV) m/z: 331 (M^+), 238, 222, 193, 182, 164, 105, 77.

(*E*)-*N*-(2,4-Dinitrophenyl)-*N′*-[(4-chlorophenyl)-1-nitromethylene]hydrazine (2g) Yellow needles, m.p. 120—122 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 7.53 (d, J=11.2 Hz, 2H), 7.73 (d, J=11.2 Hz, 2H), 8.24 (d, J= 11.2 Hz, 1H), 8.52 (dd, J=2.0, 13.2 Hz, 1H), 9.10 (d, J=2.0 Hz, 1H), 11.26 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 118.1, 121.8, 122.8, 129.2, 130.2, 130.6, 130.7, 132.5, 139.3, 141.2, 142.9, 149.7. EIMS (70 eV) m/z: 365 (M^+), 336, 290, 274, 256, 227, 164, 156, 139, 111, 75.

(*E*)-*N*-(4-Nitrophenyl)-*N′*-(nitro-phenyl-methylene)-hydrazine (2h) Red needle, m.p. 112—114 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 7.16—7.60 (m, 7H), 8.18 (d, J=12.0 Hz, 2H), 11.73 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 124.1, 124.9, 129.0, 129.9, 130.5, 135.0, 150.1, 154.5, 181.3; IR (KBr) v: 3434, 3265, 1595, 1570, 1497, 1445, 1409, 1340, 1248, 1176, 1106, 1003, 968, 850, 766, 747, 688, 620 cm^{-1}. HRESIMS calcd for $C_{13}H_{10}N_4O_4$ ($M+H^+$) 287.0775, found 287.0786. EIMS (70 eV) m/z: 286 (M^+), 257, 239, 194, 167, 149, 105, 77.

(*E*)-*N*-(2,4-Dinitrophenyl)-*N′*-[(4-nitrophenyl)-1-nitromethylene]hydrazine (2i) Yellow needles, m.p. 164 ℃ (decomp); ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 7.72 (d, J=8.8 Hz, 2H), 8.22 (d, J=9.6 Hz, 1H), 8.33—8.52 (m, 3H), 9.06 (d, J=2.4 Hz, 1H), 11.28 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 118.0, 122.6, 123.7, 125.1, 129.7, 130.5, 130.6, 132.8, 141.5, 142.4, 149.8; IR (KBr) v: 3276, 3104, 2847, 1615, 1598, 1536, 1520, 1500, 1439, 1343, 1316, 1222, 1143, 1118, 1024, 1007, 909, 850, 812, 740, 706, 692, 618, 557 cm^{-1}. EIMS (70 eV) m/z: 376 (M^+), 343, 311, 279, 195, 167, 149, 69, 57, 43.

(*E*)-*N*-(2,4-Dinitrophenyl)-*N′*-[(3,4-dimethoxyphenyl)-1-nitromethylene]hydrazine (2j) Red needles, m.p. 128—130 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 3.94 (s, 3H), 4.01 (s, 3H), 6.96 (d, J=2.4 Hz, 1H), 7.16—7.19 (m, 2H), 8.24 (d, J=12.8 Hz, 1H), 8.48 (dd, J= 2.8, 12.8 Hz, 1H), 9.11 (d, J=2.8 Hz, 1H) 11.45 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 31.2, 56.4, 111.1, 112.1, 115.2, 117.5, 118.3, 122.6, 123.1, 130.7, 132.7, 141.1, 143.5, 150.6, 152.9; IR (KBr) v: 3270, 3089, 2962, 2936, 2841, 1618, 1594, 1542, 1509, 1452, 1427, 1342, 1316, 1263, 1202, 1170, 1138, 1013, 912, 846 cm^{-1}. HR-ESI-MS calcd for $C_{15}H_{13}N_4O_8$ (M^+-H) 390.0691, found 390.0682. EIMS (70 eV) m/z: 391 (M^+), 362, 300, 202, 165, 77.

Results and discussion

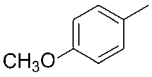
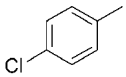
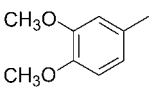
Results for the reaction of NO with **1** are summarized in Table 1. As seen from Table 1, there was a substituent effect on the reaction. The properties of R group affected the facility of the nitro substitution and hence controlled the rate of reaction. When R in **1** was an alkly group, the time needed for reaction completion became

shorter than an aryl group. Electron-donating groups on the aromatic ring of **1** facilitated the reaction and took a shorter time for reaction completion than electron-withdrawing groups at the same positions (Entries 5 and 9), whereas electron-withdrawing substituents prolonged the reaction time somewhat. In general, hydrazones **1** were more reactive than ketone arylhydrazones,[9a] particularly for those with an aliphatic R.

Before the whole system was filled with NO gas carried by argon, it was found that the O_2 concentration in the system influenced the composition of product and the reaction time. No product was formed when air (or O_2) was rigorously excluded from the medium. In contrast, when there is more oxygen in the system, a fast reaction occurred, leading to a complex pattern of products. Most of the products are highly polar compounds that are difficult to be purified. We found that the best reaction condition is that the argon-purging time was controlled to 5—10 min and kept at a pressure of up to +10 mm H_2O column over local atmospheric pressure, and NO gas can be inputted in a flask, thus the desired products were obtained in the presence of trace oxygen. These results are similar to the reaction of NO with alken.[22]

All the products were identified by ^{1}H and ^{13}C NMR, NOE 1D, MS, HRMS, and IR. The presence of NH groups was confirmed by IR bands near 3200 cm^{-1} and ^{1}H NMR singlet peaks near δ 11.3. Products **2** were identified to have (*E*)-configurations both for alkyl and aryl aldehyde hydrazones by NOE experiments. The chemical shift and 1D-NOESY (η%) of Hb are listed in Table 2. The observation of NOE enhancement of

Table 2 ^{1}H NOE difference spectral data for **2a**—**2j**

Product	R	Ha	Hb	
		δ	δ	NOESY (η%)
2a	CH_3	11.12	1.67	3.80
2b	*n*-C_3H_7	11.29	3.03	5.72
2c	*i*-C_4H_9	11.32	2.95	6.49
2d	*i*-C_3H_7	11.29	3.50	4.13
2e		11.38	7.50	2.78
2f		11.33	7.72	3.10
2g		11.28	7.52	2.66
2h		11.73	7.58	2.46
2j		11.45	6.96, 7.15	4.32

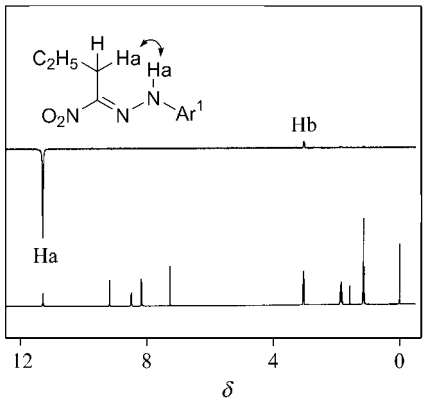


Figure 1 ^{1}H NOE difference spectra of **2b**.

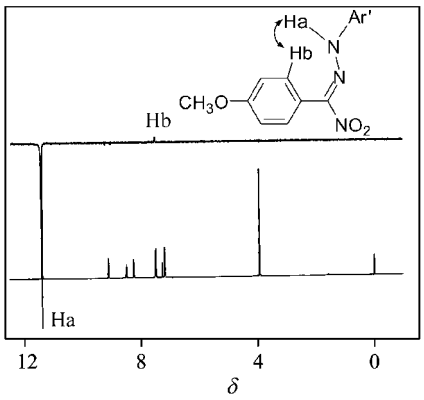


Figure 2 ^{1}H NOE difference spectra of **2e**.

α-proton Hb signals of alkyl (R=alkyl) for **2a—2d** or *ortho*-proton Hb signals of aryls (R=aryl) for **2e—2j** resulted from irradiation of NH protons (Ha, about δ 11.3) as shown in Figures 1 and 2.

Figures 3 and 4 show ^{1}H NOE difference spectra of **1b** and **1e**, respectively. An NOE enhancement was observed at proton Hb of the C—N double bond upon irradiation of proton Ha of NH in **1**. This indicates that Ha was related to Hb, that is, R (alkyl or aryl) and NHAr^1 groups are on opposite sides of the C—N double bond. Figures 1 and 2 display ^{1}H NOE difference spectra of **2b** and **2e**. NOE enhancements were observed at Hb upon irradiation of Ha, giving η% Hb of 5.72% for

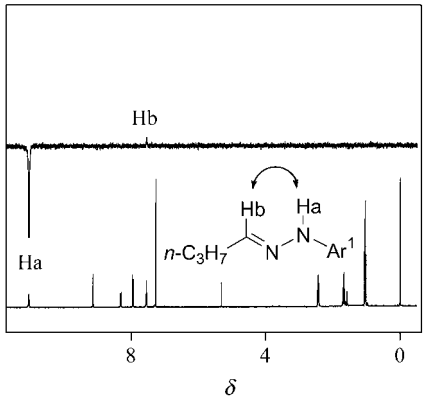


Figure 3 ^{1}H NOE difference spectra of **1b**.

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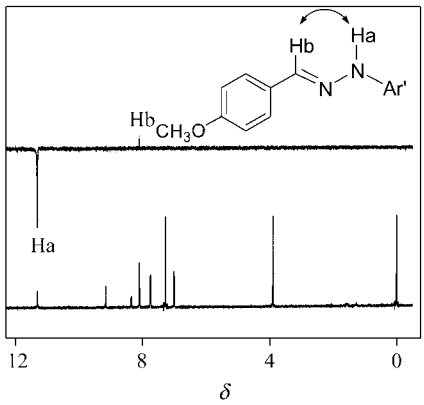


Figure 4 ^{1}H NOE difference spectra of **1e**.

2b and of 2.78% for **2e**, respectively. They indicate that R and NHAr[1] groups are on the same sides of the C—N double bond, whereas NO_2 and NHAr[1] groups are on opposite sides. This confirms **2** with an (*E*)-configuration.

Their structures were further confirmed by X-ray crystallography diffraction. The molecules of both compounds displayed *trans* configurations with respect to the C—N double bonds. Figure 5 shows the molecular structure of **2b** and its Newman project viewed along the N(4)—C(7) bond, in which an NO_2 group is linked on the carbon atom C(7) [*i.e.*, C(1')-atom; N(5)—C(7),

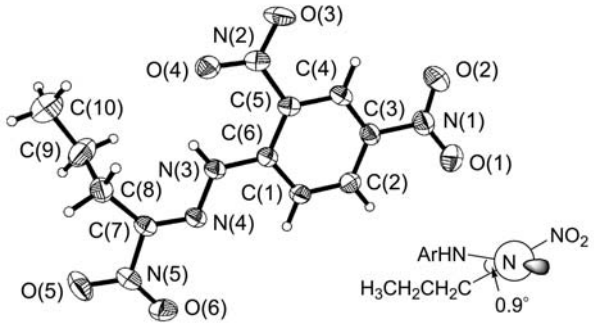


Figure 5 Molecular structure of **2b** and its Newman project viewed along the N(4)—C(7) bond

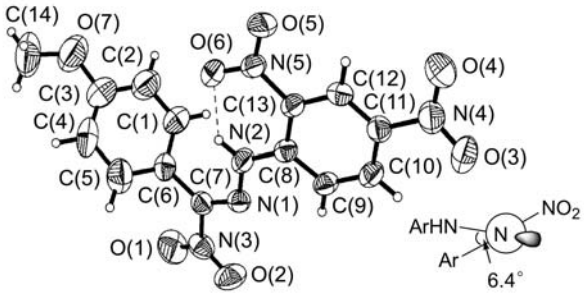
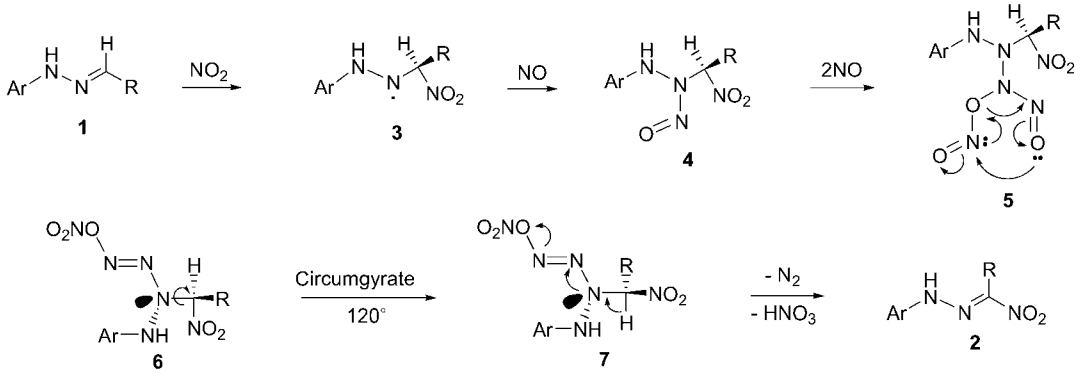


Figure 6 Molecular structure of **2e** and its Newman project viewed along the N(1)—C(7) bond.

0.1487(2) nm; C(7)—N(4), 0.1270(2) nm] and has an (*E*)-configuration. Figure 6 shows the molecular structure of **2e** and its Newman project viewed along the N(1)—C(7) bond, in which an NO_2 group linked on the carbon atom C(7) [*i.e.*, C(1')-atom; N(3)—C(7), 0.1489(4) nm, C(7) — N(1), 0.1273(4) nm] and has an (*E*)-configuration. Both the C(7)—N(4) bond length of 0.1270 nm in **2b** and the C(7)—N(1) bond length of 0.1273 nm in **2e** confirm that their imine double bonds are preserved. The benzene ring and alkyl carbon chain (R = *n*-propyl) are nearly coplanarity with a dihedral angle of 0.9° in **2b**, which is much less than that of 6.4° in **2e** between the dinitro-benzene ring and the methoxy-benzene ring. This might be attributed to the steric effect of R group (R = *p*-methoxyphenyl).

Based on the reaction of NO and NO_2 with alkenes,[20-23] a mechanism for the reaction of NO with **1** is proposed in Scheme 1. It is suggested that an initial electrophilic addition of an NO_2 to the carbon of the imine double bond of **1** leads to formation of radical **3**. It couples with one molecule of NO to give nitroso adduct **4**. The addition of two molecules of NO to its nitroso group yields *N*-nitroso-*N*-nitrite **5**. The followed rearrangement gives the diazonium nitrate **6**, which isomerizes to **7** via an 120° rotation around the C—N bond. Compound **7** undergoes an *anti* (180°) elimination of HNO_3 with the expulsion of N_2 generating **2**. Besides product **2**, nitric acid is also detected in liquid phase.[9a]

Scheme 1



The existence of components such as N_2 and NO_2 in the gas phase was hard to detect due to technical difficulties.

Conclusion

The present study demonstrats that the reaction of NO with aldehyde arylhydrazones in the presence of trace oxygen at room temperature occurs at their C—N double bonds, uniquely giving C(1')-nitrohydrazones with (*E*)-configurations in high yield. It offers an efficient method for preparing C(1')-nitrohydrazones with (*E*)-configurations.

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