Generation of Nitrile Oxides from Oxime Derivatives by the Oxidation with Ammonium Hexanitratocerate(IV)

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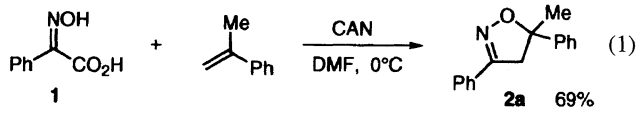
Aromatic and aliphatic nitrile oxides are generated by the oxidation of α-hydroxyimino carboxylic acid with ammonium hexanitratocerate(IV). They react with olefinic and acetylenic dipolarophiles to give the corresponding cycloaddition products in good yield. The oxidation of α-oxo aldoximes also affords α-oxo carbonitrile oxides.

The 1,3-dipolar cycloaddition reaction between nitrile oxides and unsaturated compounds has attracted much interest as a useful method for preparation of isoxazole derivatives in a regio- and stereoselective manner.[1] Three methods have been conventionally employed to generate nitrile oxides: that is, the dehydrohalogenation of hydroximoyl chlorides under basic conditions,[2] the oxidation of aldoximes by aqueous solution of sodium hypochlorite,[3] and the dehydration of primary nitroalkanes by phenyl isocyanate in the presence of a catalytic amount of base.[4] We would like to report here a method to generate nitrile oxides from α-hydroxyimino carboxylic acids or α-oxo aldoximes.

Results and Discussion

Generation of Nitrile Oxides from α-Hydroxyimino Carboxylic Acids. When a dimethylformamide (DMF) solution of 2-(hydroxyimino)-2-phenylacetic acid (**1**)[4] was added to a solution of 2 molar amounts of cerium(IV) ammonium nitrate (CAN) and 2-phenylpropane in DMF at 0 °C, 4,5-dihydro-5-methyl-3,5-diphenylisoxazole (**2a**) was obtained in 69% yield (Eq. 1). The yield decreased when the reaction was carried out below 0 °C, while **2a** was obtained in almost the same yield at room temperature.

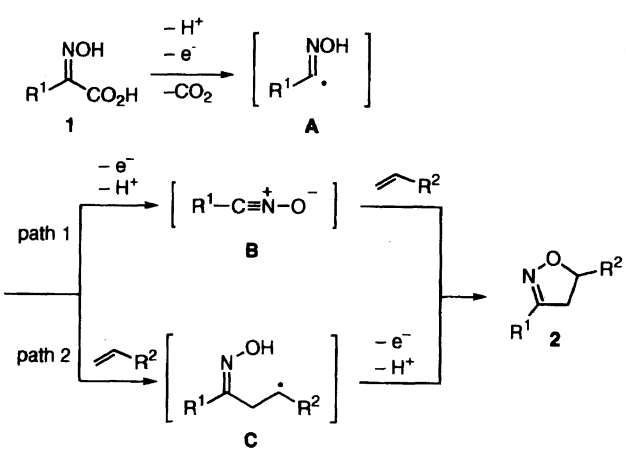


(1)

When tris(2-pyridinecarboxylato)manganese(III), bis(2-pyridinecarboxylato)silver(II), and tris(2,2′-bipyridyl)iron-(III) tris(hexafluorophosphate), were employed as oxidants instead of CAN, they gave the product **2a** in low yield: 2, 8, and 28%, respectively. Oxidation did not proceed with Ce(*N*,*N*′-disalicylideneethylenediaminato)$_2$. Although methanol and acetonitrile can dissolve CAN and **1** as well as DMF, the reaction in these solvents gave the product **2a** in low yield.

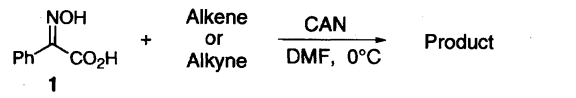
Thus, under these optimum conditions, the reaction of **1** and various olefins was carried out in DMF at 0 °C using CAN as an oxidant. The results are summarized in Table 1. The cycloaddition reaction proceeded with aromatic (Entries 1 and 2), aliphatic (Entry 3), and electron-deficient olefins (Entries 4 and 5) to give cycloadducts in moderate yield, whereas the reaction with vinyl acetate gave the product **2f** in inferior yield (Entry 6). The cyclization also occurred with acetylenes to afford isoxazole derivatives **2g**, **2h**, **2i**, and **2j** in moderate yield (Entries 7, 8, and 9). In the reactions with ethyl propiolate, two regioisomers **2i**, and **2j** were obtained in the ratio of 76 : 24. This ratio shows good agreement with the reported reaction of benzonitrile oxide generated from benzohydroximoyl chloride.[5] When the yield of the addition product was low or when no acceptor was employed, 3, 4-diphenylfurazan 2-oxide (3,4-diphenylfuroxane) (**3**) was isolated (Entries 6 and 10).

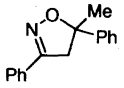
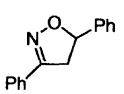
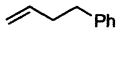
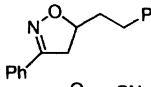
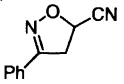
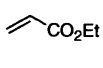
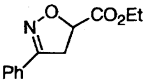
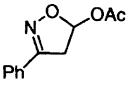
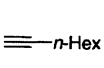
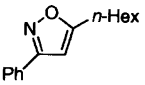
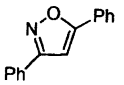
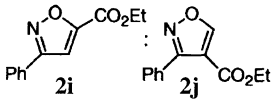
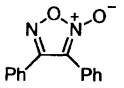
The plausible mechanism of the reaction is depicted in Scheme 1, in which two pathways are conceivable. The α-hydroxyimino carboxylic acid **1** is oxidized to the carboxyl radical, which immediately cleaves into a carbohydroximic radical **A**. The successive oxidation of the radical **A** generates a nitrile oxide **B**, which reacts with an olefin and gives the cycloadduct **2** (path 1). Another reaction pathway is possible; that is, the addition of the hydroxyimino radical **A** to the



Scheme 1.

Table 1. Reaction of 2-Hydroxyimino-2-phenylacetic Acid with Alkenens and Alkynes[a)]



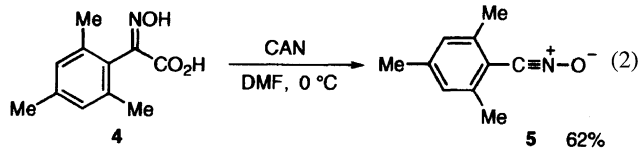
Entry	Acceptor	Product	Yield/%
1		 **2a**	69
2		 **2b**	72
3		 **2c**	65
4		 **2d**	60
5		 **2e**	70
6		 **2f**	42 (12)[b)]
7		 **2g**	41
8		 **2h**	59
9		 **2i** : **2j** =76 : 24	62
10	None	 **3**	59

a) 2 molar amounts of CAN and 2 molar amounts of acceptor were employed. b) Yield of furoxane **3**.

olefin generates an radical addition intermediate **C**, and then oxidation and cyclization proceed to give the product **2** (path 2).

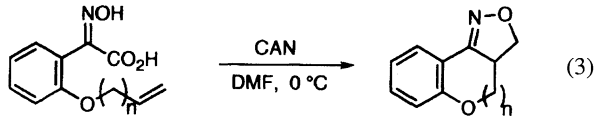
Although these two pathways are conceivable, nitrile oxides are supposed to be the intermediates in the olefin addition process on the basis of the results in Table 1. That is, the better reactivity with simple and electron-rich olefins, not to be observed in the usual radical reaction, combined with the regioselectivity obtained in Entry 9, well agrees with that of the conventional cycloaddition reaction of nitrile oxides as before mentioned. Furthermore, the furoxane **3**, known as the dimer of benzonitrile oxide, was obtained when **1** was oxidized with CAN in the absence of dipolarophile (Entry 10). These results strongly support the intermediacy of nitrile oxides.

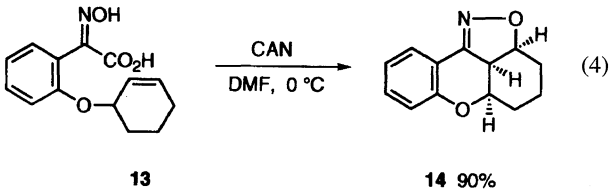
To obtain further support for the formation of nitrile oxide, the isolation of nitrile oxide was attempted. Though nitrile oxides are so unstable that they are generated usually in situ, some with bulky groups which prevent themselves from dimerization can be isolated.[6] Accordingly, 2-(hydroxyimino)-2-(2,4,6-trimethylphenyl)acetic acid (**4**) was oxidized under the same reaction conditions in the absence of dipolarophile, and 2,4,6-trimethylbenzonitrile oxide (**5**) was isolated in 62% (Eq. 2).



Besides the generation of arenecarbonitrile oxide, alkanenitrile oxides can also be formed by the method described above. When 2-hydroxyimino-5-phenylpentanoic acid (**6**) was treated with CAN in the presence of a dipole acceptor, 3-phenylpropanenitrile oxide was generated to afford the corresponding addition product **7** in moderate yield. The results are listed in Table 2. The tendency of reactivity was similar to that of benzonitile oxide, and a furoxan **8** was also obtained when the yield of products was poor.

This reaction was further applied to the intramolecular cycloaddition. When α-hydroxyimino carboxylic acids **9** and **13**, which have an olefinic part in the molecules, were treated with CAN, the cyclized products **11** and **14** were obtained in excellent yield, and **14** was a single stereoisomer as shown below (Eqs. 3 and 4). Similar to the case of six-membered ring formation reaction, a seven-membered ring product **12** was obtained from a homoallyl ether **10** (Eq. 3).

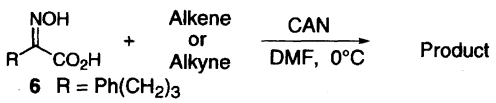


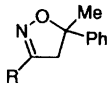
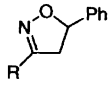
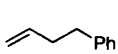
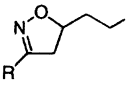
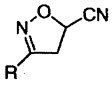
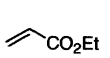
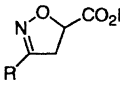
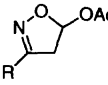
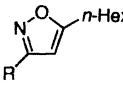
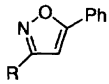
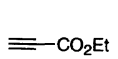
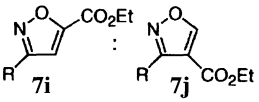


Although oxidation with lead(IV) acetate is known as a method for generation of nitrile oxides from oxime derivatives, such reactions require the starting materials to be (*E*)-aldoximes or β-stannyl ketoximes to generate nitrile oxides. In contrast, the present method can be successfully applied to various 2-hydroxyiminocarboxylic acids to afford the corresponding isoxazole derivatives in good to moderate yield. Oxidation with CAN has a further advantage as a synthetic method, since CAN is less toxic and much more stable than lead(IV) acetate.

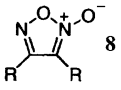
Generation of α-Oxo Carbonitrile Oxides from α-Oxo Aldoximes. In the course of our study on the oxida-

Table 2. Reaction of 2-Hydroxyimino-5-phenylpentanoic Acid with Alkenens and Alkynes[a)]

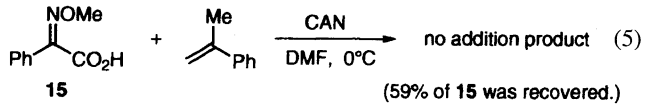


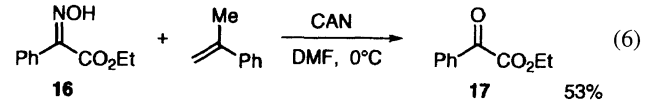
Entry	Acceptor	Product	Yield/%
1		 **7a**	61
2		 **7b**	70
3		 **7c**	57
4		 **7d**	63
5		 **7e**	64
6		 **7f**	12 (14)[b)]
7		 **7g**	29 (10)[b)]
8		 **7h**	37
9		 = 85 : 15	64

a) 2 molar amounts of CAN and 2 amounts of acceptor were employed. b) Yield of furoxane **8**.

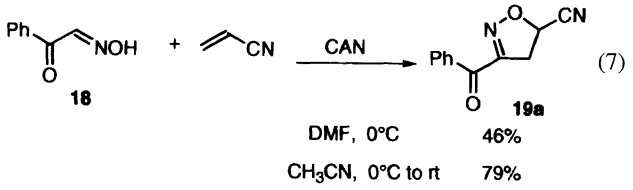


tion of α-hydroxyimino carboxylic acid with CAN, the effect of substituents around the hydroxyimino carboxylic part was investigated. The oxidation of an *O*-methyl derivative, 2-(methoxyimino)-3-phenylacetic acid (**15**), with CAN did not proceed well, and the reaction of ethyl 2-(hydroxyimino)acetate (**16**) gave ethyl 2-oxo-2-phenylacetate (**17**) as a major product (Eqs. 5 and 6). These results indicate that the generation of nitrile oxide from oxime derivatives with CAN require both a free *N*-hydroxy group and a certain leaving group on the oxyimino carbon such as carboxy group. Thus, we decided to examine the oxidation of α-oxoaldoximes which have a free *N*-hydroxy group and an eliminable hydrogen on the oxyimino carbon.





When 2-oxo-2-phenylacetaldehyde 1-oxime (**18**) was treated with CAN in the presence of acrylonitrile according to the above reaction conditions, 3-benzoyl-4,5-dihydro-5-isoxazolecarbonitrile (**19a**) was obtained in 46% yield. Optimization of the reaction conditions revealed that the best yield (83%) of the product **19a** was obtained when the reaction was carried out in acetonitrile at 0 °C and allowed to warm to room temperature (Eq. 7).

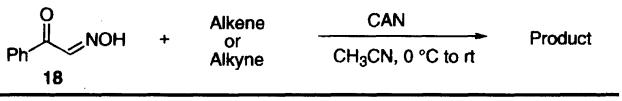


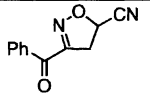
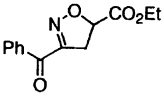
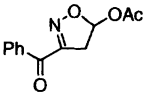
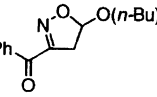
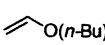
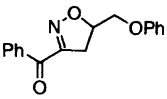
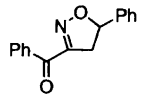
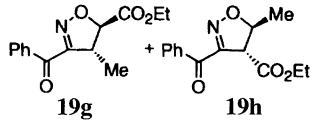
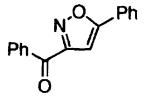
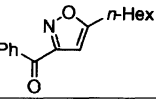
Results of the reaction of **18** in the presence of various alkenes and alkynes are summarized in Table 3. Reactions with electron-deficient olefins (Entries 1 and 2), vinyl acetate (Entry 3), vinyl ether (Entry 4), and allylic ether (Entry 5) gave the corresponding 3-benzoyldihydroisoxazole derivatives **19** in good yield, whereas styrene gave poor yield of isoxazole **19f** (Entry 6). In the reaction with methyl crotonate, the stereochemistry of the olefin was completely retained, to be reflected in the exclusive *trans* relative configuration of the product, which implies that the reaction proceeds in a concerted manner (Entry 7). The reaction with phenylacetylene afforded the product **19i** in good yield (Entry 8). When 1-octyne was employed, the product **19j** was obtained in 47% yield (Entry 9).

Aliphatic α-oxo aldoxime **20** and 2-(hydroxyimino)acetic ester **21** were suitable substrates for this type of reaction as well as **18**. Results of their reaction with alkenes and alkynes in Table 4 show a similar tendency to that of the reaction of **18**.

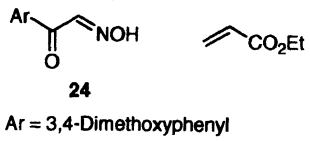
Oxidation of aldoximes with sodium hypochlorite or *N*-bromosuccinimide (NBS) is one of the best known methods of generation of nitrile oxides. In order to evaluate the synthetic utility of our method of the generation of 2-oxoacetonirile *N*-oxides, a comparison between CAN oxidation and hypochlorite or NBS oxidation was carried out.

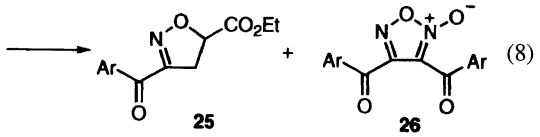
Table 3. Reaction of 2-Oxo-2-phenylacetaldehyde 1-Oxime with Alkenens and Alkynes[a)]



Entry	Acceptor	Product		Yield/%
1			**19a**	83
2			**19b**	85
3			**19c**	79
4			**19d**	56[b)]
5			**19e**	72
6			**19f**	21
7		 **19g** 2 : 1 **19h**		23
8			**19i**	70
9			**19j**	47

a) 2 molar amounts of CAN and 5 molar amounts of acceptor were employed. b) This reaction was performed with $[(n\text{-Bu})_4N]_2[Ce(NO_3)_6]$ in CH_2Cl_2.



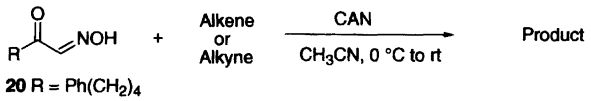


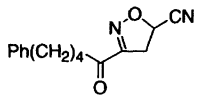
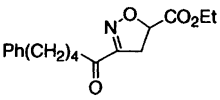
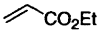
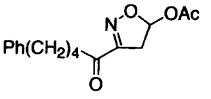
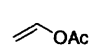
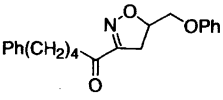
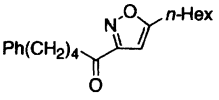
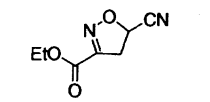
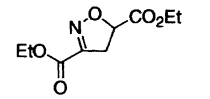
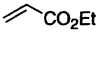
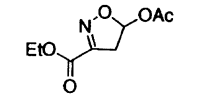
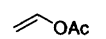
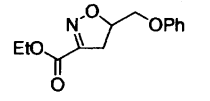
(8)

CAN / CH_3CN	97%	0%
NBS / DMF	10%	72%
NaClO / $CHCl_3$–H_2O	90%	0%

As shown in Eq. 8, the oxidation of **24** with both CAN and NaClO gave a cycloadduct **25** in high yield, while the reaction with NBS afforded a furoxane **26** mainly (72%) and the yield of the desired product **25** was 10%. Thus it was disclosed that hypochlorite oxidation gives a result comparable to CAN oxidation in the case of the generation of α-oxo areneacetonitrile *N*-oxide. We turned our attention to generation of aliphatic α-oxo carbonitrile oxides. When 1-hydroxyimine-6-phenyl-2-hexanone (**20**) was treated with CAN in

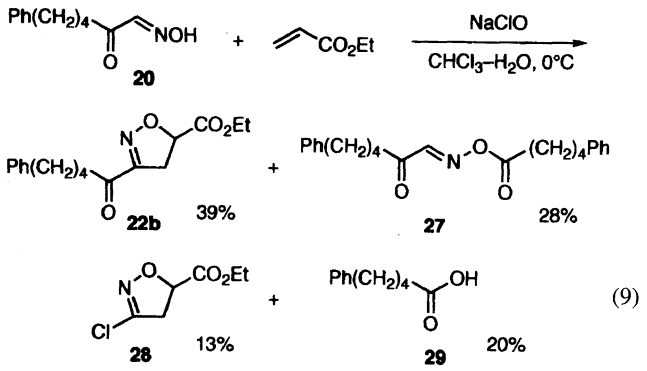
Table 4. Reaction of 1-Hydroxyimino-6-phenyl-2-hexanone and Ethyl 2-(Hydroxyimino)acetate with Alkenens and Alkynes[a)]



Entry	Acceptor	Product		Yield/%
20 R = $Ph(CH_2)_4$				
1			**22a**	41
2			**2ba**	64
3			**22c**	63
4			**22d**	48
5			**22e**	24
21 R = EtO				
6			**23a**	56
7			**23b**	65
8			**23c**	61
9			**23d**	62
10			**23e**	29

a) 2 molar amounts of CAN and 5 molar amounts of acceptor were employed.

the presence of ethyl acrylate, the corresponding 4,5-dihydroisoxazole derivative was obtained in moderate yield (64%) as shown in Table 4 (Entry 2). The addition reaction between 1-hydroxyimine-6-phenyl-2-hexanone (**20**) and ethyl acrylate by the use of sodium hypochlorite afforded the product **22b** in 39% yield, accompanied by a self-condensation product **27** (28%) and a 3-chloro-4,5-dihydroisoxzole derivative **28** (13%) (Eq. 9). 5-Phenylpentanoic acid (**29**) was obtained in 20% yield from the aqueous phase.



(9)

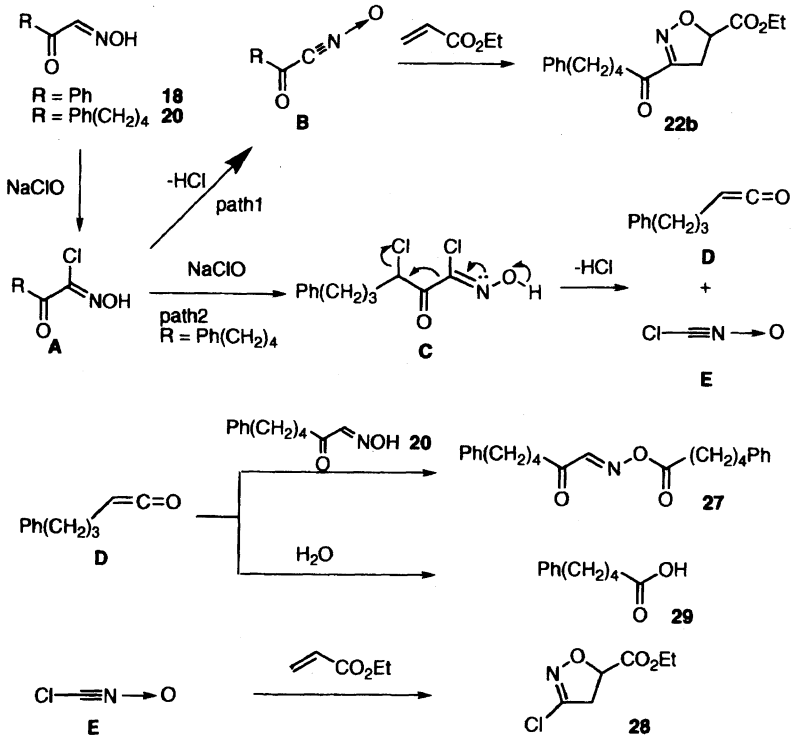
A probable mechanism is shown in Scheme 2, which explains the formation of these by-products.

Chlorination of the aldoxime **18**, **20** with sodium hypochlorite affords a carbohydroximoyl chloride **A**, which is transformed to the corresponding nitrile oxide **B** when R = Ph (path 1). On the other hand, when R = $Ph(CH_2)_4$, another competing pathway is available (path 2). That is, chlorination of 3-position of the 2-oxocarbohydroximoyl chloride would take place to afford dichloride **C**. Dehydrochlorination of **C** accompanied by C–C bond cleavage would give a ketene **D** and a cyanogen chloride *N*-oxide **E**. Reaction of the ketene **D** with the oxime **20** or H_2O would form an *O*-acyl oxime **27** or a carboxylic acid **29**, respectively, which are described in Eq. 9. The formation of another by-product in Eq. 9, chlorodihydroisoxazole **28**, could be explained by cycloaddition reaction between the chloro nitrile oxide **E** and ethyl acrylate. In our oxidative method with CAN, such side reactions caused by chlorination are completely excluded.

In conclusion, a simple method for the generation of nitrile oxides from oxime derivatives was developed by the use of CAN. This method can be used with advantage over the conventional methods especially in the generation of aliphatic 2-oxo carbonitrile oxides to avoid unfavorable side reactions.

Experimental

General. ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) spectra were recorded on a Bruker AM 500 spectrometer in $CDCl_3$ solutions using $CHCl_3$ (for ^{1}H, $\delta = 7.24$) and $CDCl_3$ (for ^{13}C, $\delta = 77.00$), or in CD_3OD solutions using CH_3OH (for ^{1}H, $\delta = 3.35$) and CD_3OD (for ^{13}C, $\delta = 49.00$) as an internal standard. IR spectra were recorded on a Horiba FT 300-S spectrophotometer. High-resolution mass spectra were obtained with a JEOL JMS-SX102A mass spectrometer at an ionization energy of 70 eV. The melting points were uncorrected. Elemental analyses were carried out at The Elemental Analysis Laboratory, Department of Chemistry, Faculty of Science, The University of Tokyo. DMF was distilled from calcium hydride and dried over Molecular Sieves 4A. Methanol was distilled from magnesium methoxide and stored under argon atmosphere. Dichloromethane was distilled from P_2O_5, then from CaH_2, and dried over Molecular Sieves 4A. Acetonitrile was distilled from P_2O_5, then from CaH_2, and dried over Molecular Sieves 4A. CAN (Kanto Chemical Co., Inc., guaranteed grade) was dried under vacuum at 80 °C for 10—12 h before use. Preparative TLC



Scheme 2.

was performed on a silica gel (Wakogel B-5F). The starting materials α-hydroxyimino carboxylic acids and 2-oxo aldoximes were prepared according to the literature procedures.[7,8] Their spectral data are as follows:

2-(Hydroxyimino)-5-phenylpentanoic Acid (6): Colorless crystals (from methanol); mp 146 °C; ^{1}H NMR (CD_3OD) δ = 1.76—1.82 (2H, m), 2.57—2.63 (4H, m), 4.71—5.09 (1H, br), 7.11—7.16 (3H, m), 7.21—7.24 (2H, m); ^{13}C NMR (CD_3OD) δ = 25.2, 28.8, 36.9, 126.8, 129.3, 129.3, 143.1, 153.6, 167.0. Found: C, 63.59; H, 6.36; N, 6.83%. Anal. Calcd for $C_{11}H_{13}NO_3$: C, 63.76; H, 6.32; N, 6.76%.

2-(2-Allyloxyphenyl)-2-(hydroxyimino)acetic Acid (9): Colorless crystals (from ether); mp 134 °C; IR (KBr) 3500—2000 (br), 1707, 1620, 1493, 1427, 1227, 1005, 947, 752 cm^{-1}; ^{1}H NMR (CD_3OD) δ = 4.56—4.58 (2H, m), 4.92 (br), 5.22—5.25 (1H, m), 5.38—5.43 (1H, m), 6.01—6.08 (1H, m), 6.95—6.98 (1H, m), 6.99—7.01 (1H, m), 7.34—7.38 (1H, m), 7.58—7.60 (1H, m); ^{13}C NMR (CD_3OD) δ = 70.8, 114.2, 117.9, 122.1, 123.0, 130.0, 132.3, 134.3, 150.7, 157.9, 167.5. Found: C, 59.58; H, 4.97; N, 6.48%. Anal. Calcd for $C_{11}H_{11}NO_4$: C, 59.73; H, 5.01; N, 6.33%.

2-[2-(3-Butenyloxy)phenyl]-2-(hydroxyimino)acetic Acid (10): Colorless crystals (from $CHCl_3$); mp 140 °C; IR (KBr) 3500—2350 (br), 1705, 1288, 1228, 1034, 955, 764 cm^{-1}; ^{1}H NMR (CD_3OD) δ = 2.50—2.54 (2H, m), 4.01 (2H, t, J = 6.8 Hz), 4.92 (1H, br), 5.05—5.07 (1H, m), 5.12—5.17 (1H, m), 5.93—6.00 (1H, m), 6.13—6.99 (2H, m), 7.34—7.37 (1H, m), 7.58—7.59 (1H, m); ^{13}C NMR (CD_3OD) δ = 34.4, 69.7, 113.5, 117.3, 121.9, 122.7, 129.9, 132.4, 135.9, 150.8, 158.1, 167.6. Found: C, 60.98; H, 5.70; N, 5.79%. Anal. Calcd for $C_{12}H_{13}NO_4$: C, 61.27; H, 5.57; N, 5.95%.

2-[2-(3-Cyclohexenyloxy)phenyl]-2-(hydroxyimino)acetic Acid (13): IR (neat) 3500—2100 (br), 1705, 1589, 1489, 1223, 1030, 951, 760 cm^{-1}; ^{1}H NMR (CD_3OD) δ = 1.61—1.66 (1H, m), 1.85—1.95 (3H, m), 1.97—2.02 (1H, m), 2.09—2.13 (1H, m), 4.88 (br), 5.82—5.85 (1H, m), 5.90—5.94 (1H, m), 6.91—6.97 (1H, m), 7.01—7.06 (1H, m), 7.26—7.37 (1H, m), 7.57—7.59 (1H, m); ^{13}C NMR (CD_3OD) δ = 20.1, 26.0, 29.2, 72.9, 114.0, 121.4, 123.1, 126.9, 130.3, 132.3, 132.9, 151.1, 157.1, 167.5. This compound was employed to the next reaction immediately after purification due to its unstability.

1-Hydroxyimino-6-phenyl-2-hexanone (20): Colorless crystals (from hexane); mp 54 °C; IR (KBr) 3404, 3298, 3033, 2995, 2862, 1657, 1466, 1024, 999, 748, 698 cm^{-1}; ^{1}H NMR (CD_3OD) δ = 1.63—1.68 (4H, m), 2.63 (2H, t, J = 7.3 Hz), 2.79 (2H, t, J = 7.2 Hz), 7.17 (3H, m), 7.26 (2H, m), 7.53 (1H, s), 8.40—8.50 (1H, br); ^{13}C NMR (CD_3OD) δ = 23.4, 30.9, 35.6, 37.8, 125.7, 128.3, 128.3, 142.1, 149.5, 199.1. Found: C, 69.97; H, 7.36; N, 6.70%. Anal. Calcd for $C_{12}H_{15}NO_2$: C, 70.22; H,7.37 ; N, 6.82%.

Typical Procedure for the Oxidation of α-Hydroxyimino Carboxylic Acid with Olefins. To a solution of CAN (223.4 mg, 0.407 mmol) in DMF (1 ml) was added a solution of 2-phenylpropene (47.4 mg, 0.401 mmol) in DMF (1 ml) and 2-(hydroxyimino)-2-phenylacetic acid (**1**) (32.4 mg, 0.196 mmol) at 0 °C under an argon atmosphere. The orange-yellow solution turned pale yellow about 5 min. After 20 min, the reaction was quenched by adding 0.1 mol dm^{-3} aqueous $Na_2S_2O_3$ (a few drops) and water. The mixture was extracted with cosolvent of hexane and ethyl acetate (2 : 1). Organic layer were dried over anhydrous Na_2SO_4. After evaporation of the solvent, chromatographic purification (hexane : ethyl acetate = 7 : 1) afforded 4,5-dihydro-5-methyl-3,5-diphenylisoxazole (**2a**) (32.1 mg, 0.135 mmol, 69%).

The spectral data of the products are as follows:

4,5-Dihydro-5-methyl-3,5-diphenylisoxazole (2a):[9] ^{1}H NMR δ = 1.79 (3H, s), 3.45 (1H, d, J = 16.5 Hz), 3.51 (1H, d, J = 16.5 Hz), 7.24—7.27 (1H, m), 7.34—7.37 (5H, m), 7.47—7.49 (2H, m), 7.63—7.65 (2H, m).

4,5-Dihydro-3,5-diphenylisoxazole (2b):[10] ^{1}H NMR δ = 3.33 (1H, dd, J = 8.3, 16.6 Hz), 3.77 (1H, dd, J = 11.0, 16.0 Hz), 5.73 (1H, dd, J = 8.3, 11.0 Hz), 7.30—7.32 (1H, m), 7.35—7.40 (7H, m), 7.67—7.69 (2H, m).

4,5-Dihydro-5-phenethyl-3-phenylisoxazole (2c): Colorless crystals (from $CHCl_3$); mp 66 °C; IR (KBr) 3028, 2881, 1493, 1448, 1354, 1041, 908, 756, 690 cm^{-1}; ^{1}H NMR δ = 1.89—1.96 (1H, m), 2.06—2.14 (1H, m), 2.73—2.79 (1H, m), 2.81—2.86 (1H, m), 2.96 (1H, dd, J = 8.0, 16.5 Hz), 3.38 (1H, dd, J = 10.4, 16.5 Hz), 4.70—4.76 (1H, m), 7.17—7.22 (3H, m), 7.27—7.32 (2H, m), 7.38—7.40 (3H, m), 7.64—7.66 (2H, m); ^{13}C NMR δ = 31.8, 37.1, 40.0, 80.4, 126.0, 126.6. HRMS: *m/z* 251.1310. Calcd for $C_{17}H_{17}NO$: M, 251.1310. Found: C, 81.11; H, 6.74; N, 5.62%. Anal. Calcd for $C_{17}H_{17}NO$: C, 81.24; H, 6.82; N, 5.57%.

4,5-Dihydro-3-phenyl-5-isoxazolecarbonitrile (2d):[10] ^{1}H NMR δ = 3.70 (1H, dd, J = 6.1, 16.7 Hz), 3.76 (1H, dd, J = 10.8, 16.7 Hz), 5.35 (1H, dd, J = 6.3, 10.8 Hz), 7.41—7.48 (3H, m), 7.63—7.65 (2H, m).

Ethyl 4,5-Dihydro-3-phenyl-5-isoxazolecarboxylate (2e):[11] ^{1}H NMR δ = 1.31 (3H, t, J = 7.1 Hz), 3.60 (1H, dd, J = 9.8, 15.6 Hz), 3.65 (1H, dd, J = 6.2, 15.6 Hz), 4.25 (2H, q, J = 7.2 Hz), 5.15 (1H, dd, J = 7.4, 11.1 Hz), 7.37—7.43 (3H, m), 7.65—7.67 (2H, m).

5-Acetoxy-4,5-dihydro-3-phenylisoxazole (2f):[10] ^{1}H NMR δ = 2.06 (3H, s), 3.34 (1H, dd, J = 1.4, 17.7 Hz), 3.59 (1H, dd, J = 6.9, 17.7 Hz), 6.82 (1H, dd, J = 1.2, 6.8 Hz), 7.40—7.46 (3H, m), 7.68—7.70 (2H, m).

5-Hexyl-3-phenylisoxazole (2g): Colorless oil; IR (neat) 2929, 1602, 1471, 1407, 916, 768, 694 cm^{-1}; ^{1}H NMR δ = 0.88 (3H, t, J = 7.0 Hz), 1.29—1.32 (4H, m), 1.36—1.40 (2H, m), 1.73—1.78 (2H, m), 2.77 (2H, t, J = 7.6 Hz), 6.26 (1H, s), 7.39—7.44 (3H, m), 7.76—7.78 (2H, m); ^{13}C NMR δ = 14.00, 22.48, 26.80, 27.50, 28.75, 31.42, 98.73, 126.74, 128.81, 129.47, 129.73, 162.31, 174.30. HRMS: *m/z* 229.1463. Calcd for $C_{15}H_{19}NO$: M, 229.1467.

3,5-Diphenylisoxazole (2h):[10] IR (KBr) 3114, 1454, 918, 822, 964, 692 cm^{-1}; ^{1}H NMR δ = 6.82 (1H, s), 7.43—7.49 (6H, m), 7.82—7.87 (4H, m).

Ethyl 3-Phenyl-5-isoxazolecarboxylate (2i): Colorless crystals (from $CHCl_3$); mp 144 °C; IR (KBr) 2985, 1725, 1440, 1288, 1247, 1022, 767, 692 cm^{-1}; ^{1}H NMR δ = 1.42 (3H, t, J = 7.2 Hz), 4.44 (2H, q, J = 7.2 Hz), 7.23 (1H, s), 7.43—7.49 (3H, m), 7.80—7.83 (2H, m); ^{13}C NMR δ = 14.0, 62.2, 107.2, 126.8, 128.0, 129.0, 130.5, 156.7, 160.9, 162.9. Found: C, 66.20; H, 5.31; N, 6.40%. Anal. Calcd for $C_{12}H_{11}NO_3$: C, 66.35; H, 5.10; N 6.45%.

Ethyl 3-Phenyl-4-isoxazolecarboxylate (2j): Not isolated. ^{1}H NMR δ = 1.28 (3H, t, J = 7.1 Hz), 4.27 (2H, q, J = 7.1 Hz), 7.43—7.49 (3H, m), 7.74—7.76 (2H, m), 8.99 (1H, s); ^{13}C NMR δ = 14.1, 61.0, 113.0, 127.3, 128.1, 129.4, 130.3, 160.8, 161.2, 164.0.

3,4-Diphenylfurazan 2-Oxide (3):[12] IR (KBr) 1593, 1577, 1504, 1421, 773, 692 cm^{-1}; ^{1}H NMR δ = 7.40—7.45 (5H, m), 7.49—7.52 (5H, m); ^{13}C NMR δ = 114.3, 122.9, 126.7, 128.3, 128.7, 129.0, 129.0, 130.6, 131.0, 156.2.

2,4,6-Trimethylbenzonitrile Oxide (5):[6] IR (KBr) 2291, 1333 cm^{-1}; ^{1}H NMR δ = 2.28 (3H, s), 2.40 (6H, s), 6.89 (2H, s); ^{13}C NMR δ = 20.7, 21.4, 111.0, 128.2, 128.3, 140.9, 141.7.

4,5-Dihydro-5-methyl-5-phenyl-3-(3-phenylpropyl)isoxazole (7a): Colorless oil; IR (neat) 2931, 1495, 1450, 901, 762, 702

cm^{-1}; ^1H NMR δ = 1.88—1.95 (2H, m), 2.40 (2H, t, J = 7.6 Hz), 2.67 (2H, t, J = 7.6 Hz), 2.87 (1H, dd, J = 7.9, 17.0 Hz), 3.30 (1H, dd, J = 10.8, 17.0 Hz), 5.53 (1H, dd, J = 7.9, 10.8 Hz), 7.15—7.21 (3H, m), 7.27—7.29 (3H, m), 7.30—7.37 (4H, m); ^{13}C NMR δ = 27.2, 28.0, 35.3, 45.4, 81.2, 125.7, 126.0, 128.0, 128.4, 128.5, 128.7, 141.4, 141.4, 158.1. HRMS: m/z 279.1606. Calcd for $C_{19}H_{21}NO$: M, 279.1623. Found: C, 81.41; H, 7.68; N, 5.20%. Anal. Calcd for $C_{19}H_{21}NO$: C, 81.68; H, 7.58; N, 5.01%.

4, 5- Dihydro- 5- phenyl- 3- (3- phenylpropyl)isoxazole (7b): Colorless oil; IR (neat) 2939, 1495, 1454, 877, 754, 700 cm^{-1}; ^1H NMR δ = 1.88—1.95 (2H, m), 2.40 (2H, t, J = 7.6 Hz), 2.67 (2H, t, J = 7.6 Hz), 2.87 (1H, dd, J = 8.0, 17.0 Hz), 3.30 (1H, dd, J = 10.8, 17.0 Hz), 5.53 (1H, dd, J = 10.8, 8.0 Hz), 7.15—7.21 (3H, m), 7.27—7.29 (3H, m), 7.30—7.37 (4H, m); ^{13}C NMR δ = 27.2, 28.0, 35.3, 45.4, 81.2, 125.7, 126.0, 128.0, 128.4, 128.5, 128.7, 141.4, 141.4, 158.1. HRMS: m/z 265.1454. Calcd for $C_{18}H_{19}NO$: M, 265.1467.

4,5-Dihydro-5-phenethyl-3-(3-phenylpropyl)isoxazole (7c): Colorless oil; IR (neat) 2939, 1495, 1452, 883, 748, 700 cm^{-1}; ^1H NMR δ = 1.77—1.84 (1H, m), 1.87—1.93 (1H, m), 1.96—2.04 (1H, m), 2.30 (2H, t, J = 7.1 Hz), 2.52 (1H, dd, J = 7.9, 16.8 Hz), 2.66—2.72 (3H, m), 2.75—2.81 (1H, m), 2.94 (1H, dd, J = 10.2, 16.8 Hz), 4.49—4.55 (1H, m), 7.17—7.23 (6H, m), 7.27—7.33 (4H, m); ^{13}C NMR δ = 27.3, 27.9, 31.8, 35.2, 37.0, 42.2, 79.0, 125.9, 128.4, 128.4, 128.4, 128.4, 141.2, 141.4, 158.4. HRMS: m/z 293.1781. Calcd for $C_{20}H_{23}NO$: M, 293.1780.

4,5-Dihydro-3-(3-phenylpropyl)-5-isoxazolecarbonitrile (7d): Colorless oil; IR (neat) 2941, 1496, 1454, 1433, 864, 750, 702 cm^{-1}; ^1H NMR δ = 1.91—1.97 (2H, m), 2.41 (2H, t, J = 7.6 Hz), 2.67—2.70 (2H, m), 3.19 (1H, dd, J = 5.6, 17.1 Hz), 3.28 (1H, dd, J = 10.8, 17.1 Hz), 5.12 (1H, dd, J = 5.6, 10.8 Hz); ^{13}C NMR δ = 26.5, 27.6, 35.0, 43.3, 65.5, 117.3, 126.2, 128.5, 128.5, 140.9, 158.4. HRMS: m/z 214.1100. Calcd for $C_{13}H_{14}N_2O$: M, 214.1106. Found: C, 72.60; H, 6.64; N, 12.90%. Anal. Calcd for $C_{13}H_{14}N_2O$: C, 72.87; H, 6.59; N, 13.07%.

Ethyl 4,5-Dihydro-3-(3-phenylpropyl)-5-isoxazolecarboxylate (7e): Colorless oil; IR (neat) 2939, 1738, 1203, 1034, 874, 750, 702 cm^{-1}; ^1H NMR δ = 1.28 (3H, t, J = 7.1 Hz), 1.87—1.93 (2H, m), 2.37 (2H, t, J = 7.6 Hz), 2.64—2.67 (2H, m), 3.15—3.17 (2H, m), 4.22 (2H, q, J = 7.1 Hz), 4.93 (1H, dd, J = 7.7, 10.2 Hz), 7.15—7.19 (3H, m), 7.25—7.28 (2H, m); ^{13}C NMR δ = 14.1, 26.7, 27.8, 35.1, 40.9, 61.8, 77.0, 126.0, 128.4, 128.5, 141.2, 158.0, 170.4. HRMS: m/z 261.1380. Calcd for $C_{15}H_{19}NO_3$: M, 261.1365.

5- Acetoxy- 4, 5- dihydro- 3- (3- phenylpropyl)isoxazole (7f): Colorless oil; IR (neat) 2935, 1749, 1373, 1232, 1041, 957, 845, 750, 700 cm^{-1}; ^1H NMR δ = 1.90—1.96 (2H, m), 2.04 (3H, s), 2.44 (2H, t, J = 7.7 Hz), 2.68 (2H, t, J = 7.7 Hz), 2.84 (1H, d, J = 18.0 Hz), 3.16 (1H, dd, J = 6.8, 18.0 Hz), 6.63 (1H, d, J = 6.8 Hz) 7.16—7.20 (3H, m), 7.26—7.29 (2H, m); ^{13}C NMR δ = 21.1, 26.7, 27.9, 35.1, 43.5, 95.3, 126.1, 128.5, 128.5, 141.1, 159.1, 169.7. HRMS: m/z 247.1194. Calcd for $C_{14}H_{17}NO_3$: M, 247.1208.

5-Hexyl-3-(3-phenylpropyl)isoxazole (7g): Colorless oil; IR (neat) 2929, 2858, 1603, 1456, 1427, 746, 700 cm^{-1}; ^1H NMR δ = 0.87 (3H, t, J = 6.9 Hz), 1.27—1.48 (6H, m), 1.61—1.68 (2H, m), 1.92—2.02 (2H, m), 2.62—2.72 (6H, m), 5.78 (1H, s), 7.16—7.18 (3H, m), 7.25—7.28 (2H, m); ^{13}C NMR δ = 14.0, 22.5, 25.6, 26.7, 27.5, 28.7, 29.9, 31.4, 35.3, 100.2, 125.9, 128.4, 128.5, 141.6, 163.6, 173.5. HRMS: m/z 271.1932. Calcd for $C_{18}H_{25}NO$: M, 271.1936.

5-Phenyl-3-(3-phenylpropyl)isoxazole (7h): Colorless oil; IR (neat) 2941, 1574, 1498, 1452, 1419, 764, 696 cm^{-1}; ^1H NMR δ = 2.02—2.08 (2H, m), 2.70—2.75 (4H, m), 6.36 (1H, s), 7.18—7.21 (3H, m), 7.28—7.31 (2H, m), 7.39—7.46 (3H, m), 7.74—7.76 (2H, m); ^{13}C NMR δ = 25.6, 29.9, 35.2, 99.1, 125.7, 125.9, 127.6, 128.4, 128.5, 128.9, 130.0, 141.5, 164.3, 169.6. HRMS: m/z 263.1299. Calcd for $C_{18}H_{17}NO$: M, 263.1310.

Ethyl 3-(3-Phenylpropyl)-5-isoxazolecarboxylate (7i): Colorless oil; IR (neat) 2933, 1737, 1469, 1288, 1207, 1097, 1020, 769, 702 cm^{-1}; ^1H NMR δ = 1.32 (3H, t, J = 7.2 Hz), 2.00 (2H, tt, J = 7.1, 7.7 Hz), 2.30 (2H, t, J = 7.1 Hz), 2.94 (2H, t, J = 7.7 Hz), 4.28 (2H, q, J = 7.2 Hz), 7.15—7.19 (3H, m), 7.23—7.31 (2H, m), 8.82 (1H, s); ^{13}C NMR δ = 14.1, 25.4, 29.7, 35.0, 62.1, 109.0, 126.0, 128.4, 128.4, 141.1, 156.9, 160.2, 164.3. HRMS: m/z 259.1192. Calcd for $C_{15}H_{17}NO_3$: M, 259.1208. Found: C, 69.23; H, 6.62; N, 5.42%. Anal. Calcd for $C_{15}H_{17}NO_3$: C, 69.48; H, 6.61; N, 5.40%.

Ethyl 3-(3-Phenylpropyl)-4-isoxazolecarboxylate (7j): Not isolated. ^1H NMR δ = 1.39 (3H, t, J = 7.1 Hz), 2.00 (2H, tt, J = 7.6, 7.6 Hz), 2.67 (2H, t, J = 7.6 Hz), 2.73 (2H, t, J = 7.6 Hz), 4.4 (2H, t, J = 7.1 Hz), 6.77 (1H, s), 7.15—7.19 (3H, m), 7.23—7.31 (2H, m).

3a,4-Dihydro-3*H*-[1]benzopyrano[4,3-*c*]isoxazole (11): Colorless crystals (from $CHCl_3$); mp 59 °C; IR (KBr) 2879, 1608, 1468, 1230, 991, 860, 766 cm^{-1}; ^1H NMR δ = 3.85—3.96 (2H, m), 4.03—4.08 (1H, m), 4.64—4.69 (2H, m), 6.92—6.93 (1H, m), 6.96—6.99 (1H, m), 7.29—7.32 (1H, m), 7.76—7.77 (1H, m); ^{13}C NMR δ = 45.8, 69.2, 70.5, 113.0, 117.4, 125.7, 132.4, 152.7, 155.5. HRMS: m/z 175.0638. Calcd for $C_{10}H_9NO_2$: M, 175.0633. Found: C, 68.72; H, 5.27; N, 7.98%. Anal. Calcd for $C_{10}H_9NO_2$: C, 68.56; H, 5.18; N, 8.00%.

3,3a,4,5-Tetrahydrobenzo[2,3]oxepino[4,5-*c*]isoxazole (12): Colorless crystals (from $CHCl_3$); mp 57 °C; IR (KBr) 2956, 2917, 1479, 1446, 1207, 1049, 943, 767 cm^{-1}; ^1H NMR δ = 1.92—1.99 (1H, m), 2.37—2.44 (1H, m), 3.67—3.75 (1H, m), 4.15—4.25 (3H, m), 4.60 (1H, dd, J = 8.3, 10.2 Hz), 6.99 (1H, d, J = 8.3 Hz), 7.05 (1H, dd, J = 7.6, 7.6 Hz), 7.27—7.31 (1H, m (dd like)), 7.73—7.75 (1H, m (d like)); ^{13}C NMR δ = 33.0, 47.8, 71.4, 75.4, 120.5, 121.1, 123.3, 129.2, 131.2, 158.5, 159.5. Found: C, 69.62; H, 5.94; N, 7.32%. Anal. Calcd for $C_{11}H_{11}NO_2$: C, 69.83; H, 5.86; N, 7.40%.

2a,3,4,5,5a,10c-Hexahydroxantheno[9,1-*cd*]isoxazole (14): Colorless crystals (from $CHCl_3$); mp 103 °C; IR (KBr) 2947, 1604, 1462, 1344, 1227, 1032, 764 cm^{-1}; ^1H NMR δ = 0.99—1.08 (1H, m), 1.22—1.32 (1H, m), 1.33—1.42 (1H, m), 1.57—1.63 (1H, m), 1.95—2.02 (2H, m), 3.81 (1H, t, J = 7.8 Hz), 4.68—4.73 (1H, m), 4.88—4.93 (1H, m), 6.90—6.92 (1H, m), 6.94—6.97 (1H, m), 7.29—7.33 (1H, m), 7.82—7.84 (1H, m); ^{13}C NMR δ = 17.1, 27.0, 27.6, 47.2, 74.6, 80.1, 112.6, 118.0, 121.3, 125.1, 132.6, 150.4, 153.4. Found: C, 72.30; H, 6.08; N, 6.71%. Anal. Calcd for $C_{13}H_{13}NO_2$: C, 72.54; H, 6.09; N, 6.51%.

Typical Procedure for the Oxidation of α-Oxo Aldoxime with Olefins. To a solution of CAN (578.0 mg, 1.054 mmol) in acetonitrile (4 ml) was added a solution of acrylonitrile (140.4 mg, 2.65 mmol) in acetonitrile (2 ml) and 2-oxo-2-phenylacetoaldehyde 1-oxime (**18**) (74.8 mg, 0.502 mmol) in acetonitrile (2 ml) at 0 °C under an argon atmosphere. The mixture was stirred for 40 min at 0 °C, then warmed up to room temperature. After 90 min, the reaction was quenched by adding 0.1 mol dm^{-3} aqueous $Na_2S_2O_3$ (a few drops) and water. The mixture was extracted with ethyl acetate. The organic layer was dried over anhydrous Na_2SO_4. After evaporation of the solvent, chromatographic purification (hexane : ethyl acetate = 4 : 1) afforded 3-benzoyl-5-cyano-4,5-dihydroisoxazole (**19a**) (83.1 mg, 0.416 mmol, 83%).

The spectral data of the products are as follows:

3-Benzoyl-4,5-dihydro-5-isoxazolecarbonitrile (19a): Col-

orless crystals (from hexane : ethyl acetate = 4 : 1); mp 52 °C; IR (KBr) 3066, 1653, 1583, 1444, 1359 cm^{-1}; ^1H NMR δ = 3.73 (1H, dd, J = 7.4 and 17.7 Hz), 3.79 (1H, dd, J = 10.9 and 17.7 Hz), 5.39 (1H, dd, J = 7.4 and 10.9 Hz), 7.48 (2H, m(t-like)), 7.63 (1H, m(t-like)), 8.19 (2H, m(t-like)); ^{13}C NMR δ = 40.8, 67.1, 116.1, 128.6, 130.3, 134.4, 134.8, 156.6, 184.4. Found: C, 66.18; H, 4.23; N, 13.96%. Anal. Calcd for $C_{11}H_8N_2O_2$: C, 65.99; H, 4.03; N, 13.99%.

Ethyl 3-Benzoyl-4,5-dihydro-5-isoxazolecarboxylate (19b): Colorless oil; IR (neat) 3066, 1653, 1583, 1444, 1359 cm^{-1}; ^1H NMR δ = (3H, t, J = 7.2 Hz), 3.57 (1H, dd, J = 7.8, 18.4 Hz), 3.63 (1H, dd, J = 11.4, 18.4 Hz), 4.24 (2H, q, J = 7.2 Hz), 5.14 (1H, dd, J = 7.8, 11.4 Hz), 7.42 (2H, m (t-like)), 7.56 (1H, m (t-like)), 8.16 (2H, m (d-like)); ^{13}C NMR δ = 14.0, 38.6, 62.1, 78.9, 128.6, 130.3, 133.8, 135.9, 156.8, 169.0, 185.4. Found: C, 62.90; H, 5.18; N, 5.77%. Anal. Calcd for $C_{13}H_{13}NO_4$: C, 63.15; H, 5.30; N, 5.67%.

3-Benzoyl-4,5-dihydro-5-isoxazole Acetate (19c): Colorless crystals (from hexane : ethyl acetate = 4 : 1); mp 60 °C; IR (KBr) 3066, 1761, 1657, 1585, 1446, 1419, 1356, 1267, 1222, 837 cm^{-1}; ^1H NMR δ = 2.06 (3H, s), 3.37 (1H, dd, J = 1.3, 18.7 Hz), 3.53 (1H, dd, J = 7.3, 18.7 Hz), 6.79 (1H, dd, J = 1.3, 7.3 Hz), 7.45 (2H, m (t-like)), 7.58 (1H, m (t-like)), 8.19 (2H, m (d-like)); ^{13}C NMR δ = 20.8, 40.4, 95.6, 128.5, 130.4, 134.0, 135.1, 157.6, 169.2, 185.2. Found: C, 62.01; H, 4.83; N, 6.10%. Anal. Calcd for $C_{12}H_{11}NO_4$: C, 61.80; H, 4.75; N, 6.01%.

3-Benzoyl-5-butoxy-4,5-dihydroisoxazole (19d): Pale yellow oil; IR (neat) 2960, 1657, 1591, 1576, 1360, 1265, 1186, 1097 cm^{-1}; ^1H NMR δ = 0.91 (3H, t, J = 7.4 Hz), 1.36 (2H, m), 1.56 (2H, m), 3.22 (1H, dd, J = 2.0, 18.3 Hz), 3.36 (1H, dd, J = 6.9, 18.3 Hz), 3.56 (1H, dd, J = 6.7, 9.4 Hz), 3.87 (1H, dt, J = 6.6, 9.4 Hz), 5.68 (1H, dd, J = 2.0, 6.9 Hz), 7.46 (2H, m (t-like)), 7.58 (1H, m (t-like)), 8.19 (2H, m (d-like)); ^{13}C NMR δ = 13.8, 19.1, 31.5, 40.6, 68.8, 104.4, 128.6, 130.4, 133.7, 135.6, 158.0, 186.0. Found: C, 67.76; H, 6.88; N, 5.57%. Anal. Calcd for $C_{14}H_{17}NO_3$: C, 68.00; H, 6.93; N, 5.66%.

3- Benzoyl- 4, 5- dihydro- 5- phenoxymethylisoxazole (19e): Pale yellow crystals (from hexane : ethyl acetate = 4 : 1); mp 46 °C; IR (KBr) 3064, 1653, 1593, 1579, 1495, 1244, 910 cm^{-1}; ^1H NMR δ = 3.40 (1H, dd, δ = 7.5, 17.6 Hz), 3.50 (1H, dd, J = 11.2, 17.6 Hz), 4.13 (2H, d, J = 4.2 Hz), 5.13 (1H, ddt, J = 7.5, 11.2, 4.2 Hz), 6.90 (2H, m (d-like)), 6.96 (1H, m (t-like), 7.28 (2H, m (t-like)), 7.47 (2H, m (t-like)), 7.59 (1H, m (t-like)), 8.20 (2H, m (d-like)); ^{13}C NMR δ = 36.3, 68.4, 80.5, 114.6, 121.4, 128.3, 128.4, 129.5, 130.3, 133.6, 135.7, 157.6, 158.2, 186.2. Found: C, 72.57; H, 5.48; N, 4.93%. Anal. Calcd for $C_{17}H_{15}NO_3$: C, 72.58; H, 5.37; N, 4.98%.

3-Benzoyl-4,5-dihydro-5-phenylisoxazole (19f): Pale yellow oil; IR (neat) 3057, 3032, 1493, 1446, 1360, 897, 752, 692 cm^{-1}; ^1H NMR δ = 3.38 (1H, dd, J = 8.8, 17.7 Hz), 3.78 (1H, dd, J = 11.5, 17.7 Hz) 5.77 (1H, dd, J = 8.8, 11.5 Hz), 7.32—7.38 (5H, m), 7.48 (2H, m (t-like)), 7.59 (1H, m (t-like)), 8.23 (2H, m (d-like)); ^{13}C NMR δ = 41.8, 84.2, 125.9, 128.4, 128.6, 128.8, 130.3, 133.6, 135.7, 139.6, 157.4, 186.2. Found: C, 76.38; H, 5.32; N, 5.64%. Anal. Calcd for $C_{16}H_{13}NO_2$: C, 76.48; H, 5.21; N, 5.57%.

Ethyl 3-Benzoyl-4,5-dihydro-4-methyl-5-isoxazolecarboxylate (19g): Colorless oil; IR (KBr) 2956, 1747, 1657, 1446, 1354, 1250, 1211, 876, 717 cm^{-1}; ^1H NMR δ = 1.45 (3H, d, J = 7.1 Hz), 3.79 (3H, s), 3.98 (1H, dq, J = 5.6, 7.1 Hz), 4.76 (1H, d, J = 5.6 Hz), 7.45 (2H, m (t-like)), 7.59 (1H, m (t-like)), 8.18 (2H, m (d-like)); ^{13}C NMR δ = 17.8, 47.7, 52.9, 85.1, 128.5, 130.4, 133.9, 135.8, 160.1, 173.2, 185.5. HRMS: m/z 247.0863. Calcd for $C_{13}H_{13}NO_4$: M, 247.0845.

Ethyl 3-Benzoyl-4,5-dihydro-5-methyl-4-isoxazolecarboxylate (19h): Colorless oil; IR (KBr) 2956, 1743, 1655, 1574, 1313, 1232, 1205, 935 cm^{-1}; ^1H NMR δ = 1.51 (3H, d, J = 6.4 Hz), 3.73 (3H, s), 4.17 (1H, d, J = 7.8 Hz), 5.01 (1H, dq, J = 7.8, 6.4 Hz), 7.45 (2H, m (t-like)), 7.59 (1H, m (t-like)), 8.18 (2H, m (d-like)); ^{13}C NMR δ = 20.5, 53.0, 58.9, 83.7, 128.4, 130.4, 133.8, 135.6, 155.4, 169.4, 185.7. Found: C, 63.01; H, 5.35; N, 5.89%. Anal. Calcd for $C_{13}H_{13}NO_4$: C, 63.15; H, 5.31; N, 5.66%. HRMS: m/z 247.0851. Calcd for $C_{13}H_{13}NO_4$: M, 247.0845.

3-Benzoyl-5-phenylisoxazole (19i):[13] IR (KBr) 1655, 1448, 1242, 893, 769, 727, 683 cm^{-1}; ^1H NMR δ = 7.02 (1H, s), 7.43—7.49 (5H, m), 7.63 (2H, m (t-like)), 7.81 (1H, m (t-like)), 8.33 (2H, m (d-like)); ^{13}C NMR δ = 100.2, 125.9, 126.6, 128.5, 129.1, 130.6, 130.6, 134.0, 135.7, 162.8, 170.7, 180.6.

3-Benzoyl-5-hexylisoxazole (19j): Colorless oil; IR (neat) 2931, 2862, 1664, 1595, 1456, 1248, 1219, 893 cm^{-1}; ^1H NMR δ = 0.87 (3H, t, J = 7.0 Hz), 1.28—1.32 (4H, m), 7.02 (1H, s), 7.43—7.49 (5H, m), 7.63 (2H, m (t-like)), 7.81 (1H, m (t-like)), 8.33 (2H, m (d-like)); ^{13}C NMR δ = 14.0, 22.4, 26.6, 28.0, 28.7, 31.3, 101.5, 128.5, 130.6, 133.8, 135.9, 161.8, 174.7, 186.1. Found: C, 74.41; H, 7.42; N, 5.48%. Anal. Calcd for $C_{16}H_{19}NO_2$: C, 74.68; H, 7.44; N, 5.44%.

4,5-Dihydro-3-(5-phenylpentanoyl)-5-isoxazolecarbonitrile (22a): Pale yellow crystals (from $CHCl_3$); mp 39 °C; IR (KBr) 2937, 1695, 1593, 1223, 899, 752 cm^{-1}; ^1H NMR δ = 1.64—1.74 (4H, m), 2.62—2.65 (2H, m), 2.91—2.94 (2H, m), 3.49 (2H, d, J = 9.0 Hz), 5.30 (1H, t, J = 9.0 Hz), 7.15—7.18 (3H, m), 7.24—7.28 (2H, m); ^{13}C NMR δ = 23.2, 30.6, 35.5, 38.8, 39.5, 68.0, 115.9, 125.8, 128.3, 128.3, 141.9, 156.6, 193.8. Found: C, 70.41; H, 6.34; N, 10.89%. Anal. Calcd for $C_{15}H_{16}N_2O_2$: C, 70.29; H, 6.29; N, 10.93%.

Ethyl 4,5-Dihydro-3-(5-phenylpentanoyl)-5-isoxazolecarboxylate (22b): Pale yellow oil; IR (KBr) 2935, 1745, 1689, 1587, 1454, 1379, 1277, 1211 cm^{-1}; ^1H NMR δ = 1.29 (3H, t, J = 7.1 Hz), 1.61—1.72 (4H, m), 2.60—2.63 (2H, m), 2.90—2.93 (2H, m), 3.37 (2H, d, J = 9.7 Hz), 4.24 (2H, q, J = 7.1 Hz), 5.12 (1H, t, J = 9.7 Hz), 7.14—7.17 (3H, m), 7.24—7.27 (2H, m); ^{13}C NMR δ = 14.0, 23.4, 30.8, 35.5, 36.4, 39.2, 62.1, 79.8, 125.7, 128.2, 128.3, 142.0, 156.8, 168.9, 194.7. Found: C, 67.02; H, 6.92; N, 4.64%. Anal. Calcd for $C_{14}H_{17}NO_3$: C, 67.31; H, 6.98; N, 4.62%.

4,5-Dihydro-3-(5-phenylpentanoyl)-5-isoxazole Acetate (22c): Pale yellow crystals (from $CHCl_3$); mp 38 °C; IR (KBr) 2933, 1761, 1693, 1375, 1225, 1155, 1047, 955, 895, 862, 750, 700 cm^{-1}; ^1H NMR δ = 1.64—1.73 (4H, m), 2.06 (3H, s), 2.61—2.64 (2H, m), 2.93—2.96 (2H, m), 3.16 (1H, dd, J = 1.8, 18.9 Hz), 3.28 (1H, dd, J = 7.2, 18.9 Hz), 6.77 (1H, dd, J = 1.8, 7.2 Hz), 7.15—7.17 (3H, m), 7.24—7.27 (2H, m); ^{13}C NMR δ = 20.7, 23.2, 30.7, 35.5, 38.4, 39.1, 96.5, 125.7, 128.2, 128.3, 141.9, 157.5, 169.1, 194.6. Found: C, 66.32; H, 6.54; N, 4.94%. Anal. Calcd for $C_{16}H_{19}NO_4$: C, 66.42; H, 6.62; N, 4.84%.

4,5-Dihydro-5-phenoxymethyl-3-(5-phenylpentanoyl)isoxazole (22d): Pale yellow crystals (from $CHCl_3$); mp 51 °C; IR (neat) 2933, 1685, 1589, 1495, 1454, 1242, 1080, 928, 754, 696 cm^{-1}; ^1H NMR δ = 1.65—1.76 (4H, m), 2.63—2.66 (2H, m), 2.92—2.95 (2H, m), 3.17 (1H, dd, J = 7.8, 17.7 Hz), 3.24 (1H, dd, J = 11.2, 17.7 Hz), 4.07 (2H, d, J = 4.6 Hz), 5.07—5.13 (1H, m), 6.87—6.99 (2H, m), 7.16—7.18 (1H, m), 7.25—7.26 (3H, m), 7.27—7.29 (4H, m); ^{13}C NMR δ = 23.6, 30.8, 34.4, 39.0, 68.3, 81.5, 114.6, 121.5, 125.7, 128.3, 128.4, 129.5, 142.1, 157.7, 158.2, 195.4. Found: C, 74.51; H, 6.88; N, 4.13%. Anal. Calcd for $C_{21}H_{23}NO_3$: C, 74.75; H, 6.87; N, 4.15%.

5-Hexyl-3-(5-phenylpentanoyl)isoxazole (22e): Colorless oil; IR (neat) 2931, 2858, 2343, 1702, 1590, 1454, 933, 748, 698, 669 cm^{-1}; ^1H NMR δ = 0.88 (3H, t, J = 6.9 Hz), 1.27—1.38 (6H, m), 1.66—1.72 (4H, m), 1.74—1.80 (2H, m), 2.64 (2H, t, J = 7.4 Hz), 2.76 (2H, t, J = 7.6 Hz), 3.04 (2H, t, J = 7.4 Hz), 6.32 (1H, s), 7.14—7.17 (3H, m), 7.24—7.27 (2H, m); ^{13}C NMR δ = 14.0, 22.4, 23.3, 26.6, 27.3, 28.6, 30.9, 31.3, 35.6, 39.6, 99.2, 125.7, 128.3, 128.4, 142.1, 161.8, 175.5, 194.9. Found: C, 76.44; H, 8.59; N, 4.71%. Anal. Calcd for $C_{20}H_{27}NO_4$: C, 76.64; H, 8.68; N, 4.47%.

Ethyl 5-Cyano-4,5-dihydro-3-isoxazolecarboxylate (23a):[14] IR (KBr) 2993, 1732, 1603, 1271, 1265, 1122 cm^{-1}; ^1H NMR δ = 1.36 (3H, t, J = 7.1 Hz), 3.57 (1H, dd, J = 7.0, 17.3 Hz), 3.64 (1H, dd, J = 10.9, 17.3 Hz), 4.35 (2H, q, J = 7.1 Hz), 5.37 (1H, dd, J = 7.0, 10.9 Hz); ^{13}C NMR δ = 14.0, 39.9, 62.8, 68.0, 115.8, 151.2, 158.9.

Diethyl 4,5-Dihydro-3,5-isoxazoledicarboxylate (23b):[14] IR (KBr) 2985, 1743, 1734, 1379, 1257, 1211, 1126 cm^{-1}; ^1H NMR δ = 1.25—1.28 (3H, m), 1.29—1.33 (3H, m), 3.43—3.45 (2H, m), 4.19—4.23 (2H, m), 4.27—4.32 (2H, m), 5.13 (1H, dd, J = 8.8, 10.9 Hz); ^{13}C NMR δ = 13.9, 14.0, 37.5, 62.1, 62.2, 79.8, 151.0, 159.8, 168.8.

Ethyl 5-Acetoxy-4,5-dihydro-3-isoxazolecarboxylate (23c): Pale yellow oil; IR (neat) 2987, 1762, 1724, 1597, 1344, 1128, 1045, 957, 823, 787, 742 cm^{-1}; ^1H NMR δ = 1.33—1.36 (3H, m), 3.20 (1H, d, J = 18.9 Hz), 3.40 (1H, dd, J = 7.3, 18.9 Hz), 4.32—4.37 (2H, m), 6.78 (1H, d, J = 7.3 Hz); ^{13}C NMR δ = 14.0, 20.8, 39.8, 62.5, 96.4, 151.9, 159.7, 169.1. Found: C, 47.68; H, 5.48; N, 6.97%. Anal. Calcd for $C_8H_{11}NO_5$: C, 47.76; H, 5.51; N, 6.96%.

Ethyl 4,5-Dihydro-5-phenoxymethyl-3-isoxazolecarboxylate (23d): Colorless crystals (from $CHCl_3$); mp 44 °C; IR (KBr) 2976, 1722, 1597, 1496, 1452, 1338, 1174, 1039, 750 cm^{-1}; ^1H NMR δ = 1.36 (3H, t, J = 7.2 Hz), 3.25 (1H, dd, J = 7.8, 17.8 Hz), 3.33 (1H, dd, J = 11.2, 17.8 Hz), 4.03—4.12 (2H, m), 4.34 (2H, q, J = 7.2 Hz), 5.10—5.16 (1H, m), 6.87—6.89 (2H, m), 6.95—6.97 (1H, m), 7.25—7.28 (2H, m); ^{13}C NMR δ = 14.1, 35.8, 62.1, 68.0, 81.3, 114.6, 121.5, 129.5, 151.5, 158.2, 160.4. Found: C, 62.37; H, 5.99; N, 5.45%. Anal. Calcd for $C_{13}H_{15}NO_4$: C, 62.64; H, 6.07; N, 5.62%.

Ethyl 5-Hexyl-3-isoxazolecarboxylate (23e):[2] Colorless oil; IR (neat) 2929, 1731, 1461, 1247, 1207 cm^{-1}; ^1H NMR δ = 0.86 (3H, t, J = 7.0 Hz), 1.25—1.35 (6H, m), 1.38 (3H, t, J = 7.0 Hz), 1.65—1.70 (2H, m), 2.76 (2H, t, J = 7.6 Hz), 4.39 (2H, q, J = 7.0 Hz), 6.37 (1H, s); ^{13}C NMR δ = 13.9, 14.1, 22.4, 26.6, 27.3, 28.6, 31.3, 62.0, 101.3, 156.3, 160.2, 175.7. Found: C, 63.81; H, 8.40; N, 6.10%. Anal. Calcd for $C_{12}H_{19}NO_3$: C, 63.98; H, 8.50; N, 6.22%.

6-Phenyl-1-[*N*-(5-phenylpentanoyloxy)imino]-2-hexanone (27): Colorless oil; IR (neat) 2937, 1786, 1705, 1603, 1454, 1101, 1076, 945, 916, 746, 700 cm^{-1}; ^1H NMR δ = 1.63—1.69 (8H, m), 2.42—2.47 (2H, m), 2.58—2.63 (4H, m), 2.86—2.91 (2H, m), 7.10—7.13 (6H, m), 7.20—7.22 (4H, m), 7.56 (1H, s); ^{13}C NMR δ = 22.9, 24.2, 30.7 (2C), 32.4, 35.4, 35.6, 38.4, 125.8, 125.9, 128.3 (2C), 128.4 (2C), 141.8, 142.0, 152.6, 170.0, 197.9.

Ethyl 3-Chloro-4,5-dihydro-5-isoxazolecarboxylate (28): ^1H NMR δ = 1.30 (3H, t, J = 7.2 Hz), 3.43 (1H, d, J = 10.5 Hz), 3.44 (1H, d, J = 8.3 Hz), 4.26 (2H, q, J = 7.2 Hz), 5.13 (1H, dd, J = 8.3, 10.5 Hz); ^{13}C NMR δ = 14.0, 41.7, 62.4, 79.0, 148.7, 168.8.

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