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X=Y-ZH Systems as Potential 1,3-Dipoles. Part 49.[1] Catalytic Palladium (II) Mediated Oxime-Nitrone-Isoxazolidine Cascades

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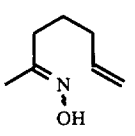
Abstract: Bis(acetonitrile) palladium (II) chloride (10 mol %) effects cyclization of δ-alkenyl oximes to nitrones which undergo *in situ* 1,3-dipolar cycloaddition reactions with suitable dipolarophiles to afford a range of complex isoxazolidine derived heterocycles in high yield (81-85%).

Palladium complexes catalyse a plethora of reactions which allow rapid access to a diverse array of molecular structures and which permit major increases in molecular complexity. Our interest in the use of metal salts to catalyse cascade processes led us to investigate the use of palladium (II) salts in our various oxime-nitrone-isoxazolidine cascades. We have previously noted the efficacy of Pd(II) salts to induce tandem formal [2,3]-sigmatropic shift-1,3-dipolar cycloaddition processes in oxime *O*-allyl ethers[2] together with their use in the catalysis of cyclization-1,3-dipolar cycloaddition cascade reactions of δ-alkenyl oximes.[3] In this paper we report more fully on our studies concerned with the latter processes.

Oximes **1-6** were prepared to study the scope of these cascades for which there are two synthetic variants.[4] Oximes **1-4** allowed the investigation of cyclization-intermolecular cycloaddition cascades whereas oximes **5** and **6** were used to investigate cyclization-intramolecular cycloaddition reactions.[4]



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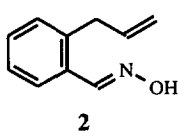

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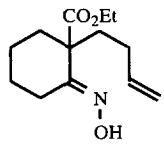

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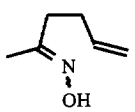

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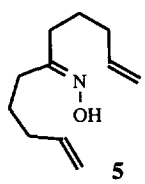

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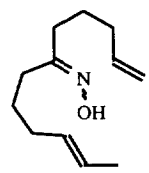
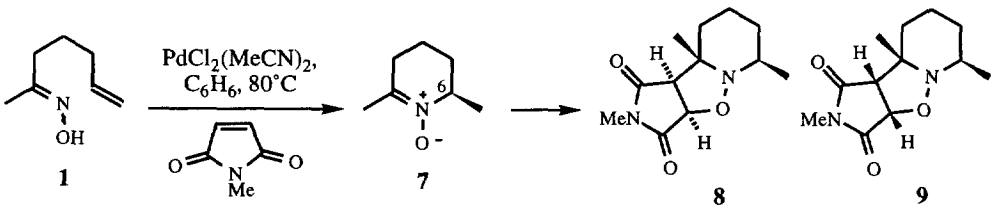


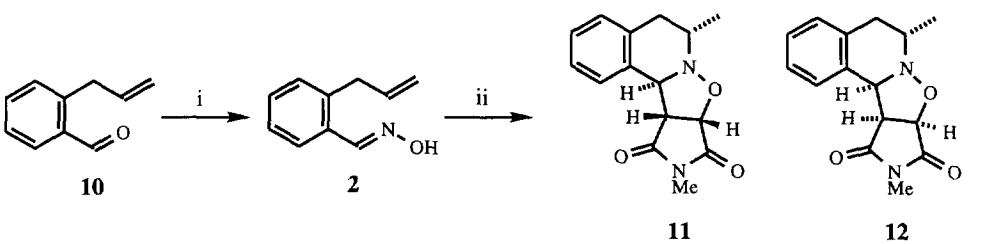
6

Treatment of ketoxime **1**[5] (*E*/*Z* 2:1) with $PdCl_2(MeCN)_2$ (10 mol %) and *N*-methylmaleimide (NMM) in benzene (80°C, 7 h) resulted in smooth cyclization and subsequent cycloaddition to afford a 3:1 mixture of

exo- and *endo*-adducts **8** and **9** (85%), stereochemistries of both **8** and **9** being assigned using data from n.O.e. experiments (see Experimental section). Both **8** and **9** are formed *via* cycloaddition processes in which NMM has added *anti* to the C(6)-methyl group of the nitrone **7** formed in the initial cyclization step.



δ-Alkenyl aldoximes are also suitable substrates in these cascades. 2-Allylbenzaldehyde **10**[6] gave the corresponding (*E*)-aldoxime **2** which, when subjected to similar treatment with Pd(II), afforded a *ca.* 10:1 mixture of *exo*- and *endo*-cycloadducts **11** and **12** (as evidenced by ^{1}H nmr of the reaction mixture) from which the major product **11** could be isolated by column chromatography (81%). The stereochemistry of **11** was established by an X-ray crystallographic study (*Figure 1*)[7] whilst **12**, which was not isolated, is tentatively assigned as the corresponding *endo*-isomer.



i, NH_2OH·HCl, C_5H_5N, MeOH, 20°C; ii, $PdCl_2(MeCN)_2$, NMM, THF, 66°C

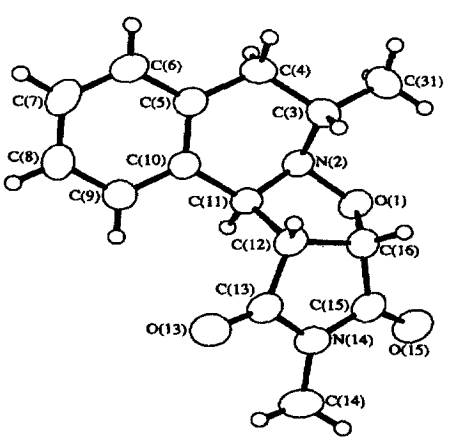
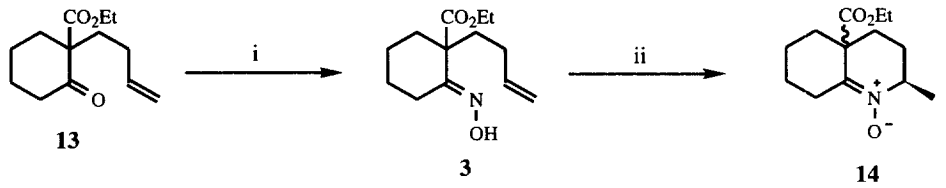


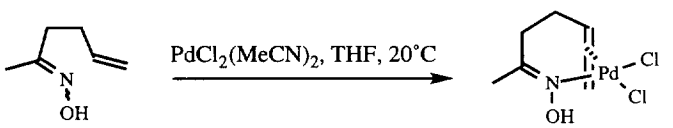
Figure 1: X-ray crystallographic structure of **11**

Cyclic (*E*)-ketoxime **3** prepared from ketoester **13**[8] also readily cyclized with palladium (II). Nitrone **14** was isolated as a 1:1 isomeric mixture (70%) upon treatment of oxime **3** with $PdCl_2(MeCN)_2$ (10 mol%) in hot tetrahydrofuran (66°C, 4 h).

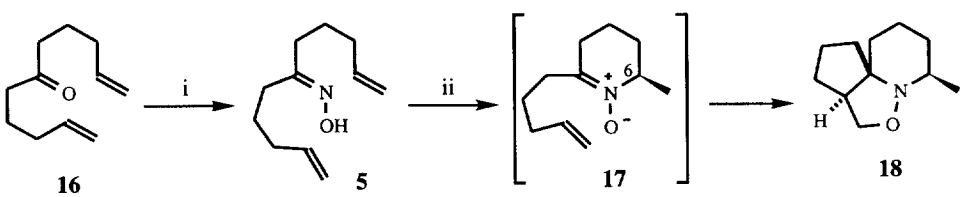


i, NH_2OH·HCl, NaOAc, MeCN, H_2O, 20°C; ii, $PdCl_2(MeCN)_2$, THF, 66°C

In stark contrast, γ-alkenyl ketoxime **4**[5] (*E*/*Z* 2:1) could not be cyclized under identical conditions to those employed for the cyclization of both **1** and **3**. Treatment of oxime **4** with $PdCl_2(MeCN)_2$ (10 mol%) and NMM in either refluxing tetrahydrofuran of benzene (66°C or 80°C) resulted only in the recovery of starting materials. Neither nitrone from palladium (II) mediated cyclization nor cycloadduct products could be detected by inspection of the ^1H nmr spectrum of the crude reaction mixture. Subsequent treatment of oxime **4** with $PdCl_2(MeCN)_2$ (1·00 mol equiv) in tetrahydrofuran (20°C, 1 h) resulted in the formation of a 1:1 Pd:oxime complex formulated as **15**. Presumably in this less conformationally flexible case the required geometry for cyclization cannot be realized after complexation of the olefin to the palladium centre due to concomitant complexation of palladium by the oxime sp^2 nitrogen atom to give a kinetically stable chelate complex **15**.



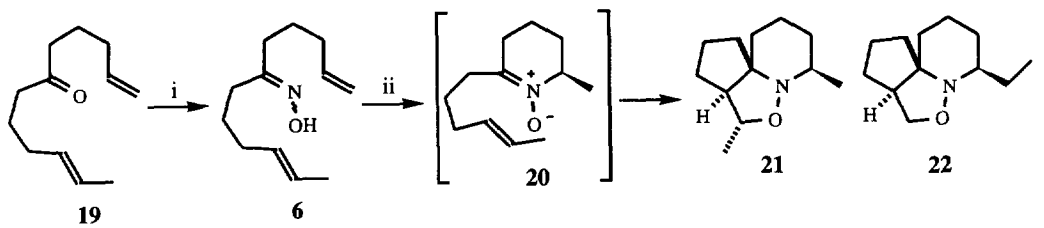
Symmetrical ketoxime **5** (prepared from ketone **16**)[9] underwent smooth Pd(II) assisted cyclization-intramolecular cycloaddition in hot benzene [$PdCl_2(MeCN)_2$ (10 mol%), 6 h]. Stereochemistry of the resulting cycloadduct **18** (isolated in 85% yield after chromatography) was assigned using n.O.e. data (see Experimental section). Cycloadduct **18** arises from nitrone **17** by cycloaddition *anti* to the C(6)-methyl group.



i, NH_2OH·HCl, NaOAc, MeCN, H_2O, 20°C; ii, $PdCl_2(MeCN)_2$, C_6H_6, 80°C

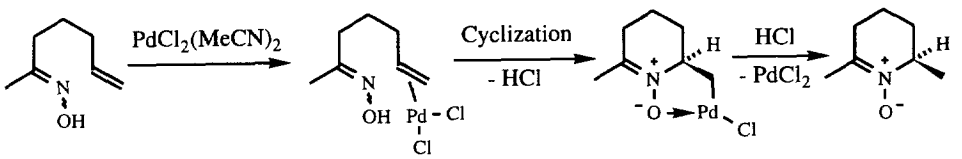
Similarly, ketoxime **6** (*E*/*Z* 1:1) prepared from **19**[10] underwent a rapid Pd(II) catalysed cyclization-cycloaddition cascade under identical conditions to afford a single cycloadduct **21** (82%) *via* nitrone **20**.

Interestingly, none of the possible alternative cyclization-cycloaddition product **22** was formed. Thus the initial palladium (II) catalysed cyclization occurs chemospecifically at the least substituted terminal alkene and not at the alternative internal (*E*)-1,2-dialkyl olefin. This phenomenon reflects the kinetic preference for complexation of the least substituted olefin to the palladium centre.



i, NH_2OH·HCl, NaOAc, MeCN, H_2O, 20°C; ii, $PdCl_2(MeCN)_2$, C_6H_6, 80°C

Mechanistically these cascades are of particular interest since no products arising from the δ-alkenyl oximes *via* cyclization-β-hydride elimination sequences were detected. The probable reason for this is that after electrophilic addition of the palladium (II) salt to the terminal alkene cyclization occurs to afford an intermediate nitrone in which the nitrone oxygen atom complexes to the palladium centre (*Scheme 1*). *Cis*-β-hydride elimination is thus geometrically precluded since the palladium and β-hydrogen atoms are prevented from adopting the synperiplanar geometry necessary for elimination. Protolysis of the carbon-palladium bond by hydrogen chloride (generated upon cyclization) results in formation of the decomplexed nitrone and regenerates the Pd(II) catalyst to complete the catalytic cycle.



Scheme 1

Pertinent observations adding weight to this hypothesis and confirming the necessity for palladium (II) to promote catalysis were noted in experiments run in the absence of $PdCl_2(MeCN)_2$ or in which either $Pd(OAc)_2$ or hydrogen chloride were substituted for the catalyst. In all cases, reaction failed to occur to any significant extent confirming the role of Pd(II) in the initial step cyclization followed by the need for strong protic acid to protolyse the palladated intermediate.

Scheme 2

The lack of influence of oxime geometry on these cascade processes indicates that *E*/*Z*-isomerization is facile under the reaction conditions. Similar insensitivity to *E*/*Z*-oxime configuration is found in all of our

oxime-nitrone-isoxazolidine cascades in which *E/Z*-interconversion is presumed to occur *via* intermediate nitroso species[11] (*Scheme 2*).

EXPERIMENTAL

Melting points were determined on a Kofler hot-stage apparatus and are uncorrected. Microanalyses were obtained using a Carlo Erba MOD 1106 instrument. Mass spectra were recorded at 70 ev on a VG Autospec mass spectrometer. ^{1}H and ^{13}C Nuclear magnetic resonance spectra were recorded using either a General Electric QE300 spectrometer (300 MHz) or a Bruker AM-400 spectrometer (^{1}H at 400 MHz, ^{13}C at 100 MHz) in the solvents specified. Flash column chromatography was performed using silica gel 60 (Merck 9385). Petroleum ethers (b.p. 40-60°C and b.p. 60-80°C) were distilled prior to use. Benzene was dried over sodium wire and tetrahydrofuran was dried by distillation from sodium benzophenone ketyl prior to use.

(*E*)-2-Allylbenzaldoxime 2. A mixture of 2-allylbenzaldehyde **10**[6] (730 mg, 5·00 mmol) and pyridine (590 mg, 7·50 mmol) in methanol (7 ml) was treated with a solution of hydroxylamine hydrochloride (520 mg, 7·50 mmol) in water (1 ml) and the mixture was stirred at room temperature overnight. After removal of the solvent *in vacuo* the residue was treated with 2M hydrochloric acid (30 ml) and the organic material was extracted into diethyl ether (2 x 30 ml). The combined organic layers were dried over anhydrous sodium sulphate and the solvent removed *in vacuo* to afford the *product* **2** (792 mg, 98%), as a colourless oil. (Found: C, 74·25; H, 6·6; N, 8·8. $C_{10}H_{11}NO$ requires C, 74·5; H, 6·9; N, 8·7%); *m/z* (%) 161 (M^+, 13), 146 (44), 133 (50), 129 (100), 115 (54), 104 (14), 89 (23), 77 (18), 63 (18), 51 (16), 39 (19); δ_H ($CDCl_3$) 8·52 (1H, s, OH), 8·43 (1H, s, CH=N), 7·75 (1H, d, *J* 7 Hz, ArH), 7·36 (1H, t, *J* 7 Hz, ArH), 7·23 (2H, m, ArH), 5·98 (1H, m, C*H*=CH_2), 5·10 (1H, d, *J* 10 Hz, CH=C*H*H), 4·98 (1H, d, *J* 15 Hz, CH=CH*H*), 3·55 (2H, d, *J* 5 Hz, CH_2CH=CH_2).

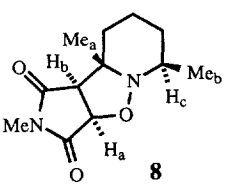
(*E*)-2-(3-Butenyl)-2-carboethoxycyclohexanone oxime 3. A solution of hydroxylamine hydrochloride (1·28 g, 18·42 mmol) and sodium acetate (1·50 g, 18·29 mmol) in water (20 ml) was added to a solution of 2-(3-butenyl)-2-carboethoxycyclohexanone **13**[8] (2·74 g, 12·23 mmol) in methanol (50 ml) and the mixture stirred at room temperature for 16 h. The solvent was removed *in vacuo*, the residue partitioned between dichloromethane (100 ml) and water (100 ml), the organic layer dried over anhydrous magnesium sulphate, the solvent removed *in vacuo* and the residue subjected to column chromatography on silica. Elution with 3:1 v/v petroleum ether (b.p. 40-60°C)-diethyl ether afforded the *product* **3** (1·90 g, 65%), R_f 0·45, as colourless needles. m.p. 74-75°C; (Found: C, 65·05; H, 8·85; N, 5·55. $C_{13}H_{21}NO_3$ requires C, 65·25; H, 8·85; N, 5·85%); *m/z* (%) 239 (M^+, 1), 222 (23), 185 (34), 170 (35), 166 (47), 139 (100), 124 (57), 98 (37), 55 (57); δ_H ($CDCl_3$) 8·53 (1H, broad s, OH), 5·80 (1H, m, C*H*=CH_2), 4·97 (2H, m, CH=CH_2), 4·19 (2H, q, *J* 7 Hz, O$CH_2$$CH_3$), 3·15 (1H, dt, *J* 12 and 4 Hz, *H*HCC=N), 2·38 (1H, dm, *J* 12 Hz, H*H*CC=N), 2·10-1·40 (10H, m, 5 x CH_2), 1·27 (3H, t, *J* 7 Hz, OCH_2CH_3).

1,10-Undecadien-6-one oxime 5. Hydroxylamine hydrochloride (417 mg, 6·00 mmol) and sodium acetate (615 mg, 7·50 mmol) were added to a solution of 1,10-undecadien-6-one **16**[9] (830 mg, 5·00 mmol) in acetonitrile (75 ml) and water (25 ml), the mixture stirred at room temperature for 3 h and the solvent removed *in vacuo*. The residue was partitioned between dichloromethane (50 ml) and water (50 ml), the organic layer dried over anhydrous magnesium sulphate, the solvent removed *in vacuo* and the residue

subjected to column chromatography on silica. Elution with 3:2 v/v petroleum ether (b.p. 40-60°C)-diethyl ether afforded the *product* **5** (688 mg, 76%), as a colourless oil. (Found: C, 73·0; H, 10·8; N, 7·8. $C_{11}H_{19}NO$ requires C, 72·9; H, 10·55; N, 7·75%); *m/z* (%) 181 (M^+, 1), 164 (10), 140 (13), 127 (67), 112 (41), 73 (97), 55 (57), 41 (100); δ_H ($CDCl_3$) 8·80 (1H, broad s, OH), 5·84 (2H, m, CH=CH_2), 5·00 (4H, m, CH=CH_2), 2·35 and 2·20 (2 x 2H, 2 x m, 2 x CH_2), 2·09 (4H, m, CH_2), 1·61 (4H, m, 2 x CH_2).

(*E*)-1,10-Dodecadien-6-one oxime 6. Hydroxylamine hydrochloride (417 mg, 6·00 mmol) and sodium acetate (615 mg, 7·50 mmol) were added to a solution of (*E*)-1,10-dodecadien-6-one **19**[10] (900 mg, 5·00 mmol) in acetonitrile (75 ml) and water (25 ml), the mixture stirred at room temperature for 3 h and the solvent removed *in vacuo*. The residue was partitioned between dichloromethane (50 ml) and water (50 ml), the organic layer dried over anhydrous magnesium sulphate, the solvent removed *in vacuo* and the residue subjected to column chromatography on silica. Elution with 3:2 v/v petroleum ether (b.p. 40-60°C)-diethyl ether afforded the *product* **6** (917 mg, 94%, 1:1 *E*/*Z* mixture), as a colourless oil. (Found: C, 73·4; H, 10·8; N, 7·3. $C_{12}H_{21}NO$ requires C, 73·8; H, 10·85; N, 7·15%); *m/z* (%) 195 (M^+, 1), 178 (4), 154 (3), 141 (14), 127 (45), 112 (29), 99 (37), 73 (100), 69 (29), 55 (45), 41 (80); δ_H ($CDCl_3$) 8·70 and 8·20 (1H, 2 x broad s, OH), 5·82 (1H, m, CH=CH_2), 5·44 (2H, m, -CH=CH-), 5·06 (2H, m, CH=CH_2), 2·33 (2H, m, CH_2), 2·09 (6H, m, 3 x CH_2), 1·64 (7H, m, 2 x CH_2 and Me).

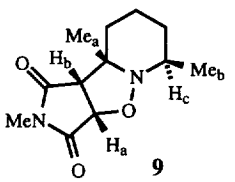
Cycloadducts 8 and 9. A solution of 6-hepten-2-one oxime **1**[5] (0·30 g, 2·36 mmol) in benzene (15 ml) was treated with $PdCl_2(MeCN)_2$ (60 mg, 0·24 mmol) and *N*-methylmaleimide (0·26 g, 2·36 mmol) and the mixture was stirred and held at reflux for 7 h. After cooling the solvent was removed *in vacuo* and the residue subjected to column chromatography. Elution with 1:2 v/v petroleum ether (b.p. 40-60°C)-diethyl ether afforded a 3:1 mixture of the *products* **8** and **9** (0·47 g, 85%), R_f 0·21, as a colourless solid. m.p. 89-92°C; (Found: C, 60·6; H, 7·75; N, 11·6. $C_{12}H_{18}N_2O_3$ requires C, 60·5; H, 7·6; N, 11·75%); *m/z* (%) 238 (M^+, 11), 223 (100), 169 (8), 138 (6), 127 (51), 111 (61), 96 (12), 83 (42), 73 (18), 67 (15), 55 (57), 42 (47).
8: δ_H ($CDCl_3$) 5·11 (1H, d, *J* 8·5 Hz, H_a), 3·68 (1H, d, *J* 8·5 Hz, H_b), 3·01 (3H, s, NMe), 2·67 (1H, m, H_c), 2·23 (1H, dm, *J* 14 Hz, CH), 1·80-1·40 (5H, m, CH and 2 x CH_2), 1·21 (3H, d, *J* 5 Hz, Me_b), 1·20 (3H, s, Me_a).



8

		Enhancement (%)		
		H_a	H_b	H_c
Irradiated hydrogen	H_a		8·0	8·3
	H_b	6·2		9·6

9: δ_H ($CDCl_3$) 4·86 (1H, d, *J* 8 Hz, H_a), 3·25 (1H, d, *J* 8 Hz, H_b), 2·97 (3H, s, NMe), 2·62 (1H, dm, *J* 14 Hz, CH), 2·33 (1H, m, H_c), 1·80-1·40 (5H, m, CH and 2 x CH_2), 1·36 (3H, s, Me_a), 1·17 (3H, d, *J* 6 Hz, Me_b).

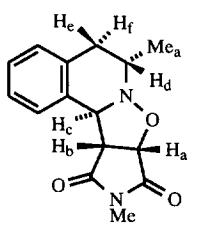


9

Enhancement (%)

Irradiated hydrogen		H_a	H_b	Me_a
	H_a		6·1	
	H_b	5·2		2·8

Cycloadduct 11. A solution of (*E*)-2-allylbenzaldoxime **2** (80 mg, 0·50 mmol) in tetrahydrofuran (8 ml) was treated with $PdCl_2(MeCN)_2$ (14 mg, 0·05 mmol) and *N*-methylmaleimide (55 mg, 0·50 mmol) and the mixture was stirred and held at reflux for 16 h. After cooling the solvent was removed *in vacuo* and the residue subjected to column chromatography. Elution with 1:2 v/v petroleum ether (b.p. 40-60°C)-diethyl ether afforded the *product* **11** (110 mg, 81%), R_f 0·40, as a colourless solid that crystallized from petroleum ether (b.p. 60-80°C)-dichloromethane as colourless prisms. m.p. 175-176°C (decomp.); (Found: C, 66·1; H, 6·05; N, 10·25. $C_{15}H_{16}N_2O_3$ requires C, 66·15; H, 5·9; N, 10·3%); *m/z* (%) 272 (M^+, 60), 257 (75), 161 (100), 144 (56), 129 (96), 115 (54); δ_H ($CDCl_3$) 7·46 (1H, d, *J* 7·5 Hz, ArH), 7·29 (1H, td, *J* 7·5 and 0·5 Hz, ArH), 7·22 (1H, td, *J* 7·5 and 0·5 Hz, ArH), 7·09 (1H, d, *J* 7·5 Hz, ArH), 4·85 (1H, d, *J* 7·5 Hz, H_a), 4·72 (1H, d, *J* 4 Hz, H_c), 3·72 (1H, dd, *J* 7·5, 4 Hz, H_b), 3·47 (1H, qdd, *J* 6·5, 6 and 4·5 Hz, H_d), 3·11 (1H, dd, *J* 16·5 and 4·5 Hz, H_e), 3·10 (3H, s, NMe), 2·55 (1H, dd, *J* 16·5 and 6 Hz, H_f), 1·22 (3H, d, *J* 6·5 Hz, Me); δ_c ($CDCl_3$) 175·5, 173·8, 132·6, 132·6, 128·7, 127·4, 127·3, 126·9, 75·8, 64·0, 56·5, 52·0, 31·9, 25·2, 17·9.



11

Enhancement (%)

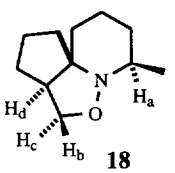
Irradiated hydrogen		H_a	H_b	H_c	H_d	H_f	Me_a
	H_a		7·9		3·7		
	H_b	9·2		4·9			
	H_c		2·9				2·9
	Me_a			3·0	5·1	2·9	

Nitrone 14. A solution of (*E*)-2-(3-butenyl)-2-carboethoxycyclohexanone oxime **3** (0·10 g, 0·42 mmol) in tetrahydrofuran (10 ml) was treated with $PdCl_2(MeCN)_2$ (10 mg, 0·042 mmol) and the mixture was stirred and held at reflux for 4 h. After cooling the residue was filtered through a very short plug of silica and the solvent removed *in vacuo* to afford the *product* **14** (70 mg, 70%, 1:1 isomeric mixture), as a colourless oil. (HRMS: 239·3151. $C_{13}H_{21}NO_3$ requires 239·3138); δ_H ($CDCl_3$) 4·20 (2H, m, OCH_2CH_3), 4·00 (1H, m, CHN), 3·68 (1H, broad s, *H*HCC=N), 2·44 and 2·40 (1H, 2 x broad s, H*H*CC=N), 2·20-1·35 (10H, m, 10 x CH), 1·55 (3H, 2 x d, *J* 6 Hz, Me), 1·30 (3H, t, *J* 7·5 Hz, OCH_2CH_3).

Palladium complex 15. A solution of 5-hexen-2-one oxime **4**[5] (0·10 g, 0·88 mmol) in tetrahydrofuran (5 ml) was treated with $PdCl_2(MeCN)_2$ (23 mg, 0·88 mmol) and the mixture was stirred at room temperature for 1 h. The precipitate was filtered to afford the *product* **15** (0·17 g, 70%), as a yellow solid that crystallized from dichloromethane as yellow plates. m.p. 114-115°C; (Found: C, 24·55; H, 3·45;

N, 4·85; Cl, 24·5. $C_6H_{11}Cl_2NOPd$ requires C, 24·8; H, 3·8; N, 4·8; Cl, 24·5%); δ_H ($CDCl_3$) 10·46 (1H, s, OH), 6·57 (1H, m, C*H*=CH_2), 5·35 (1H, d, *J* 8·5 Hz, CH=C*H*H), 4·88 (1H, d, *J* 14·5 Hz, CH=CH*H*), 2·96 (1H, m, CH), 2·78 (2H, m, 2 x CH), 2·40 (1H, m, CH), 2·13 (3H, s, Me).

Cycloadduct 18. A solution of 1,10-undecadien-6-one oxime **5** (0·20 g, 1·10 mmol) in benzene (10 ml) was treated with $PdCl_2(MeCN)_2$ (28 mg, 0·11 mmol) and the mixture was stirred and held at reflux for 6 h. After cooling the solvent was removed *in vacuo* and the residue subjected to column chromatography. Elution with 1:1 v/v petroleum ether (b.p. 40-60°C)-diethyl ether afforded the *product* **18** (0·17 g, 85%), as a colourless oil. (Found: C, 72·95; H, 10·45; N, 7·75. $C_{11}H_{19}NO$ requires C, 72·9; H, 10·55; N, 7·75%); *m/z* (%) 181 (M^+, 7), 166 (100), 152 (65), 139 (51), 127 (46); δ_H ($CDCl_3$) 4·23 (1H, t, *J* 8·5 Hz, H_c), 3·40 (1H, dd, *J* 8·5 and 4 Hz, H_b), 2·64 (1H, m, H_d), 2·54 (1H, m, H_a), 1·92 and 1·86 (2 x 1H, 2 x m, 2 x CH), 1·78-1·48 (8H, m, 8 x CH), 1·24 (2H, m, 2 x CH), 1·15 (3H, d, *J* 7·5 Hz, Me).



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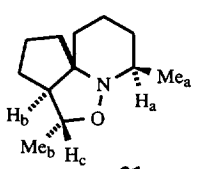
Irradiated hydrogen	Enhancement (%)			
	H_b	H_c	H_d	Me
H_a		6·1		4·4
H_c	18·3		5·6	
H_d		4·1		

Cycloadduct 21. A solution of (*E*)-1,11-dodecadien-6-one oxime **6** (0·20 g, 1·00 mmol) in benzene (10 ml) was treated with $PdCl_2(MeCN)_2$ (26 mg, 0·10 mmol) and the mixture was stirred and held at reflux for 6 h. After cooling the solvent was removed *in vacuo* and the residue subjected to column chromatography. Elution with 1:1 v/v petroleum ether (b.p. 40-60°C)-diethyl ether afforded the *product* **21** (0·16 g, 82%), as a colourless oil. (Found: C, 73·2; H, 11·4; N, 7·25. $C_{12}H_{21}NO$ requires C, 73·8; H, 10·85; N, 7·15%); *m/z* (%) 195 (M^+, 30), 180 (100), 166 (16), 152 (20), 138 (82), 127 (27); δ_H ($CDCl_3$) 3·70 (1H, m, H_c), 2·80 (1H, m, H_a), 2·21 (1H, t, *J* 6·5 Hz, H_b), 1·80 (3H, m, 3 x CH), 1·71-1·42 (8H, m, 8 x CH), 1·33 (3H, d, *J* 6 Hz, Me_a), 1·27 (1H, m, CH), 1·18 (3H, d, *J* 6 Hz, Me_b).



21

Irradiated hydrogen	Enhancement (%)		
	H_a	H_b	Me_a
H_a		1·9	5·9
H_b	3·4		
Me_b	2·0	2·6	

Single crystal X-ray analysis of 11.[7] All crystallographic measurements were carried out on a Stoe STADI 4 diffractometer at ambient temperature using graphite monochromated copper K_α X-radiation (λ=1·54184 Å). Two equivalent sets of data were collected in the ranges 4·0<2θ<130·0° using ω/θ scans.

No significant variation was observed in the intensity of five standard reflections. Lorentz and polarization corrections were applied to the data sets together with a semi-empirical absorption correction based on azimuthal ψ-scans. The structures were solved by direct methods using SHELXS-86[12] and were refined by full-matrix least squares (based on F^2) using SHELXS-93[13] which uses all data for refinement.

Crystal data for **11**:[7] $C_{15}H_{16}N_2O_3$, 0·49 x 0·34 x 0·30 mm, M = 272·30, monoclinic, space group $P2_1/c$, a = 6·8781(3) Å, b = 27·9412(14) Å, c = 7·3480(2) Å, α = 90°, β = 111·799(2)°, γ = 90°, U = 1311·18(9) Å^3, Z = 4, D_x = 1·379 gcm^{-3}, μ = 0·798 mm^{-1}, F(000) = 576.

Non-hydrogen atom co-ordinates (x 10^4) and equivalent isotropic thermal parameters (Å^2 x 10^3) for **11** with estimated standard deviations in parentheses. (U_{eq} = $^1/_3$ x the orthogonalized U_{ij} matrix).

Atom	x	y	z	U_{eq}
O(1)	4079·3(15)	5655·5(3)	2942·1(15)	43·3(3)
N(2)	5174(2)	5639·1(4)	1593(2)	37·4(3)
C(3)	7284(2)	5428·3(5)	2603(2)	40·6(3)
C(31)	7089(3)	4928·0(5)	3322(3)	53·5(4)
C(4)	8331(2)	5422·8(5)	1104(2)	44·8(4)
C(5)	8242(2)	5897·1(5)	103(2)	38·8(3)
C(6)	9580(2)	6000·3(6)	-882(2)	46·6(4)
C(7)	9480(2)	6431·4(6)	-1816(2)	49·9(4)
C(8)	8019(2)	6772·4(6)	-1812(2)	47·8(4)
C(9)	6665(2)	6675·3(5)	-863(2)	42·6(3)
C(10)	6779(2)	6242·2(5)	106(2)	35·8(3)
C(11)	5292(2)	6147·7(4)	1141(2)	34·9(3)
C(12)	5811(2)	6405·5(5)	3153(2)	38·9(3)
C(13)	4625(2)	6868·5(5)	2954(2)	45·2(4)
O(13)	4966(2)	7245·1(4)	2325(2)	67·1(4)
N(14)	2982(2)	6790·7(4)	3569(2)	45·5(3)
C(14)	1414(3)	7153·4(6)	3454(3)	62·7(5)
C(15)	2966(2)	6337·3(5)	4302(2)	45·3(4)
O(15)	1660(2)	6193·2(4)	4901(2)	65·7(4)
C(16)	4841(2)	6068·4(5)	4201(2)	40·6(3)

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