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Iminyl Radicals: Part III. Further Synthetically Useful Sources of Iminyl Radicals.

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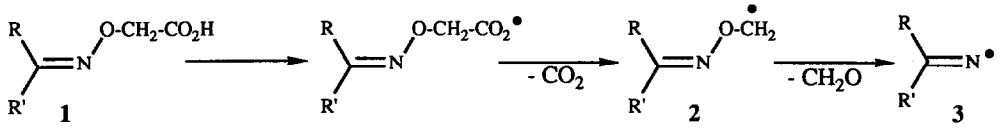
Abstract: New methods for generating iminyl radicals have been developed using suitable derivatives of oximes; Barton's decarboxylation of O-carboxymethyl derivatives proved to be particularly effective.

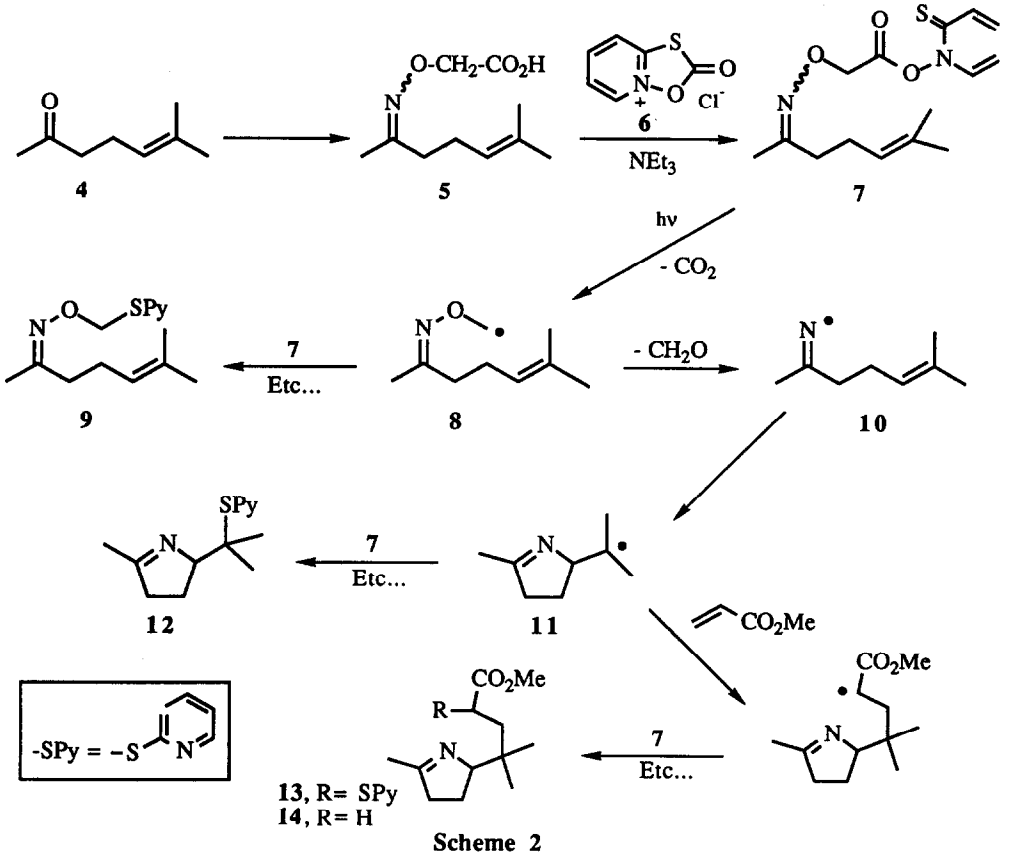
In the first two parts of this series,[1] we reported that iminyl radicals can be conveniently generated by treatment of S-aryl sulphenylimines with tributylstannane and cleanly captured by suitably located internal olefin. Those derived from strained ketones such as cyclobutanones undergo ring opening to a nitrile and a carbon centered radical which in turn can be used in a number of synthetically useful ways. One of the limitations associated with the use of tributylstannane is the loss of a potential functionality in the final product, since the last step in the radical chain involves a transfer of a hydrogen atom. In order to circumvent this limitation, we have developed an alternative approach based on an earlier, pioneering work of Forrester and his assosiates[2] who discovered accidentally that radicals such as **2** underwent fragmentation to give an iminyl radical and formaldehyde, as shown in Scheme 1. Radicals **2** were generated by oxidative decarboxylation of the corresponding acids **1** under somewhat harsh experimental conditions and through a process that is a non chain, difficult to control, radical sequence. These factors seriously limited the scope of the method which has been applied mostly to study aromatic systems.



Scheme 1

An attractive solution to these difficulties would be the effecting of the decarboxylation step by the Barton method[3] using esters of N-hydroxy-2-thiopyridone. If successful, such an approach would open up tremendous synthetic possibilities; for not only are the reaction conditions mild, but the last step in the radical chain process introduces an exceedingly useful thiopyridine group into the final product. In addition, this system is compatible with a much wider range of traps than the one based on stannane chemistry; hence a great variety of hitherto impractical variations and modifications thus become conceivable. The key question upon which this approach hinges, and which had to be answered from the outset, was whether loss of formaldehyde from radical **2** is sufficiently fast to compete successfully with premarutre capture by the starting thiohydroxamate ester. This potentially serious complication is outlined in Scheme 2 for the case of acid **5**.

Thus, if extrusion of formaldehyde from the corresponding radical **8** is too slow, addition to the thiocarbonyl group of ester **7** will dominate to give the unwanted sulfide **9** through the usual decarboxylative rearrangement. A fast rupture of radical **8**, in contrast, would channel the material first through iminyl radical **10** then carbon radical **11** producing finally pyrrolenine **12**, the pyridyl sulfide group being introduced in the last propagation step.

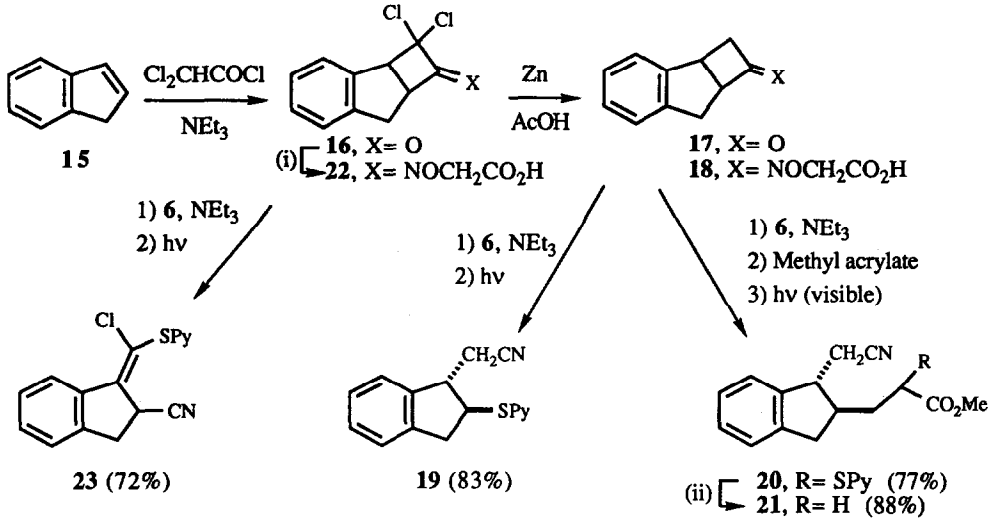


Scheme 2

Acid **5** was prepared in a straightforward manner as a mixture of isomers by condensation of ketone **4** with carboxymethoxylamine, commercialy available as the hemihydrochloride[$(H_2NOCH_2CO_2H)_2.HCl$)]. Treatment (in the dark) of the material thus obtained with 1-oxa-2-oxo-thiaindolizinium chloride **6**[4] and triethylamine afforded the required radical precursor **7**.[5] This intermediate was not isolated but irradiated direcly (500W tungsten lamp) for 40 minutes as an ice-cooled solution (0.2 M) in dichloromethane. In this way a mixture of **14** (mixture of Z and E isomers) and **17** was produced (total yield 78 %, **17/14**= 1.7). It appears clearly from this experiment that the bimolecular reaction between **13** and **12** competes significantly with the loss of formaldehyde (**13**--->**15**).

As would be expected, fivefold dilution (to 0.04 M), and allowing the mixture to reflux under the heat generated by the lamp favoured the unimolecular loss of formaldehyde at the expense of the unwanted bimolecular side reaction. The selectivity could thus be dramatically improved to 11/1. Moreover, if methyl

acrylate (5 equivalents) is added to the medium before irradiation, the intermediate carbon radical **11** can be captured in a new carbon-carbon bond forming step leading ultimately to adduct **13** in 55% unoptimised yield (Scheme II). For correlation purposes, the latter was reduced by n-Bu_3SnH (toluene, AIBN, reflux, 2 hrs.; 85 %) into the previously prepared derivative **14**.[1]

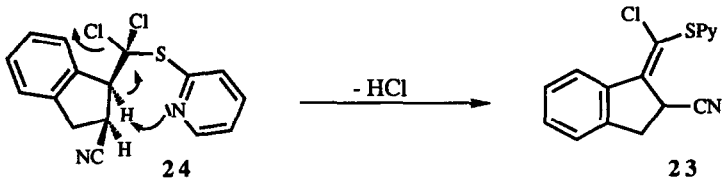


(i) $H_2NCH_2CO_2H$. HCl / AcONa / MeOH ; (ii) Bu_3SnH / AIBN (cat.)

Scheme 3

In part II of this series,[1] we showed that ring opening of cyclobutyliminyl radicals to give a nitrile function and a carbon radical can be a very useful transformation. A wide variety of cyclobutanone precursors are easily prepared through dichloroketene addition onto a double bond, eventually followed by dechlorination with zinc powder.[6] Application of the present procedure for generating iminyl radicals to cyclobutanone **17**, derived from indene **15** via the dichloro intermediate **16**, furnished an excellent yield of the *trans* nitrile **19** (83 %), resulting from the regioselective ring opening of the transient iminyl (scheme 3). In this case too, the intermediate carbon radical could be intercepted by an external, electron poor olefin (methyl acrylate, 5 eq), to provide **20** (77 %), the structure of which was again confirmed by stannane reduction (88 %) into the previously prepared derivative **21**.[1]

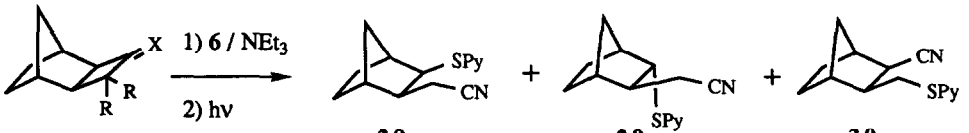
One important advantage of the present method is its compatibility with the presence of halogens in the starting compounds, in contrast to the stannane based approach. This allows the use of the dichloro-cyclobutanones themselves as substrates with quite interesting results. For example, when derivative **16** was transformed into the corresponding iminyl radical, ring opening occured to give the cis compound **24** which, however, could only be observed in the nmr of the crude reaction mixture. Attempts to purify it by chromatography on silica gel resulted in its clean transformation into **23** in 72 % overall yield. Moreover, only one geometrical isomer was observed. Thus, not only is the regioselectivity of the ring opening different from that observed on the dechlorinated analogue **17**, but also the elimination of hydrogen chloride is spontaneous and stereospecific. We presume that the stereochemistry of **24** is that indicated by assuming that the pyridyl residue acts as an internal base favouring a transition state where the steric interactions are minimised (scheme 4).



24 23

Scheme 4

Cyclobutanone **26**, made by cycloaddition of dichloroketene to norbornene followed by dechlorination, behaved in a similar way when subjected to the usual sequence. A mixture of **28**, **29**, and **30** with a strong predominance of the first isomer (ratio 12 :1.5 :1) was obtained in 71% total yield. This result further underlines the regio- and stereoselectivity of the process, since it reflects again the strong preference for rupture to the most stable secondary radical but, unlike the above example involving ketone **17**, exo addition is now favoured to give mainly the *cis*- product.



28 29 30

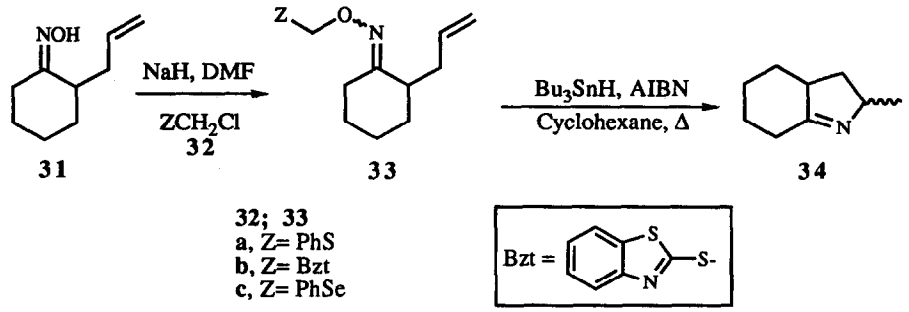
(i) **25**, R = Cl ; X= O
26, R = H ; X= O
(ii) **27**, R = H ; X= $NOCH_2CO_2H$

(i) Zn / NH_4Cl / MeOH; (ii) $H_2NCH_2CO_2H$. HCl / AcONa / MeOH

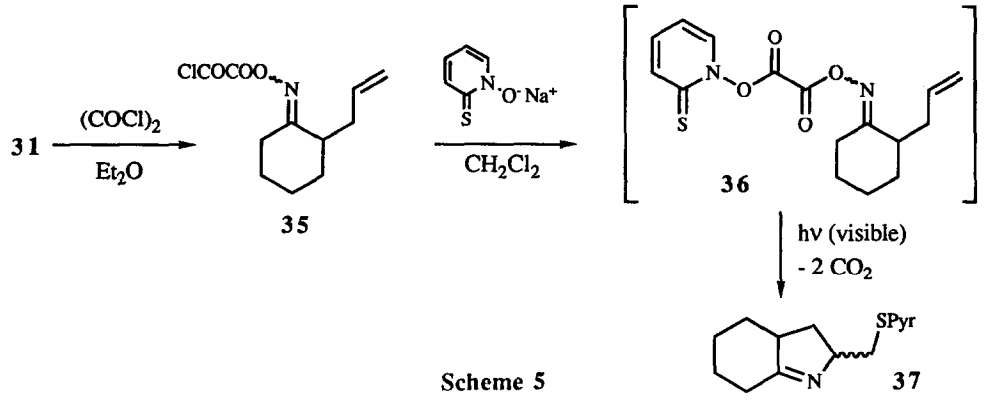
After this brief study of the scope of the decarboxylation reaction as a source of iminyl radicals, we examined the possibility of using derivatives such as **33** as further precusors for these species. Such a compound, pyridyl sulfide **9**, was indeed obtained as an unwanted side product in the first experiment described above. When attacked by tin radicals, an intermediate of type **2** would be produced, followed by expulsion of formaldehyde to give the desired iminyl radical. However, when sulfide **33a**, prepared by alkylation of oxime **31** with chloromethyl phenylsulfide **32a**, was treated with tributylstannane and AIBN as initiator, no reaction occured. Such a lack of reactivity of primary phenylsulfides had been observed before[7] and, as a consequence, we replaced the phenyl group by a benzothiazolyl residue in the hope of obtaining a more reactive system. Indeed, when compound **33b**, prepared in a similar way, was subjected to the same treatment, a reaction ensued to give the expected pyrrolenine **34b** but only in in 33% yield.

The selenium analog **33c** turned out to be the best substrate. It reacted smoothly with tributylstannane to produce **34b** in 67% yield. Unfortunately, the preparation of this precursor by alkylation of the oxime was inefficient (only 32%) and not always reproducible.

The co-production of formaldehyde in these reactions did not appear to be a nuisance, at least not in the cases that have been examined. The presence of such a reactive species could however be a source of difficulties with more complex systems or when operating on a larger scale. We therefore examined another variant to accede to iminyl radicals which did not carry such a potential drawback. This involved irradiation of the oxalate derivative **36** which would thus undergo a double loss of the innocuous carbon dioxide to give finally the desired iminyl radical, as depicted in scheme 5.



Such fragmentations have been used to deoxygenate tertiary alcohols[8] where the second extrusion of CO_2 occurs sufficiently rapidly to be useful. In our case, the much weaker N-O bond of the oxime moiety as compared with a C-O bond should ensure an even speedier rupture. Indeed, when compound **35**, prepared in situ from oxime **31** and oxalyl chloride was treated with the sodium salt of N-hydroxy-2-thiopyridone and the resulting mixture irradiated in the usual way, a useful yet unoptimised overall yield (55%) of the expected cyclised derivative **37** was obtained.



Scheme 5

The work on iminyl radicals described in this series is essentially preliminary in nature. A number of approaches for generating these species have been developed and their chemistry briefly examined. Nevertheless, the results thus far accumulated serve to give a feeling for their reactivity and an idea of their tremendous synthetic potential.

Acknowledgements: *We wish to thank Rhône-Poulenc Agrochimie for very generous financial support .*

Experimental Section

General experimental techniques as well as the preparation of starting materials **16** and **17** are described in the first two parts[1] of this series.

Exo-tricyclo[4,2,1,0^{2,5}]nonan-3-one 26. This compound was prepared by dechlorination of **25**[6b,9] according to the procedure described in Part II of this series[1] and used without further purification. Yield: 86 %; IR (cm^{-1}): 1775, 1094; n.m.r. ^1H: 2.95-3.04 (2H, m) ; 2.47 (1H, td, J = 3.5 Hz, J = 18.4 Hz) ; 2.33-2.38 (2H, m) ; 2.21 (1H, m) ; 1.42-1.56 (3H, m) ; 1.04-1.22 (3H, m); n.m.r.^{13}C: Secondary: 26.7 ; 27.8 ; 31.2 ; 32.4; tertiary: 37.2 ; 39.5 ; 50.3; 68.0; quaternary: 212.6.

Preparation of Iminooxyacetic Acids. Carboxymethoxylamine hydrochloride (1.75 g, 8.0 mmol) and sodium acetate (0.82 g, 6.0 mmol) were successively added to a solution of the carbonyl compound (4.0 mmol.) in methanol (20 ml). The reaction mixture was heated under reflux and appearance of the acid monitored by TLC (eluent: petroleum ether/ dichloromethane/ether: 1/2/1). Usually the reaction was completed within 90 min. The reaction mixture was then poured into water (20 ml) and pH adjusted to 9-10 by addition of an aqueous solution of potassium carbonate. The aqueous layer was washed with ether (2 x 50 ml), then acidified to pH 3 by addition of hydrochloric acid. Extraction with dichloromethane (2 x 50 ml), drying over sodium sulphate and removal of the solvent under reduced pressure gave a residue which was used without further purification. The following compounds were prepared according to this procedure:

[[1,5-Dimethyl-4-hexenylidene)amino]oxyl]-acetic acid 5. Yield: 82 %; n.m.r. ^{1}H: two isomers, ratio: 75/25: Major product: 10.90 (1H, br. s), 5.08 (1H, m), 4.62 (2H, s), 2.18-2.36 (4H, m), 1.91 (3H, s), 1.68 (3H, s), 1.60 (3H, s); Minor product: 10.90 (1H, br. s), 5.08 (1H, m), 4.60 (2H, s), 2.18-2.36 (4H, m), 1.87 (3H, s), 1.68 (3H, s), 1.60 (3H, s); n.m.r. ^{13}C: Major product: 175.5, 160.4, 132.6, 122.7, 69.6, 35.6, 25.6, 24.9, 17.7, 14.4; Minor product: 175.5, 161.1, 132.8, 123.1, 69.6, 29.8, 25.6, 24.1, 19.9, 14.4.

[[2,2a,7,7a-Tetrahydro-1H-cyclobut[a]inden-1-ylidene)amino]oxyl]-acetic acid 18. Yield: 85 %; IR (cm^{-1}): 3670, 3500, 1750, 1230, 1100, 1030; n.m.r. ^{1}H: 9.35 (1H, br. s), 7.22 (4H, br. s), 4.53 (2H, s), 3.95 (2H, m), 3.39 (1H, dd, J = 7.8 Hz, J' = 17.4 Hz), 3.22 (2H, m), 2.83 (1H, d, J = 17.4 Hz); n.m.r. ^{13}C: two isomers, ratio: 2/1:Major product: 175.5, 163.0, 143.4 (2C), 127.3, 127.2, 125.3, 125.0, 70.0, 40.8, 39.8, 39.6, 37.0; Minor product: 175.7, 164.3, 144.7, 143.5, 127.4, 127.2, 125.1, 124.8, 69.9, 47.5, 39.7, 39.6, 35.0.

[[2,2-Dichloro-2,2a,7,7a-tetrahydro-1H-cyclobut[a]inden-1-ylidene)amino]oxyl]-acetic acid 22. Yield: 90 %; IR (cm^{-1}): 3200, 1740, 1250, 1110, 740; n.m.r. ^{1}H: two isomers, ratio: 60/40: Major product: 9.43 (1H, br. s), 7.26-7.46 (4H, m), 4.74 (2H, s), 4.47 (1H, t, J= 7.4 Hz), 4.24 (1H, br. t, J= 8.6 Hz), 3.68 (1H, d, J= 16.7 Hz), 3.22 (1H, dd, J= 16.7 Hz, J= 9.4 Hz); Minor product: 9.43 (1H, br. s), 7.26-7.46 (4H, m), 4.69 (2H, s), 4.47 (1H, t, J= 7.4 Hz), 4.14 (1H, m), 3.28-3.31 (2H, m); n.m.r. ^{13}C: Major product: 174.9, 161.3, 144.1, 137.8, 129.1, 128.1, 127.0, 125.4, 82.4, 71.0, 62.6, 44.6, 34.2; Minor product: 174.7, 158.3, 144.0, 138.3, 129.1, 128.3, 127.1, 125.5, 78.8, 71.0, 62.5, 42.9, 37.1.

[Tricyclo[4.2.1.$0^{2,5}$]non-3-ylidenamino)oxy]-(1α,2β,5β,6α)-acetic acid 27. Yield: 93 %; IR (cm^{-1}): 3200, 1732, 1409, 1243, 1090; n.m.r. ^{1}H: 9.81 (1H, br. s), 4.56 (2H, br. s), 2.76-3.12 (2H, m), 2.10-2.58 (4H, m), 1.35-1.72 (3H, m), 1.02-1.22 (3H, m); n.m.r. ^{13}C: two isomers, ratio: 60/40: Major product: 175.5, 163.7, 69.8, 52.2, 39.3, 38.5, 35.9, 33.7, 32.3, 28.1, 26.7; Minor product: 175.7, 163.1, 69.8, 52.4, 39.5, 36.6, 35.3, 33.8, 32.6, 27.8, 26.7.

Preparation and Photolytic Decomposition of Thiohydroxamic Esters. 1-Oxa-2-oxo-3-thiaindolizium chloride (1.5 mmol.) was added to a solution (protected from light with an aluminum foil) of the iminooxy acetic acid (1 mmol.) prepared above in dry dichloromethane (5 ml). Triethylamine (1.5 mmol) was then added slowly. When the formation of the intermediate thiohydroxamic ester was completed (as judged by TLC, 1-2 hrs; in the preparation of compounds **13** and **20**, 5 equivalents of methyl acrylate were added at this point), the aluminum foil was removed and the solution irradiated with a 500W tungsten lamp for 40 min. The solvent was evaporated under reduced pressure and the residue chromatographed on a silica gel column. The following compounds were obtained according to this procedure:

6-Methyl-2-[O-(pyridine-2-thiomethyl]oximino-5-heptene 9. This compound was isolated in small amounts 7% by chromatography on silica gel (eluent: dichloromethane/ether 90/10); IR (cm^{-1}): 1760, 1470, 1430, 1140, 1110, 1040; n.m.r. ^{1}H: 8.46 (1H, d, J = 4.1 Hz), 7.51 (1H, td, J = 7.6, J'= 1.3 Hz), 7.30 (1H, d, J = 8.0 Hz), 7.02 (1H, m), 5.81 (2H, s), 5.08 (1H, m), 2.18 (4H, br. s), 1.80 (1H, s), 1.68 (3H, s), 1.59 (3H, s); n.m.r. ^{13}C: 160.1, 158.1, 149.3, 136.3, 132.4, 122.8, 122.5, 119.9, 73.9, 35.9, 25.4, 24.8, 17.4, 14.5; M.S.: 264 ($M^{+\circ}$), 149, 140, 124 (base peak = M^{+} - $PyrSCH_2O$). Further elution (dichloromethane/ether 20/80) gave **[2-(3,4-Dihydro-5-methyl-2H-pyrrol-2-yl)-2-methylethyl]-thioxo-1(2H)-pyridine 12** in 78 % yield, identical with the sample prepared by decomposition of the mixed oxalate (see below).

Methyl α-(pyridine-2-thiyl)-5,γ,γ-trimethyl-3,4-dihydro-2H-pyrrol-2-butanoate 13. This compound was isolated by chromatography on silica gel (eluent: dichloromethane/ether 50/50 to 10/90) in 55% yield; IR (cm^{-1} ; solution in CCl_4): 1740, 1660, 1430, 1170, 1130, 820 ; n.m.r. ^1H: mixture of two diastereoisomers: A/B = 1.5/1: 8.42 (1H, d, J = 4.8 Hz), 7.47 (1H, td, J = 7.6, J'= 1.8 Hz), 7.20 (1H, J = 8.0 Hz), 6.99 (1H, m), 4.73 (1H, dd, J = 4.4, J'= 8.8 Hz), 3.79 (1H, m), 2.48-2.17 (3H, m), 2.00 (3H, s), 1.91-1.56 (3H, m), 1.07 (B) 1.00 (A) (3H, s), 0.96 (A) 0.92 (B) (3H, s); n.m.r.^{13}C: Major product: 174.9, 174.4, 157.4, 149.4, 136.1, 122.2, 119.9, 81.7, 52.4, 42.6, 41.7 39.3, 37.6, 24.0, 23.6, 23.4, 19.7; Minor product: 174.4, 174.1, 157.4, 149.4, 136.1, 122.2, 119.9, 81.7, 51.7, 42.4, 42.0 39.3, 37.6, 24.0, 23.8, 22.8, 19.7.

Trans-2-(Pyridine-2-thiyl)-2,3-dihydro-1H-indene-1-acetonitrile 19. This compound was obtained following silica gel chromatography (eluent: dichloromethane/ether 90/10) in 83 % yield; IR (cm^{-1}): 2230, 1590, 1470, 1430, 1135, 770; n.m.r. ^1H: 8.44 (1H, dd, J = 4.8 Hz, J'= 1.0 Hz), 7.44 (1H, td, J = 7.7 Hz, J'= 1.9 Hz), 7.36-7.15 (5H, m), 6.99 (1H, m), 4.41 (1H, m), 3.63 (1H, dd, J = 16.6, J'= 8.1 Hz), 3.54 (1H, m), 3.02 (1H, dd, J = 16.6, J'= 6.8 Hz), 2.98 (1H, dd, J = 16.8, J'= 4.9 Hz), 2.80 (1H, dd, J = 16.8, J'= 7.2 Hz); n.m.r.^{13}C: 158.4, 149.6, 141.5, 136.1, 128.1, 127.3, 124.9, 124.8, 123.7, 122.5, 120.0, 118.5, 48.6, 47.1, 38.6, 21.6; HRMS: (M - SPy) Calc.: 156.0808. Found: 156.0812; (M - CH_2CN) Calc.: 226.0685. Found: 226.0693.

3ß-(Pyridine-2-thiyl)-bicyclo[2.2.1]heptane-2ß-acetonitrile 28. This compound was obtained following silica gel chromatography (eluent: dichloromethane/ether 90/10) in 71 % yield; n.m.r. ^1H: 7.38 (1H, d, J = 4.8 Hz), 7.45 (1H, td, J = 7.7, J'= 1.8 Hz), 7.13 (1H, d, J = 8.0 Hz), 7.0 Hz (1H, m), 3.96 (1H, m), 2.39 (4H, br. s), 1.56-1.23 (7H, m); n.m.r.^{13}C: 159.3, 149.8, 136.0, 122.1, 120.4, 119.7, 50.5, 44.5, 44.3, 41.8, 34.6, 29.1, 20.2.

1-[Chloro(Pyridine-2-thiyl)methylene]-2,3-dihydro-1H-indene-2-carbonitrile 23. This compound was obtained following silica gel chromatography (eluent: dichloromethane/ether 90/10) in 72 % yield; IR (cm^{-1}; solution in CCl_4): 2270, 1465, 1435, 1130, 920; n.m.r. ^1H: 8.54 (1H, d, J = 4.7 Hz), 8.39 (1H, d, J = 7.7 Hz), 7.66 (1H, td, J = 8.0 Hz, J'= 1.8 Hz), 7.40-7.22 (4H, m), 7.17 (1H, m), 4.38 (1H, dd, J = 8.6 Hz), 3.56 (1H, dd, J = 17.0, J'= 8.6 Hz), 3.41 (1H, dd, J = 17.0 Hz, J'= 2.9 Hz).

Methyl trans-1-cyanomethyl-2,3-dihydro-1H-inden-2-propionate 20. This compound was obtained following silica gel chromatography (eluent: dichloromethane/ether 80/20) in 77 % yield; IR (cm^{-1}): 2260, 1745, 1590, 1470, 1430, 1180, 1130, 770, 745; n.m.r. ^1H: two diasrereoisomers A and B, ratio: 1/1: 8.43 (1H, m), 7.49 (1H, m), 7.33-7.13 (5H, m), 7.01 (1H, m), 5.27 (1H, m), 4.82 (1H, q, J = 7.6 Hz), 3.75 (3.73) (3H, s), 3.40-2.12 (7H, m); n.m.r.^{13}C: A: 172.9, 156.5, 149.4, 142.4, 142.1, 136.3, 127.8, 126.9, 124.9, 123.6, 122.4, 120.2, 118.5, 84.3, 46.6, 44.6, 43.3, 37.5, 36.6, 35.3; B: 172.6, 156.5, 149.4, 142.4, 142.1, 136.3, 127.8, 126.9, 124.9, 123.8, 122.4, 120.2, 118.5, 84.3, 46.7, 44.4, 43.5, 38.9, 37.4, 37.1; M.S.: 352 ($M^{+\circ}$), 321, 312, 196, 164, 155.

Tributylstannane Reduction of 13 and 20: Tributylstannane (0.48 mmol) and AIBN (0.04 mmol) were added to a solution of pyridyl sulphide (0.4 mmol) in dry toluene (6 ml). The reaction mixture was refluxed for 2 hrs. After cooling and removal of the solvent under reduced pressure, the crude reaction mixture was purified by chromatography on silica gel: yields: 91 % for the reduction of **13** into **14**; 88 % for the reduction of **20** into **21**. Both **14** & **21** were identical to samples prepared in the previous study.[1]

Preparation of O-substituted oxime 33a: Sodium hydride (167 mg of a 50 % dispersion in oil, 3.45 mmol) was added to a solution of oxime **31** (500 mg, 3.25 mmol) in anhydrous DMF(10 ml). The reaction mixture was stirred for 3 hrs at 20°C. Phenyl chloromethylsulphide **32a**[10] (477 mg, 3 mmol.) was then added. and the reaction mixture stirred overnight then poured into water (50 ml) and extracted with pentane (2 x 30 ml). The usual work-up gave a residue which was purified by silica gel chromatography (eluent: petroleum ether / dichloromethane: 90/10 to 60/40) and used as such; yield: 71 %; IR (cm^{-1}): 3073, 1639 (C = N), 1480, 1439, 1022 (C-S), 739, 691; n.m.r. ^1H: 7.43-7.50 (2H, m), 7.16-7.32 (3H, m), 5.80 (1H, m), 5.46 (2H, s), 5.03-5.08 (2H, m), 2.71 (1H, m), 2.46 (1H, m), 2.00-2.41 (3H, m), 1.36-1.90 (6H, m); n.m.r. ^{13}C: Secondary: 23.7, 24.8, 26.2, 32.3, 35.4, 78.2, 116.1; tertiary: 41.9, 126.6 (2C), 128.8 (2C), 130.3, 137.0; quaternary: 136.3, 164.1.

Preparation of O-substituted oxime 33b: This compound was prepared in the same way from oxime **31** and 2-(chloromethylthio)benzothiazole **32b**.[11] The crude product was used in the radical cyclisation without further purification. n.m.r. ^{1}H: 8.0-7.0 (4H, m), 6.0-5.6 (1H, m), 5.35 (2H, s), 5.2-4.9 (2H, m), 2.7-1.2 (11H, m)

Preparation of O-substituted oxime 33c: Sodium hydride (306 mg of a 50 % dispersion in oil, 6.34 mmol) was added to a solution of oxime **31** (900 mg, 5.87 mmol) in anhydrous DMF (5 ml). The reaction mixture was stirred for at 20°C until the sodium hydride disappeared (ca 3 hrs). Phenyl chloromethylselenide **32c**[7,12] (820 ml, 5.92 mmol) was added with the aid of a syringe. After 3 hrs, the reaction mixture was poured into water (50 ml) and extracted with pentane (2 x 30 ml). The usual work-up gave a residue which was purified by silica gel chromatography (eluent: petroleum ether / dichloromethane: 90/10 to 60/40) and the product used as such in the radical cyclisation; yield: 32 %; IR (cm^{-1}): 3071, 1640 , 1478, 1438, 1032, 910, 737, 691; n.m.r. ^{1}H: 7.58-7.62 (2H, m), 7.23-7.26 (3H, m), 5.80 (1H, m), 5.72 (2H, s), 4.97-5.05 (2H, m), 2.71 (1H, m), 2.46 (1H, m), 2.00-2.37 (3H, m), 1.36-1.92 (6H, m); n.m.r. ^{13}C: Secondary: 23.7, 24.7, 26.0, 32.2, 35.1, 73.8, 115.8; tertiary: 41.7, 126.7, 128.6 (2C), 132.8 (2C), 136.7; quaternary: 131.5, 163.7.

Radical Cyclisations of 33a, b and c. The oxime (1.0 mmol.) and AIBN (0.1 mmol.) were dissolved in deoxygenated cyclohexane (10 ml). The reaction mixture was heated to reflux and a solution of tributylstannane (280 ml, 1.2 mmol.) in cyclohexane (10 ml) was added dropwise over 4 hrs. The reaction mixture was cooled and concentrated under reduced pressure. The residue thus obtained was chromatographed on silica gel (eluent: petroleum ether to ether/methanol: 90/10) affording **34** (0 % from **33a**; 30 % from **33b** ; 67 % from **33c**).

Photolytic Decomposition of Mixed Oxalate 36: A solution of oxime **31** (600 mg, 3.92 mmol) in dry ether (4 ml) was added dropwise under stirring to a cold (-50°C) solution of oxalyl chloride (0.68 ml, 7.84 mmol) in anhydrous ether (1 ml). Stirring was continued for 3 hrs while temperature was allowed to rise to - 10 °C. The ether and excess oxalyl chloride were removed by distillation under reduced pressure. The crude residue was dissolved in dichloromethane (10 ml), cooled to -10°C, and protected from light. N-Hydroxypyridine-2-thione as the sodium salt (1.17 g, 7.84 mmol) was then added and stirring was maintained for 1 hour. The flask was then exposed to a 500 W tunsten lamp for 1 hour at room temperature. Evaporation of the solvent and purification over silica gel (eluent: dichloromethane / ether: 100/0 to 10/90) afforded **37** in 55% yield; IR (cm^{-1}): 160, 1600, 1470, 1430, 1130, 800, 775; n.m.r. ^{1}H: 8.49 (1H, dd, J = 4.7, J'= 1.3 Hz), 7.51 (1H, td, J = 7.7, J'= 1.9 Hz), 7.39 (1H, d, J = 8.0 Hz), 7.07 (1H, m), 4.42 (1H, m), 2.60-2.42 (2H, m), 2.04 (3H, d, J = 1.7 Hz), 2.08-1.91 (2H, m), 1.58 (3H, s), 1.41 (3H, s); n.m.r.^{13}C: 175.5, 157.6, 149.4, 135.9, 127.9, 120.9, 80.9, 54.2, 39.4, 26.6, 24.9, 24.6, 19.8; M.S.: 234 (M+), 220, 152, 124 (base), 112; H.R.M.S.: (M - S Pyr) Calc. = 124.1126. Found: 124.1123; (Pyr S-CMe_2) Calc. = 152.0534 Found: 152.0530.

References and Notes.

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