

## Tin(IV) Chloride-promoted Reactivity of $\beta$ -Dicarbonyls with Non-electrophilically Activated Nitriles: Role of the Metal Centre

B. CORAIN, B. LONGATO, M. BASATO, R. ANGELETTI

Centro di Studio sulla Stabilità e Reattività dei Composti di Coordinazione, C.N.R., Dipartimento di Chimica Inorganica Metallorganica ed Analitica, Via Marzolo 1, 35100 Padova, Italy

and A. C. VERONESE

Laboratorio di Chimica Organica, Facoltà di Farmacia, Via Scandiana 21, 44100 Ferrara, Italy

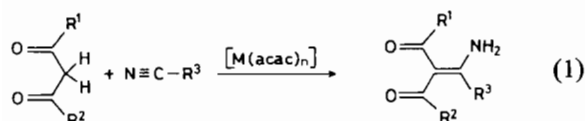
(Received December 6, 1985; revised March 4, 1986)

### Abstract

$\text{SnCl}_4$  promotes the addition reaction of ethylacetoacetate to propionitrile, under stoichiometric conditions, to give 3-ethoxycarbonyl-4-amino-3-hexen-2-one (**9**), which can be isolated as the adduct [**9**· $\text{SnCl}_4$ ] (**1**). The product is probably a polymer in which the  $\beta$ -enaminodione is bound to two  $\text{SnCl}_4$  entities through the amino and the ester groups, and it undergoes extensive dissociation in dimethylsulfoxide. Compound **9** can be easily obtained by mild base hydrolysis of **1**; addition of **9** to  $\text{SnCl}_4$ , in the molar ratio 1:1, in toluene affords **1** as the only product. This metal-promoted carbon–carbon bond forming reaction is discussed with reference to a metal-catalysed analogous synthesis of  $\beta$ -enaminodiones involving electrophilically activated nitriles.

### Introduction

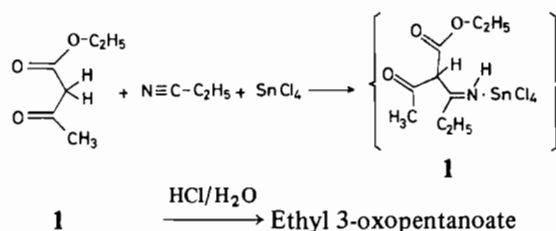
In the course of our investigation on the metal-catalysed addition reactions of  $\beta$ -dicarbonyls to the  $\text{C}\equiv\text{N}$  bond of nitriles, we have found that a variety of multifunctional olefins (potentially useful synthones in organic synthesis) can be prepared under mild conditions in the presence of catalytic amounts



of  $[\text{M}(\text{acac})_n]$  complexes in aprotic solvents (eqn. 1)) [1]. However, for non-electrophilically activated nitriles, when  $\text{R}^3$  = alkyl or aryl group, our catalyst was ineffective, so far, for synthesizing the relevant  $\beta$ -enaminodiones.

It is known since 1967 from the Japanese patent literature [2] that  $\text{SnCl}_4$  promotes under stoichio-

metric conditions the addition of diethylmalonate to various non-electrophilically activated aliphatic and aromatic nitriles to give alleged 'imino' derivatives, proposed to contain the  $\text{SnCl}_4$  moiety chemically bound to an adduct of diethylmalonate with the relevant nitrile. Moreover, in 1978 these 'imino' derivatives turned out to be useful intermediates in a convenient synthetic route to ethyl-3-oxopentanoate (Scheme 1) and to 3,5-disubstituted 1,2-oxazole-4-carboxylic acids [3].



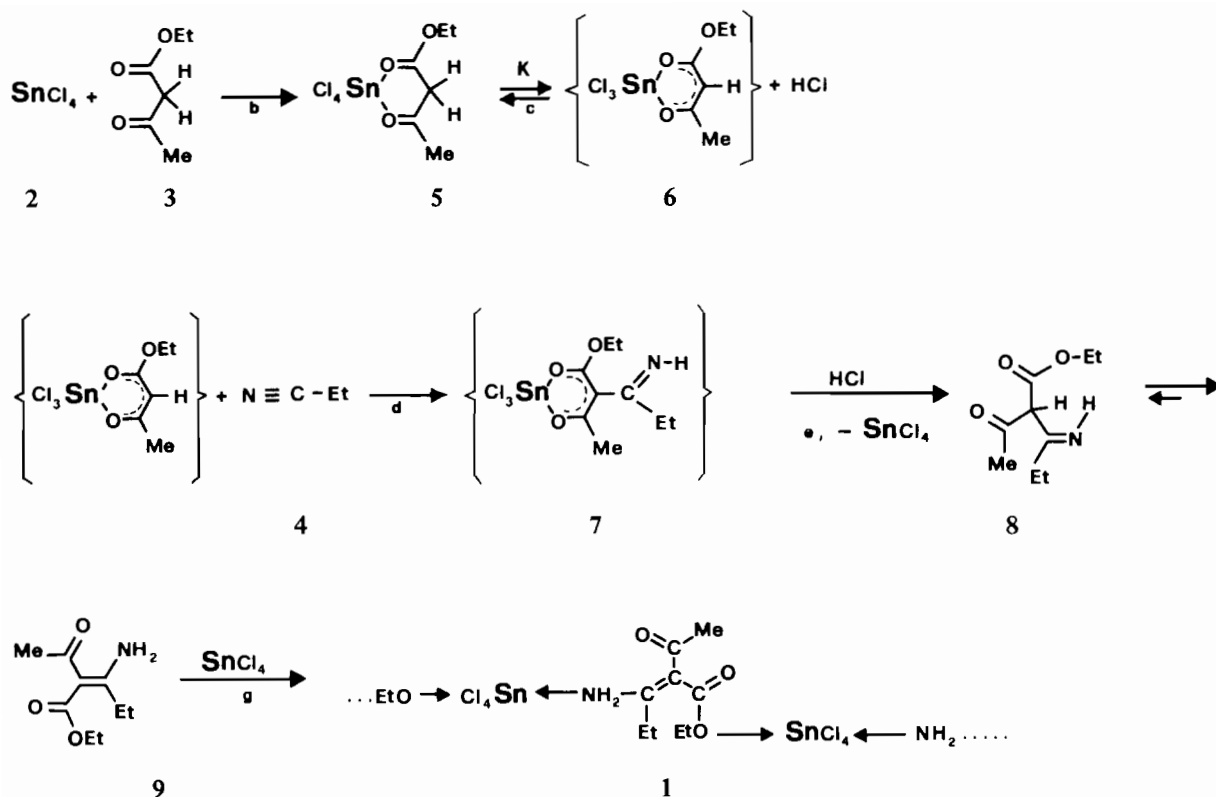
Scheme 1.

These results appeared interesting to us as (i) this metal-promoted carbon–carbon bond forming reaction was apparently successful with alkyl and aryl nitriles and (ii) the structure of the organic moiety in the tin(IV) adducts appeared in striking contrast with that of all free analogous  $\beta$ -enaminodiones synthesized by us and fully characterized in the solid state [1b, 4] and in solution [1a, 1c].

On the basis of these considerations we focused our attention on the reaction pattern exhibited by ethylacetoacetate (Heaa), propionitrile, and  $\text{SnCl}_4$  with the aim (i) to clarify the nature of compound **1** and (ii) to obtain the organic addition compound as a free pure species.

### Results and Discussion

Compound **1** could be prepared according to ref. 3 and was characterized by elemental analysis, infrared



Scheme 2.

spectroscopy, <sup>1</sup>H NMR and <sup>13</sup>C NMR in (CD<sub>3</sub>)<sub>2</sub>SO at variable temperature and by mass spectrometry.

Addition of SnCl<sub>4</sub> (2) to a toluene solution of ethylacetoacetate (3) and propionitrile (4) (molar ratio 1:1:1) at room temperature generates a white compound, which can also be prepared by adding 2 to 3 in toluene at 0 °C or at room temperature in the absence of 4. This species can reasonably be proposed to be the 1:1 adduct 5 (see Scheme 2) in which ethylacetoacetate binds SnCl<sub>4</sub> by acting as a β-diketone ligand, as was observed for the analogous adduct of SnCl<sub>4</sub> with 3,3-dimethylacetylacetone, 3-methylacetylacetone and acetylacetone [5].

The nature of 5 is supported by its IR spectrum in the solid state [5] (broad and composite ν<sub>C=O</sub> band at 1660 cm<sup>-1</sup> as compared with the corresponding band of free Hea centred at 1725 cm<sup>-1</sup>), and by <sup>1</sup>H NMR and <sup>13</sup>C NMR data in (CD<sub>3</sub>)<sub>2</sub>SO, which respectively show that 3 undergoes coordination to tin(IV) as a β-diketone in the solid state and it is quantitatively released in (CD<sub>3</sub>)<sub>2</sub>SO solution.

Upon heating the toluene suspension of 5 in the presence of 4 at 80 °C for 4 h, compound 1 was obtained as a white microcrystalline material. Compound 1 is proposed to be a relatively unstable adduct of SnCl<sub>4</sub> with the functionalized ligand 9

(see Scheme 2) as shown (i) by the ready formation of 1 from SnCl<sub>4</sub> and 9 in toluene, (ii) by the infrared spectrum of 1, which shows the presence of the SnCl<sub>4</sub> moiety and of Sn<sup>IV</sup>-coordinated 9, (iii) by the complete dissociation of 1 into SnCl<sub>4</sub> and 9 in (CD<sub>3</sub>)<sub>2</sub>SO (see Table I), (iv) by the easy removal of 9 under mild hydrolytic basic conditions (see 'Experimental'), (v) by the almost complete thermal dissociation of 1 into free 9 under mild mass spectrometric conditions.

The infrared spectrum of both 1 and 9 are reported in Fig. 1. It is seen that, apart from significant differences in the regions 3500–3000 and 1200–1000 cm<sup>-1</sup>, both spectra are very similar, particularly in the ν<sub>C=O</sub> bands range. The spectrum of 9 agrees with those of similar β-enaminodiones prepared by us [1] and is consistent with the structure depicted in Scheme 2.

The infrared data of 1 reveal that the metal coordination of 1 has to occur through the –NH<sub>2</sub> and the –O–Et coordination sites. In fact, the doublet at 3390 and 3190 cm<sup>-1</sup> present in the spectrum of 9 is shifted to 3290 and 3155 cm<sup>-1</sup> and the ν<sub>C–O</sub> at 1140 cm<sup>-1</sup> disappears in the spectrum of 1. Furthermore, the lack of any appreciable change in the position of the ν<sub>C=O</sub> bands

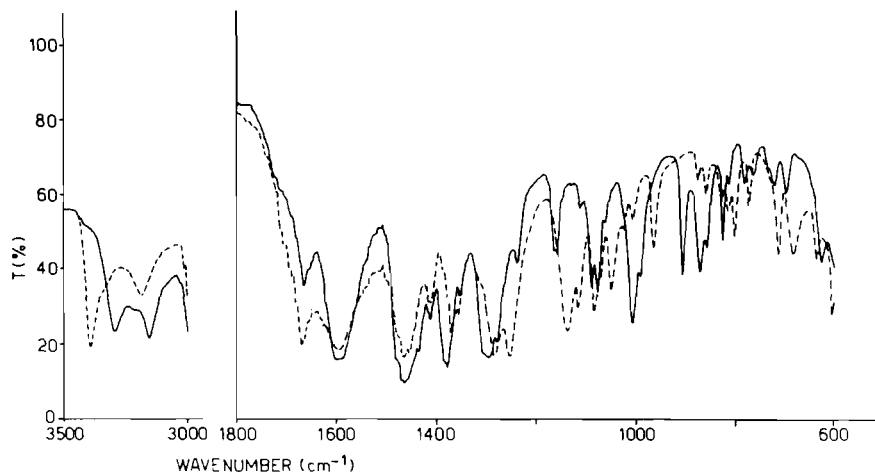


Fig. 1. IR spectra (nujol mull) of compounds 1 (—) and 9 (---).

of **9** upon metal coordination rules out the involvement of these two coordination sites, which have been proposed in the structure of **5**.

The spectrum of **1** exhibits a composite band in the region  $350\text{--}300\text{ cm}^{-1}$  with peaks at 340, 325,  $310\text{ cm}^{-1}$ , corresponding to those observed for octahedral  $[\text{SnCl}_4\text{L}_2]$  complexes [6]. Thus, the whole of the infrared data in the solid state suggests that the structure of **1** is a distorted octahedron in which four  $\text{Cl}^-$ , one  $-\text{NH}_2$ , and one  $-\text{O}-\text{Et}$  'ligands' (*vide infra*) are connected to  $\text{Sn}^{\text{IV}}$ . The very weak solubility of **1** in any solvent but DMSO suggests that the hexacoordination in **1** is achieved in a polymeric structure in which each  $\text{Sn}^{\text{IV}}$  ion sees the  $-\text{NH}_2$  and the  $-\text{O}-\text{Et}$  coordination sites, which belong to two different bridging molecules of **9** (Scheme 2). This structure differs substantially from that proposed in ref. 3, in that it implies coordination of **9** in its amidic form.

Polymeric chains in which  $\text{Sn}^{\text{IV}}$  metal centres are preferentially coordinated to amino rather than to carbonyl groups are not unprecedented [7]. Thus, this coordination mode has been proved in trimethylglucinate [7a] and postulated in the adduct between  $\text{MeSnCl}_3$  and bis(acetylaceton)ethylenediimine [7b]. Moreover, the proposal of the three-coordinated bonding mode of the ester ethoxy oxygen is supported by the known coordination to tin(IV) of ether [8a] and bridging alkoxy oxygen atoms [8b].

The solution behaviour of adduct **1** has been studied by the NMR technique. The complete  $^1\text{H}$  and  $^{13}\text{C}$  NMR data for **1** are listed in Table I. The reported data are consistent with extensive dissociation into  $\text{SnCl}_4$  and **9** occurring in  $(\text{CD}_3)_2\text{SO}$ . The  $^1\text{H}$  and  $^{13}\text{C}$  spectra are identical to that of pure **9** and clearly indicate that **9** maintains in solution the  $\beta$ -enaminodione structure observed in the solid state. In the range  $20\text{--}100^\circ\text{C}$  the amine hydrogen peaks broaden to

TABLE I.  $^1\text{H}$  and  $^{13}\text{C}$  NMR Data for Compound **1** in  $(\text{CD}_3)_2\text{SO}$

Nucleus	$\delta$ (ppm) (attribution)
$^1\text{H}$	10.63 and 8.52 (broad singlet, $\text{NH}_2$ ); 4.12 (quartet, $J = 7\text{ Hz}$ , $\text{CH}_3\text{--CH}_2\text{--O}$ ); 2.39 (quartet, $J = 7\text{ Hz}$ , $\text{CH}_3\text{--CH}_2\text{--C=}$ ); 1.23 (triplet, $J = 7\text{ Hz}$ , $\text{CH}_3\text{--CH}_2\text{--O}$ ); 1.10 (triplet, $J = 7\text{ Hz}$ , $\text{CH}_3\text{--CH}_2\text{--C=}$ ); 2.10 (singlet, $\text{CH}_3\text{--C(O)}$ ).
$^{13}\text{C}\{^1\text{H}\}$	13.17 ( $\text{CH}_3\text{--CH}_2\text{--C=}$ ); 13.95 ( $\text{CH}_3\text{--CH}_2\text{--O}$ ); 27.5 ( $\text{CH}_3\text{--C(O)}$ ); 29.55 ( $\text{CH}_3\text{--CH}_2\text{--C=}$ ); 59.37 ( $\text{CH}_3\text{--CH}_2\text{--O}$ ); 101.0 ( $=\text{C}(\text{CO})_2$ ); 169.0 ( $\text{C(O)O-Et}$ ); 171.6 ( $=\text{C}(\text{NH}_2)\text{Et}$ ); 194.8 ( $\text{C(O)CH}_3$ ).

give a single broad resonance centred at  $\delta$  ca. 9.2, at  $100^\circ\text{C}$ . This pattern is reversible with temperature.

We propose that complex **1** is formed along a fairly complex sequence of ensuing steps (Scheme 2). Step *b* represents the formation of the preliminary adduct **5**, which is proposed to coexist in equilibrium with complex **6**, whose structure is analogous to that found in the adduct formed in the reaction between  $\text{SnCl}_4$  and 3-cyanopentane-2,4-dione [9]. Step *c* is seen as an equilibrium which must occur when tin(IV)- $\beta$ -carbonylenolate complexes are formed from  $\text{SnCl}_4$  and  $\beta$ -dicarbonyls at higher temperatures. It is supported by the ascertained evolution of HCl when **2** is reacted with **3** in the absence of **4** in toluene at  $80^\circ\text{C}$  under a nitrogen stream. Under these last conditions, the known complex *cis*- $[\text{SnCl}_2(\text{eaa})_2]$  [10] can be obtained in substantial yields regardless of the molar ratios of the reactants. In the conditions suitable to drive steps *b*–*g* to give **1**, compound **6** should react with **4** to give **7**. Step *d* represents the attack of the nucleophilically activated  $\beta$ -dicarbonyl to **4**, thus leading to the required

functionalization of the  $\beta$ -carbonylenolate skeleton [1a-c], which is the key step of the title reaction. In this connection, both **6** and **7** may be present in solution at low, but nevertheless sufficient, concentrations to make possible the regeneration of  $\text{SnCl}_4$  and the release of the organic adduct **8** upon attack of HCl to **7**. In fact, the molecular structure of the above-mentioned adduct is expected to be **9**, as can be predicted on the basis of the extensive investigation on closely related compounds carried out in these laboratories and as is demonstrated by the thorough NMR analysis presently reported (Table I).

An alternative mechanism involving external attack by free  $\beta$ -dicarbonyls to the nitrile activated via  $\text{Sn}^{\text{IV}}$  coordination is possible, and it has been proposed in the rather similar  $\text{SnCl}_4$  promoted addition of organic acids to nitriles [11]. However, in view of the recognized ligand ability of  $\beta$ -dicarbonyls towards  $\text{SnCl}_4$ , this hypothesis presently seems less likely.

In any case, the data reported here show that the title reaction can be an easy way of access to  $\text{SnCl}_4$ - $\beta$ -enaminodione adducts, which can be readily decomposed to tin(IV) compounds and free  $\beta$ -enaminodione. Work is in progress to exploit the potential synthetic utility of these reactions both in stoichiometric and catalytic metal-promoted syntheses.

## Experimental

Toluene and n-hexane were purified and dried by standard methods.  $\text{SnCl}_4$ , propionitrile, and ethylacetoacetate were reagent grade chemicals.  $(\text{CD}_3)_2\text{SO}$  was dried over molecular sieves. The synthetic work and all manipulations of the products were performed on a vacuum-line using standard Schlenk-tube techniques. NMR spectra were recorded on a Jeol FX 90Q spectrometer, with the residual solvent resonance peak as an internal reference. IR spectra were recorded on a Perkin-Elmer 599B spectrophotometer.

### Synthesis of Compound 1

Compound **1** was prepared as described in ref. 3 by using toluene rather than benzene. *Anal.* Calc. for  $\text{C}_9\text{H}_{15}\text{NO}_3\text{SnCl}_4$ : C, 24.25; H, 3.39; N, 3.28. Found: C, 23.10; H, 3.28; N, 3.05%. The  $^1\text{H}$  NMR spectrum in  $(\text{CD}_3)_2\text{SO}$  was found to be very close to that reported in ref. 3, but a broad peak at 10.63 (see Table I) having the same integration ratio as that at 8.25 was also detected. By carrying out the synthesis of **1** under continuous stirring with a stream of nitrogen (to remove HCl), a white material still containing a significant amount of **1** was obtained, as shown by  $^{13}\text{C}$  and  $^1\text{H}$  NMR spectra (Found: C, 20.59; H, 3.51; N, 1.36%).

### Synthesis of 5

Compound **5** was not obtained in an analytically pure form. To a toluene solution of  $\text{SnCl}_4$  (6.8 mmol in 13 ml) ethylacetoacetate (7.0 mmol) was slowly added (15 min) under vigorous stirring. A white precipitate appeared immediately, which was stirred for further 20 min and then filtered off and washed with n-hexane. *Anal.* Calc. for  $\text{C}_6\text{H}_{10}\text{O}_3\text{SnCl}_4$ : C, 18.45; H, 2.58. Found: C, 17.85; H, 3.21%. Infrared spectrum (nujol mull, significant bands): 1670vs,br, 1595s,br, 400m, 350s,br, 305m, 230m  $\text{cm}^{-1}$ . The  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectra in  $(\text{CD}_3)_2\text{SO}$  are identical to that of free Heaa;  $^1\text{H}$ :  $\delta$  4.10 (quartet,  $J$  7 Hz,  $\text{CH}_3\text{CH}_2\text{O}$ ); 3.57 (s,  $\text{CH}_2$ ); 2.18 (s,  $\text{CH}_3\text{C}(\text{O})$ ); 1.19 (triplet,  $J$  7 Hz,  $\text{CH}_3\text{CH}_2\text{O}$ ).  $^{13}\text{C}$ :  $\delta$  201.2 ( $\text{CH}_3\text{-C}(\text{O})$ ); 167.1 ( $\text{C}(\text{O})\text{OEt}$ ); 60.4 ( $\text{CH}_2$ ); 49.5 ( $\text{CH}_3\text{-CH}_2\text{O}$ ); 29.7 ( $\text{CH}_3\text{C}(\text{O})$ ); 13.7 ( $\text{CH}_3\text{CH}_2\text{O}$ ).

### Attempts to Prepare 6

$\text{SnCl}_4$  and ethylacetoacetate were mixed in toluene in the same conditions used for preparing **5**, but the white suspension so obtained was heated at 80 °C for 4 h under a vigorous stream of nitrogen. The white solid still present was found to be unreacted **5** (50%), and from the mother solution the known complex  $[\text{SnCl}_2(\text{eaa})_2]$  and not  $[\text{SnCl}_3(\text{eaa})]$  could be precipitated after addition of n-hexane (20 ml) (yield = 10%). Quite analogous results were also obtained using an initial 2:1 ratio of Heaa to  $\text{SnCl}_4$  (under this condition the yield of  $[\text{SnCl}_2(\text{eaa})_2]$  was 35%).

### Preparation of 9 from 1

Compound **1** (10 mmol) was dissolved in  $\text{CHCl}_3$  (20 ml) and the solution was stirred for 3 h with a  $\text{K}_2\text{CO}_3$  saturated water solution (20 ml). The organic phase was dried over  $\text{Na}_2\text{SO}_4$  and, after solvent removal, **9** was obtained as colorless crystals (melting point (m.p.) 38–40 °C; yield = 75%). *Anal.* Calc. for  $\text{C}_9\text{H}_{15}\text{NO}_3$ : C, 58.43; H, 8.10; N, 7.56. Found: C, 58.86; H, 8.71; N, 7.57%. MS\* [12]  $m/e$  (relative intensities (%)): 185(60) ( $\text{M}^+$ ), 170(50), 156(20), 148(55), 139(25), 124(20), 111(100), 98(70), 96(25), 69(35), 56(35), 43(70), 41(25), 28(45).

### Preparation of 1 from 9 and $\text{SnCl}_4$

Compound **9** (2.83 mmol) was dissolved in toluene (15 ml) under stirring. After addition of  $\text{SnCl}_4$  (2.83 mmol) to this solution, a white precipitate was immediately observed. The white suspension was left under stirring and filtered off after 4 h. Compound **1** was washed with toluene ( $2 \times 25$  ml) and dried under vacuum (m.p. 161–3 °C; yield ca. 100%). *Anal.* Found: C, 23.19; H, 3.33; N, 3.00%. The MS was almost identical to that of **9**.

\*DEI technique.

### Acknowledgements

This work was partially supported by C.N.R., Progetto Finalizzato Chimica Fine e Secondaria. We thank Mr. A. Ravazzolo for skilled technical assistance.

### References

- 1 (a) M. Basato, B. Corain, A. C. Veronese, F. D'Angeli, G. Valle and G. Zanotti, *J. Org. Chem.*, **49**, 4696 (1984) and refs. therein; (b) M. Basato, B. Corain, M. Cofler, A. C. Veronese and G. Zanotti, *J. Chem. Soc., Chem. Commun.*, 1593 (1984); (c) M. Basato, R. Camprostrini, B. Corain, B. Longato, S. Sitran and A. C. Veronese, *J. Chem. Soc., Perkin Trans. 2*, 2019 (1985).
- 2 (a) *Jpn. Patent 17170* (1968) to Y. Isowa, Toyo Koatsu Industries; *Chem. Abstr.*, **70**, 57173 (1969); (b) *U.S. Patent 3441579* (1969) to Y. Isowa, Toyo Koatsu Industries; *Chem. Abstr.*, **67**, 43561 (1967).
- 3 B. Singh and G. Y. Leshner, *Synthesis*, 829 (1978).
- 4 B. Corain, M. Basato, E. Mori and G. Valle, *Inorg. Chim. Acta*, **76**, L277 (1983).
- 5 A. L. Allred and D. W. Thompson, *Inorg. Chem.*, **7**, 1196 (1968).
- 6 D. M. Adams, 'Metal-Ligand and Related Vibrations', Arnold, London, 1967.
- 7 (a) B. Y. K. Ho, K. C. Molloy, J. J. Zuckerman, F. Reidinger and J. A. Zubieta, *J. Organomet. Chem.*, **187**, 213 (1980); (b) R. Barbieri, R. Cefalu', S. C. Chandra and R. H. Herber, *J. Organomet. Chem.*, **32**, 97 (1971).
- 8 (a) J. L. Janier-Dubry and C. Devin, *J. Inorg. Nucl. Chem.*, **38**, 1739 (1976); (b) D. C. Bradley, R. C. Mehrotra and D. P. Gaur, 'Metal Alkoxides', Academic Press, London, 1978.
- 9 D. W. Thompson, P. B. Barrett, J. F. Lefelhocz and G. A. Lock, *J. Coord. Chem.*, **3**, 119 (1973).
- 10 J. Angenault, C. Mondi and A. Rimsky, *Inorg. Chim. Acta*, **37**, 145 (1979).
- 11 R. A. Slavinskaya, T. N. Sumarokova, M. Nurakhynova and N. A. Dolgova, *J. Gen. Chem. USSR*, **50**, 332 (1980).
- 12 P. Traldi, U. Vettori and F. Dragoni, *Org. Mass Spectrom.*, **17**, 581 (1982).