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One-pot synthesis of transition metal-substituted carboxylic acids

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Abstract

Transition metal-substituted carboxylic acids, MRCOOH ($R = CH_2$, CH_2CH_2), are prepared by the reactions of metal anions with trimethylsilyl halocarboxylates, XRCOOSiMe₃, followed by treatment with silica gel. The carboxylic acid moiety is readily transformed into various acyl derivatives MRCONu such as esters and amides via an acyl chloride intermediate, MRCOCl.

Of the transition metal-substituted carboxylic acid derivatives MRCONu, metal enolates (1) (R = CH₂) have attracted much attention, because they can undergo condensations not only with polar substrates such as aldehydes and ketones but also with less polar substrates such as acetylenes and olefins [1]. The compounds 1 have been prepared by the usual alkylation of metal anions with chloroacetic acid derivatives ClCH₂CONu (Nu = OR, NR₂ etc.) by route I. Recently, we [2] and Bergman's group [1a] have shown independently that the parent carboxylic acid MCH₂COOH (2) serves as a useful precursor for various η^1 -(C)-enolato complexes MCH₂CONu (1) via the acyl chloride intermediate (3) (Scheme 1). However, 2 has been hitherto prepared by acidic hydrolysis of 1 (route I) [1a,3]. Here we describe the direct, one-pot synthesis of a variety of transition metal-substituted carboxylic acids including 2 (route II).

Results and discussion

The reaction of NaFp [Fp = $(\eta^5 - C_5H_5)$ Fe(CO)₂] with trimethylsilyl chloroacetate (4), which was readily prepared by condensation of chlorotrimethylsilane with cloroacetic acid, gave a deep yellow oil. ¹H NMR spectroscopy revealed that the only product was FpCH₂COOSiMe₃ (5a) [δ (CDCl₃) 0.30 (SiMe₃), 1.48 (CH₂), 4.41 (Cp)]. Deprotection of the silyl group was readily accomplished during separation by column chromatography on silica gel to give an iron-substituted acetic acid, FpCH₂COOH (2a), in 70% yield. The action of the bromoacetic acid ester in place



Scheme 1

of 4 gave Fp_2 as a main product (> 90%) perhaps via free radical intermediates [1,4]. Similarly, four examples of carboxylic acids 2b-2e were successfully prepared in good to moderate yields *. These procedures are favourable in that acidic treatment for deprotection of the ester group is avoided, because in the conventional method (route I) 1 or 2 often decomposes by protonation of the M-C bond. For instance, when the preparation of 2a-2c was attempted by acidic hydrolysis (refluxing in aq. 4 *M* HCl) of the corresponding amides $(\eta^5-C_5R_5)Fe(CO)_2CH_2$ -CONH₂ [3], 2a was obtained in good yield but only tarry products were obtained for the other amides. Suitable conditions should be sought for successful preparation of 2b,2c by conventional procedures **.

The carboxylic acids obtained (2a-2e) were successively transformed into various acyl derivatives 1 via an acyl chloride intermediate (3) (Scheme 1) [1,2b]. Treatment of a suspension of 2a-2e in aprotic solvents such CH_2Cl_2 , THF or ether with oxalyl chloride gave homogeneous yellow to orange solutions of 3a-3e. Although only 3awas isolated and fully characterized [2b], the presence of 3b-e was confirmed by reaction with methanol, which gave the corresponding methyl esters (6) as sole products in high yields (eq. 1). Reactions with other nucleophiles produce a variety of acyl derivatives. As a typical example, 3a was converted $MCH_2COOH \xrightarrow{(COCl)_2} MCH_2COCI \xrightarrow{MeOH}_{Et_3N} MCH_2COOMe$ (1) (2) (3) (6) (75-96% yield)

 ^{*} Reaction with Li[η⁵-C₅Me₅)Mo(CO)₃] gave (η⁵-C₅Me₅)Mo(CO)₃Cl in 21% yield. P. Leoni, E. Grilli, M. Pasquani and M. Tomassini, J. Chem. Soc., Dalton Trans., (1986) 1041.

^{** 2}b was obtained in 56% yield by careful hydrolysis, by dissolution of the amide in hot aq. 2 M HCl.

into the corresponding amide or the diiron μ -ketene complex [2b], by reaction with NH₃ or Fp⁻, respectively (eq. 2.)

$$\begin{array}{ccc} FpCH_2COOH \xrightarrow{(COCl)_2} & FpCH_2COCl \xrightarrow{Nu^-} & FpCH_2CONu & (2) \\ (2a) & (3a) & (6a) \\ & & (Nu = OMe, NH_2, Fp, OH.) \end{array}$$

As reported previously [2b], $FpCH_2CH_2COOH$ (7) containing one more methylene group could also be prepared by essentially the same procedures, except for the use of bromocarboxylate as an alkylating reagent. In addition, 7 was also successively converted into the methyl ester and $FpCH_2CH_2COFp$ [2b] via $FpCH_2CH_2COCI$.

The preparative methods described here can be used to synthesize a wide range of transition metal-substituted carboxylic acid derivatives as shown in eqs. 3 and 4.

$$M^{-} + XRCOOSiMe_{3} \rightarrow [MRCOOSiMe_{3}] \xrightarrow{Silica gel} MRCOOH$$
(3)

....

X = Cl for R stabilizing radical intermediates $\cdot RCOOSiMe_3$ X = Br or I for others

$$MRCOOH + (COCl)_2 \rightarrow [MRCOCl] \xrightarrow{Nu^{-}} MRCONu$$
(4)

Experimental

All the manipulations were carried out under standard Schlenk techniques. ¹H NMR and IR facilities have been described previously [2b]. THF and ether were dried over Na-K alloy, then distilled and stored under argon. Column chromatography was carried out on silica gel (Merck Art. 7734). Metal anions were generated by published procedures [5].

Preparation of trimethylsilyl chloroacetate (4)

A solution of chloroacetic acid (20 g, 0.21 mol) in ether (50 ml) was added dropwise to an ethereal solution (50 ml) of chlorotrimethylsilane (24 g, 0.22 mol) and triethylamine (23 g, 0.23 mol) at 0 °C. After the mixture had been refluxed for 1 h in a water bath, the resulting white precipitates were removed by filtration with the aid of Celite and washed with pentane (30 ml \times 3). Concentration of the extract followed by distillation at reduced pressure (68 °C/22 Torr) gave 4 as a colorless liquid (23 g, 0.14 mol, 67% yield). ¹H NMR (CDCl₃) δ 0.30 (SiMe₃), 3.99 (CH₂). 4 was readily hydrolyzed by exposure to moisture.

Preparation of carboxylic acids (2)

A solution of metal anion M^- (20 mmol) in THF (30 ml) was added dropwise to a solution of 4 (4.17 g, 25 mmol) in 10 ml of THF at -78° C.

After the reaction mixture had been stirred at the same temperature for 1 h and at ambient temperature for 3 h, the solvent was removed under reduced pressure. The product was extracted with ether and the insoluble inorganic salts were separated by filtration through a Celite pad. Then a quantity of silica gel was added to the filtrate and it was evaporated to dryness. The residue was placed in a silica gel column made up in hexane. The dimetallic complex M-M was eluted first with hexane- $CH_2Cl_2 = 5-3:1$. Elution with polar solvent (acetone for **2a**, **2b**, **2d**; CH_2Cl_2 for **2c**, **2e**) gave a yellow to orange band, from which **2** was isolated as yellow to orange microcrystals after recrystallization.

The structures of **2a**, **2b**, **2d**, **2e** were determined by comparison of spectral data with those of authentic samples reported by Green [3]. **2c**: yellow microcrystals. ¹H NMR (CDCl₃) δ 1.14 (C₅Me₅), 1.75 (CH₂). IR (KBr) ν (O–H) 2800–2200, ν (C=O) 1993, 1938, ν (C=O) 1648, ν (C–O) 1281 cm⁻¹. Found: C, 53.62; H, 6.08. C₁₄H₁₈O₄Fe calcd.: C, 53.19; H, 5.93%.

Reactions of 2a-2e with nucleophiles

Oxalyl chloride (1.52 g, 12 mmol) was added dropwise to a solution or suspension (10 ml) of the carboxylic acid (2) (10 mmol) in THF (10 ml). After cessation of the vigorous gas evolution, the mixture was cooled at -78° C, and MeOH (2 ml) and Et₃N (2 ml) were simultaneously added dropwise to the solution, which was then stirred at room temperature for 1 h. Evaporation of the volatiles, extraction with ether and filtration through an alumina plug followed by recrystallization from ether-hexane yielded the methyl ester as yellow [6a (84%), 6b (83%), 6c (96%), 6d (75%)] or white crystals [6e (79%)].

The structures were confirmed by comparison of spectral data with those of authentic samples. **6c**: yellow crystals. ¹H NMR (C_6D_6) δ 1.33 (C_5Me_5), 1.39 (CH₂), 3.60 (OMe). IR (CH₂Cl₂) ν (C=O) 1996, 1947, ν (C=O) 1677 cm⁻¹. Found: C, 56.58; H, 6.42. C₁₅H₂₀O₃Fe calcd.: C, 56.27; H, 6.30%.

Reactions of **2a** with NH₃ [3] and **7** with MeOH were carried out in the manner as described above. If an excess amount of nucleophile is not available, the excess oxalyl chloride and the dissolved HCl should be removed in vacuo before nucleophile is added. FpCH₂CH₂COOMe: yellow crystals. ¹H NMR (CDCl₃) δ 1.40–1.77 (Fp-CH₂), 2.21–2.61 (CH₂COOMe), 3.62 (OMe), 4.69 (C₅H₅). Found: C, 50.62; H, 5.06. C₁₁H₁₂O₄Fe calcd.: C, 50.03; H, 4.58%.

The preparation of 7 and the diiron complexes bridged by μ -CH₂CO and μ -CH₂CH₂CO ligands was published previously [2b].

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References

- (a) E.R. Burkhardt, J.J. Doney, R.G. Bergman and C.H. Heathcock, J. Am. Chem. Soc., 109 (1987) 2022. (b) E.R. Burkhardt, J.J. Doney, J.G. Stack, C.H. Heathcock and R.G. Bergman, J. Mol. Cat., 41 (1987) 41.
- 2 (a) M. Akita, A. Kondoh and Y. Moro-oka, J. Chem. Soc., Chem. Commun., (1986) 1296. (b) M. Akita, A. Kondoh, T. Kawahara, T. Takagi and Y. Moro-oka, Organometallics, 7 (1988) 366.
- 3 J.K. Ariyaratne, A.M. Bierrum, M.L.H. Green, M. Ishaq, C.K. Prout and M.G. Swanwick, J. Chem. Soc. (A) (1969) 1309.
- 4 P.J. Crusic, P.J. Fagan and J. San Fillippo, Jr., J. Am. Chem. Soc., 99, 250 (1977).
- 5 (a) R.B. King, Organometallic Synthesis, Vol. 1, Academic Press, New York, 1965, pp. 145 and 151. (b) M.E. Wright and G.O. Nelson, J. Organomet. Chem., 263 (1984) 371.