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Synthesis of Enantiomerically Enriched Tricarbonyl(vinylketene)iron(0) Complexes

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Abstract: Addition of tricarbonyl(vinylketene)iron(0) complexes **2a-d** to 0.5 equiv. of a phosphoramidate anion derived from (*S*)-α-methylbenzylamine affords the first enantiomerically enriched samples of **2a-d**; the absolute configurations of **2a-d** have been established as 5*pS*

The current intense interest in the stereochemistry of fundamental *organic* processes is resulting in our control and understanding of these processes becoming more and more sophisticated. The rich diversity of structure and reactivity encountered in organometallic chemistry, however, is partly responsible for the relatively limited and fragmentary nature of the stereochemical information currently available about fundamental *organometallic* processes.

Some time ago we discovered that alkyllithiums react with iron tricarbonyl complexes of vinylketones under a carbon monoxide atmosphere to give iron tricarbonyl complexes of vinylketenes.[1] This gave us rapid access to these stable crystalline complexes and enabled us to explore the fundamental reactivity of vinylketenes bound to a transition metal. We have found that isonitriles,[2] phosphonoacetate anions,[3] phosphoramidate anions,[4] alkynes[5] and alkenes[6] react with iron tricarbonyl complexes of vinylketenes to produce between them a rich diversity of both first generation organometallic products and second generation organic products by a variety of routes all involving fundamental organometallic processes.

Access to enantiomerically enriched samples of iron tricarbonyl complexes of vinylketenes should enable us to probe whether or not their reactions proceed with retention, inversion or racemisation of configuration and should ultimately yield a wealth of stereochemical and mechanistic information about a range of organometallic processes. We thus wish to report herein that samples of tricarbonyl(vinylketene)iron(0) complexes of good enantiomeric purity and known absolute configuration may be generated using a kinetic resolution procedure based on a phosphoramidate readily derived from (*S*)-α-methylbenzylamine.

We recently demonstrated that anions of achiral *N*-alkylphosphoramidates react with iron tricarbonyl complexes of vinylketenes to give iron tricarbonyl complexes of vinylketenimines.[4] It was subsequently postulated that a non-racemic chiral *N*-alkylphosphoramidate may react preferentially with one of the enantiomers of tricarbonyl(vinylketene)iron(0) complexes to generate enantiomerically enriched vinylketene complexes by a kinetic resolution procedure. In order to test this hypothesis, phosphoramidate **1**[7] was prepared from diethyl phosphite and (*S*)-α-methylbenzylamine (e.e. = 99%) using a literature procedure,[8] and

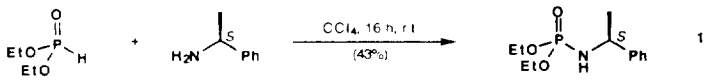
Dedicated to the memory of Professor Hidemasa Takaya, deceased on 5 October 1995

Table Reaction of tricarbonyl(vinylketene)iron(0) complexes **2** with 0.5 equiv. of the lithium anion of (*S*)-α-methylbenzyl diethylphosphoramidate to give diastereomerically enriched tricarbonyl(vinylketenimine)iron(0) complexes **4** and enantiomerically enriched tricarbonyl(vinylketene)iron(0) complexes **2**[a]

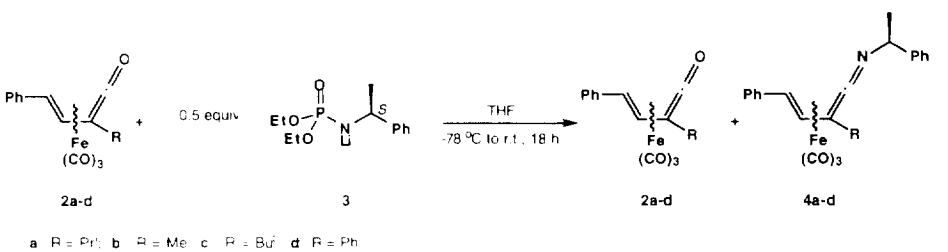
		crude product[b]		isolated ketenimine **4**[c]		isolated ketene **2**[d]		crystallised ketene **2**			
entry	R	ketene **2** : ketenimine **4**	*pR* ketenimine : *pS* ketenimine	yield *pR* (%)	yield *pS* (%)	yield (%)	e.e. (%)[e]	yield (%)	e.e. (%)[e]	$[\alpha]_D$[f]	*R*/*S*
a	Pr^i	43:57[g]	92:8	47 (92:8)[h]		37	80	23	99	+1312	*S*
b	Me	52:48	84:16	39 (84:16)[h]		44	46	9	99	+1494	*S*
c	Bu^t	56:44	87:13	32	5	48	40	19	94	+1139	*S*
d	Ph	44:56	82:18	37	8	37	60	19	91	+1275	*S*

[a] Typical procedure: A solution of (*S*)-α-methylbenzyl diethylphosphoramidate **1** (0.347 g, 1.35 mmol) in THF (20 cm^3) was cooled to -78 °C, treated with methyllithium (1.4 M solution in Et_2O, 0.89 cm^3, 1.25 mmol) and then allowed to warm to room temperature. After stirring for 10 min, the mixture was cooled again to -78 °C and treated with a yellow solution of (±)-[tricarbonyl(3,5-diphenyl-1-oxapenta-1,2,4-triene)iron(0)] (±)-**2d** (0.900 g, 2.50 mmol) in THF (5 cm^3). The mixture was then allowed to warm very slowly to ambient temperature over a period of 18 h, giving rise to a deep red solution. Solvent was removed *in vacuo* and the sticky red-brown residue examined by ^{1}H NMR spectroscopy. The crude product was then partitioned between a mixture of 9:1 CH_2Cl_2:Et_2O (10 cm^3) and water (5 cm^3) and the aqueous layer extracted once more with the former (5 cm^3). The combined organic extracts were then passed down a short filtration column (SiO_2; CH_2Cl_2:Et_2O, 9:1) to give a semi-purified product mixture as a yellow powder (0.987 g) which was examined by ^{1}H NMR spectroscopy and then subjected to column chromatography (SiO_2). Elution with 40-60 °C petroleum ether:CH_2Cl_2 (2:1) afforded enantiomerically enriched **2d** (0.337 g, 37%, 60% e.e.) as a yellow solid. Further elution with CH_2Cl_2 gave diastereomerically enriched **4d** (0.550 g, 47%, 64% d.e.) as a yellow oil. Further column chromatography (SiO_2) of **4d** led to the separation of the diastereomers. Elution with CH_2Cl_2:40-60 °C petroleum ether (1:1) gave pure major diastereomer (-)-**4d** as a lemon yellow solid foam (0.430 g, 37%) and further elution with dichloromethane afforded the pure minor diastereomer (+)-**4d** as a yellow oil (0.089 g, 8%). Crystals of (-)-**4d** suitable for *X*-ray diffraction were obtained by slow evaporation of a pentane solution affording orange-yellow blocks. Similarly, slow evaporation from pentane solution afforded large orange crystals of (+)-**4d**. Enantiomeric enrichment of **2d** was accomplished by crystallisation from Et_2O at 4 °C. After preferential crystallisation of two batches of (±)-**2d**, and repeated crystallisation of the remaining material, (+)-**2d** was obtained as a yellow solid (0.169 g, 19%, 91% e.e.). [b] The ratios quoted for the crude product were found to be identical within experimental error before and after removal of the phosphoramidate residues. [c] Isolated yield and diastereomeric ratio after column chromatography. [d] Isolated yield and e.e. after column chromatography. [e] E.e.s measured by HPLC. [f] All values measured at 25 °C in CH_2Cl_2 (c = 1.00). [g] All ratios measured by ^{1}H NMR spectroscopy. [h] Inseparable diastereomers.

the tricarbonyl(vinylketene)iron(0) complexes **2a-d** (**a**: R = Pr^i; **b**: R = Me; **c**: R = Bu^t; **d**: R = Ph) were prepared from the corresponding tricarbonyl(vinylketone)iron(0) complexes as described previously.[1]



Phosphoramidate **1** and the isopropyl-substituted vinylketene complex **2a** were chosen for the initial reaction (Table, entry a). After deprotonation of 0.54 equiv. of **1** with 0.5 equiv. of methyllithium, the lithium anion **3** was treated with 1.00 equiv. of complex **2a** at -78 °C and the resulting reaction mixture allowed to warm very slowly to room temperature. After 18 h, the solvent was removed and the residue examined by ^{1}H NMR spectroscopy. This crude product contained *inter alia* the vinylketene complex **2a** and the two diastereomers of the vinylketenimine complex **4a**. The ratio of vinylketene complex **2a** to vinylketenimine complexes **4a** was observed to be 43:57, and we were delighted to note that the ratio of the two vinylketenimine diastereomers was 92:8 suggesting that the phosphoramidate anion **3** had reacted preferentially with one of the enantiomers of the vinylketene complex. After the phosphoramidate residues had been removed from the crude product by washing and a short filtration column, the ratios of ketene to ketenimine and of ketenimine diastereomers were examined again by ^{1}H NMR spectroscopy and found to be unaltered. Separation of the vinylketene complex **2a** from vinylketenimine complex **4a** was achieved by column chromatography and produced a 47% yield of an inseparable 92:8 diastereoisomeric mixture of vinylketenimines **4a** as a viscous yellow oil, and a 37% yield of vinylketene **2a** as a yellow solid. The enantiomeric excess of the vinylketene complex was measured by HPLC [CHIRALCEL OD-H, Daicel Chemical Industries; hexane-isopropanol (7:3), 1 cm^3 min^{-1}] and found to be 80%. Crystallisation gave a 23% yield of vinylketene complex **2a** with an e.e. of 99% {$[\alpha]_D^{25}$ = +1312 (*c* 1.00, CH_2Cl_2)}.



Application of the procedure described above to the vinylketene complexes with methyl, *tert*-butyl and phenyl substituents (**2b-d**) also led to enantioselective reactions which, on purification and crystallisation of the product mixtures, afforded enantiomerically enriched samples of the vinylketene complexes **2b-d** (Table, entries b, c and d). At this point the absolute configuration of the vinylketene complexes, which is clearly of paramount importance for the stereochemical studies planned for these complexes, was unknown. It was determined by an *X*-ray crystallographic analysis[9] of the major vinylketenimine diastereomer obtained from the phenyl-substituted vinylketene complex **2d**.[10] This was found to have the absolute configuration shown in the Figure and its planar chirality was defined as 5*pR*.[11] Thus, assuming that the ketene to ketenimine reaction occurs with retention of configuration with respect to the planar chirality of the system, the absolute configuration of the optically enriched vinylketene complex **2d** is as shown in the Figure and is defined as

5*pS*. Comparison of the $[\alpha]_D^{25}$ data obtained for **2a-c** and **2d** results in the conclusion that **2a-d** all have the same absolute configuration.

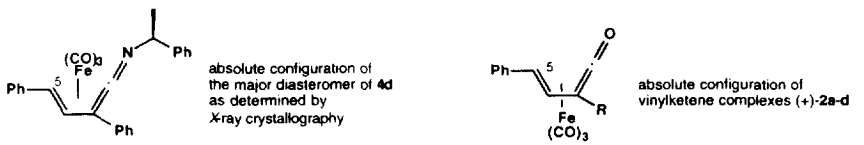


Figure Absolute configurations of the major diasteromer of **4d** and vinylketene complexes (+)-**2a-d**.

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9. Details of this analysis will be reported in the full account of this work.
10. See footnote a in Table for details of the experiment that produced these crystals.
11. Application of the Cahn-Ingold-Prelog convention for π-complexes (R.S. Cahn, C. Ingold and V. Prelog, *Angew. Chem., Int. Ed. Engl.*, 1966, **5**, 385) to carbon-5 of the vinylketenimine ligand leads to the *R* designation.

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