The spectral properties of 2 are closely related to those of 1 and, as already mentioned, it also possesses a two-fold rotation axis. 2D-^{1}H NMR[9] experiments (J-RES and COSY 45)[10] demonstrate that the signal attributable to H-10 (H-10') is a double doublet with coupling constants of 3 and 10.5 Hz. This implies that it is coupled to both an axial and an equatorial proton. The only way to satisfy these requirements is to admit that petrosin -A (2) has the reverse configuration at C-1 (C-1') and C-10 (C-10') with respect to those of petrosin (1).

Because of the absence of symmetry, the ^{1}H and ^{13}C NMR spectra of 3 are more complex. As for the two other derivatives, the assignments of the signals in the ^{1}H NMR spectrum of 3 (see table 1), are mainly based on homonuclear 2D-^{1}H NMR experiments (J-RES, COSY 45 and COSY 90)[10]. Although these experiments allowed us to measure the δ and J of most of the relevant protons, H-6 and H-6' did not come out clearly, thus precluding to measure with precision their chemical shifts. The H-10 appears in the COSY 90 spectrum as a double doublet with J_{1-10} = 11 Hz and J_{9-10} = 4.5 Hz. The coupling constants $J_{1'-10'}$ (3.5 Hz) and $J_{9'-10'}$ (9.5Hz) could not be measured by this way, but were obtained from spin decoupling and pseudo-INDOR experiments. Thus, 3 appears as a combination of the quinolizidine ring systems found in 1 and 2.

We have to point out that the spectroscopic values obtained for 3 do not rule out the structure where the two quinolizidine ring systems are linked tête-bêche (C-1 to C-1' and C-9 to C-9'). But, this alternative may be considered as much less probable on the basis of biogenetic arguments.

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(9) ^{1}H NMR and ^{13}C NMR measurements were carried out on a BRUKER WM250 spectrometer, equipped with an Aspect 2000 computer. 256 x 1K files and 128 x 2K files (with zero filling in F1) were respectively used for the 2D COSY and J-RES experiments.
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TRANSITION-METAL-CATALYSED REACTIONS OF DIAZOESTERS. INSERTION INTO C-H BONDS OF PARAFFINS CATALYSED BY BULKY RHODIUM(II) CARBOXYLATES : ENHANCED ATTACK ON PRIMARY C-H BONDS§

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ABSTRACT

Rhodium(II) carboxylates associated with bulky ligands catalyse the insertion of carbalkoxycarbenes (generated from diszoesters) into C-H bonds of normal and branched alkanes with selectivities differing substantially from those associated with non-bulky carboxylates.

Rhodium(II) carboxylates are at the present time among the best catalysts for the cyclopropanation of mono- and polyolefins and acetylenes with diazoesters.[1] We have recently described already and high yield synthesis of cycloheptatrienes by tetrakis (trifluoroacetato) dirhodium(II), (rhodium trifluoroacetate, Rh-CF_3)-catalysed addition of carbalkoxycarbenes to aromatic substrates.[2] The methodology is quite versatile and can be applied successfully not only to promote regioselective insertion into OH bonds (bond energy > 120 kcal.mol^{-1}) but also insertion into C-H bonds of paraffins[3] (bond energy ± 98 kcal.mol^{-1}). In this latter case, unusually high yields of functionalized alkanes were achieved with rhodium complexes substituted by strongly electroattracting ligands. Moreover, rhodium(II)-catalysed C-H insertions exhibit regioselectivities markedly different from those observed in typical free-carbene processes.[4] 5h-CF_3 displayed a selectivity highly unfavourable for CH_3 attack (insertions into secondary C-H bonds is largely favoured over insertions into primary C-H bonds, (2° ≫ 1°)) and paralleled the relative C-H bond energies, respectively ∿98, 94 and 90 kcal.mol^{-1} for primary, secondary and tertiary C-H bonds. In fact, C-H insertions at C_1, C_2 and C_3 of *n*-pentane were respectively 7,66 and 27% (see Table 1), as compared with 32, 43 and 25% when the carbene was photolytically promoted. With other "ordinary" rhodium(II) carboxylates, *e.g.* Rh(II) acetate, pivalate, pentafluorobenzoate, the catalytic insertion into primary C-H bonds was also nearly suppressed (Table 1).

However, the use of bulkier Rh(II) carboxylates led to a dramatic change in selectivities. For example, when ethyl diazoacetate was catalytically decomposed by Rh-$C_{10}H_4Cl_4NO_2$ (see figure) and/or Rh-$C_{16}H_8Cl_4NO_2$, insertion into the methyl C-H bonds of *n*-pentane went up to 12 and 16% respectively. In the case of Rh-TC (where TC represents the 9-triptycenecarboxylate ligand), insertion

§ This paper is dedicated to Professor R.H. Martin for his 70th birthday.

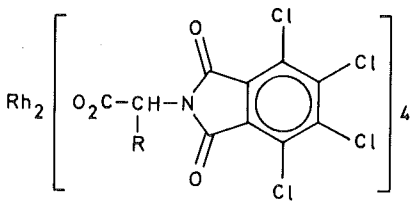
TABLE 1

Regioselectivities of C-H monoinsertion in the Rh(II)-catalysed decomposition of EtDA[a] in *n*-pentane.

Catalyst Rh-*R'*	Insertion[b] yield (%)	Regioselectivities[a] (%) C_1	C_2	C_3	2°/1°[d] statistical ratio
Rh-CH_3	20	4	63	33	24
Rh-$C(CH_3)_3$	-	5	64	31	19
Rh-CF_3	65	7	66	27	13.5
Rh-C_6F_5 [e]	26	7	62	31	13.5
Rh-$C_{10}H_4Cl_4NO_2$ [f]	30	12	64	24	7.5
Rh-$C_{16}H_8Cl_4NO_2$ [g]	-	16	61	23	5.3
Rh-TC [h]	86	30	61	9	2.3

Reaction conditions : alkane 15.10^{-2} mol; catalyst $1\text{-}3.10^{-5}$ mol; diazoester 3.10^{-3} mol; perfusion time 4h; 22°C, except for Rh-CH_3, Rh-$C(CH_3)_3$ and Rh-TC : 36°C; [a]Ethyldiazoacetate; [b]Yields calculated on EtDA (g.l.c.). With Rh-$C(CH_3)_3$ and Rh-$C_{16}H_8Cl_4NO_2$, yields were estimated to be in the 25-30% range; [c]Average of at least two runs; [d]Value corrected for number of H (selectivity per H). Catalyst carboxylato group : [e]perfluorobenzoato; [f]L(+)-2-(tetrachlorophthalimido) propionato; [g]L(+)-2-(tetrachlorophthalimido)-3-phenylpropionato; [h]9-triptycenecarboxylato.

into the methyl group was as high as 30%, corresponding to a large increase of the primary to secondary C-H insertion selectivity.



R = CH_3 : Rh-$C_{10}H_4Cl_4NO_2$

R = CH_2-C_6H_5 : Rh-$C_{16}H_8Cl_4NO_2$

Moreover, the regioselectivity of insertion also depended on the diazoester alkoxy-group. For example, the Rh-$C_{16}H_8Cl_4NO_2$-catalysed decomposition of *methyl* diazoacetate in *n*-pentane afforded 28,47 and 25% of C-H insertion respectively at C_1-H, C_2-H and C_3-H. Under the same conditions, *n-butyl* diazoacetate was more selective for C_2-H with respectively 8, 63 and 29% of insertion (values close to those obtained with non-bulky ligands).

Similar trends were also evidenced with both higher and branched alkanes and the results are summarized in Table 2. Again, replacement of Rh-CH_3 or Rh-CF_3 by Rh-TC resulted in an enhanced insertion into primary C-H bonds : for 2,3-dimethylbutane, the relative reactivity of tertiary and primary C-H (3°/1°)

decreased from 115/1 with Rh-CH_3 to 12/1 with Rh-TC, (value corrected for number of hydrogens) and for 3-methylpentane, the 3°/2°/1° ratio decreased from 93/9.2/1 with Rh-CH_3 to 2.7/1.6/1 with Rh-TC. In any case, there remained however a preference for tertiary centres over primary and secondary ones.

On the other hand, the two types of methyl groups (C_1 and C_4) in 2-methylbutane are strongly differentiated by Rh-TC catalysis, although they display the same reactivity with "free"-carbene species (thermally or photochemically generated).

TABLE 2

Regioselectivities of C-H monoinsertion in the Rh(II)-catalysed decomposition of EtDA in alkanes.

Alkane	Catalyst Rh-*R'*	Regioselectivities (%) C_1	C_2	C_3	C_4	C_5
n-Decane	Rh-CH_3[a]	3	40	20	18.5	18.5
	Rh-CF_3	5	40	19	18	18
	Rh-TC	18	49	11	11	11
2-Methylbutane	Rh-CH_3	1	8	90	1	
	Rh-CF_3	5	25	66	4	
	Rh-TC	18	18.5	27	36.5	
2,3-Dimethyl-butane	Rh-CH_3	5	95			
	Rh-CF_3	12	88			
	Rh-TC	33	67			
3-Methylpentane	Rh-CH_3	6.5[b]	26.5	67		
	Rh-CF_3	8.5	43.5	48		
	Rh-TC	49.5	35.5	15		

Same reaction conditions as in Table 1 but 60° instead of 22°C.

[a] Regioselectivities similar to those described in ref. 5.

[b] Overlap of the g.l.c. peaks of the 2 diastereomeric methyl insertion products.

The foregoing observations demonstrate that an introduction of bulky substituents in the steric environment of the reaction site can substantially alter the distribution of the isomers resulting from C-H insertion. Similar large effects of steric and/or lipophilic nature on regioselectivity have also been described both for rhodium(III) porphyrins-catalysed functionalization of n-alkanes[5] and of olefins.[6] In the same context, Groves and Nemo have shown recently that the selectivity of alkane oxidations by iodosylbenzene also varied as a function of the peripheral substitution pattern of the catalyst.[7]

The dependence of the regioselectivity of C-H insertions on the structure of the metal complex, as well as the unique alterations brought about by such

minor changes as a homologation of the diazoester alkoxy-group (*e.g.* methyl vs ethyldiazoacetate, see also ref. 3) substantiates the presence of significant interactions metal ligands-carbene (or diazoester)-substrate. The stereochemical outcome of the reaction could therefore be determined largely by secondary interactions (non-bonded steric and lipophilic interactions) and to a lesser extent by the relative bond strength of reacting C-H bonds.

EXPERIMENTAL

The general procedure and the analytical methods are described elsewhere.[1,3] All isomers were identified by g.l.c., including analysis on a capillary column (50m x 0.25mm, FFAP), by comparison with authentic samples synthesized by independent methods, and by coupled g.l.c.-mass spectrometry.

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TRANSITION-METAL-CATALYSED REACTIONS OF DIAZOESTERS : SYNTHESIS OF CHRYSANTHEMIC AND PERMETHRIC ACID ESTERS BY CYCLOPROPANATION OF CONJUGATED DIENES[*]

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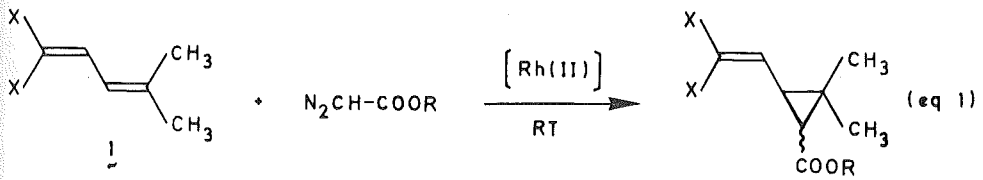
ABSTRACT

Pyrethroid precursors (permethric and chrysanthemic acid esters) are efficiently synthesized by rhodium(II)-catalysed cyclopropanation of the properly substituted conjugated diene. Reaction selectivities depend on both the catalyst counter-ion and the diazoester alkoxy-group (carbene precursor) and are attributed to non-bonded interactions.

Pyrethroids derived from chrysanthemic acid 2-a (R=H) and permethric acid 2-b (R=H) exhibit exceptionally potent insecticidal activity together with very low mammalian toxicity and rapid biodegradability.[1] Therefore, their synthesis from readily available precursors provides an attractive commercial target.[2]



(a) X = CH_3

(b) X = Cl

2

The synthetic goal can be met by direct cyclopropanation of dienes 1 with diazoesters under homogeneous conditions. Traditionally, such reactions have been promoted by copper derivatives,[3] catalysts which are however not very efficient in this particular case. Recent works indicate that a number of reactions where a carbene (generated from a diazoester) is transferred onto an olefinic bond, presumably via formation of a metal-carbene complex (carbenoid), can be efficiently controlled by catalytic amounts of rhodium(II) carboxylates, $Rh_2(O_2C\text{-}R')_4$ *(by convention* Rh-*R')*.[4] It was shown that in such reactions, the carboxylate counter-ion *R'* plays an important role. According to its electronic, steric and/or lipophilic requirements, it largely determines the efficiency and selectivity of carbenoid intermediate (regio- and stereo-selectivities).[4]

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[*] This paper is dedicated to Professor R.H. Martin for his 70th birthday.