Stereoselective Synthesis of *Z*-Enol Esters catalysed by [Bis(diphenylphosphino)alkane]bis(2-methylpropenyl)ruthenium Complexes

Henri Doucet, Jürgen Höfer, Christian Bruneau and Pierre H. Dixneuf*

Laboratoire de Chimie de Coordination Organique, URA CNRS 415, Campus de Beaulieu, Université de Rennes, 35042 Rennes, France

Z-Enol esters are obtained *via* regio- and stereo-selective addition of carboxylic acids to terminal alkynes, with formation of a C(1) carbon–oxygen bond, in the presence of a $[Ru\{Ph_2P(CH_2)_nPPh_2\}\{\eta^3\text{-}CH_2\text{–}C(Me)=CH_2\}_2]$ catalyst precursor.

Enol esters have been shown to be useful precursors in organic synthesis, especially for the regio- and stereo-selective generation of enolates.[1] The regioselective addition of carboxylates at the C(2) atom of terminal alkynes affords direct access to enol esters of type **I**, mild acylating reagents, and has been performed with catalytic systems based on bis(η^5-cyclooctadienyl)ruthenium[2] and $[Ru(arene)Cl_2(PR_3)]$[3] complexes. On the other hand, in spite of their interest as protected aldehyde enolates, very few examples of the selective formation of enol esters of type **II**, with the carboxylate attached to C(1), are known. These unsaturated esters are usually produced from vinylmercury derivatives in the presence of palladium acetate as catalyst[1] or from epoxysilanes.[4]

We now report that the bis(2-methylpropenyl)ruthenium complex **4** containing the chelating 1,4-bis(diphenylphosphino)butane ligand (*i*) completely reverses the previously observed regioselectivity of the addition to terminal alkynes,[2,3] (*ii*) allows the unprecedented catalytic stereoselective synthesis of *Z*-enol esters **II** by direct *trans* addition of carboxylic acids to terminal alkynes and thus (*iii*) offers the selective transformation of the -C≡CH moiety into a potential $-CH_2CHO$ group.

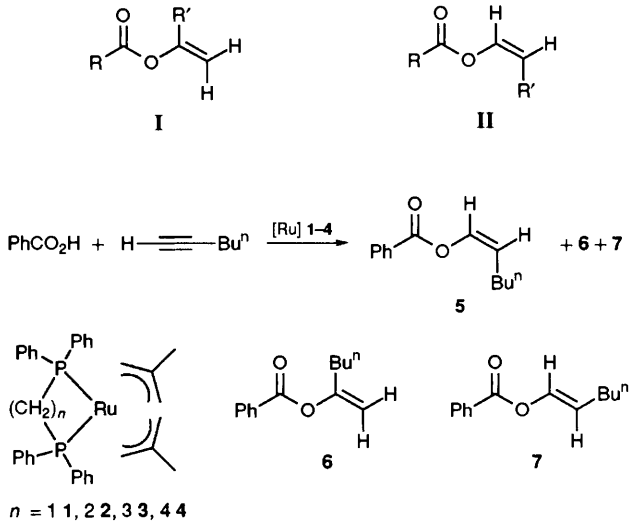
The reaction of benzoic acid (10 mmol) and hex-1-yne (10 mmol) at 65 °C in toluene, in the presence of [bis(diphenylphosphino)alkane]bis(2-methylpropenyl)ruthenium complexes **1–4** (0.1 mmol) afforded the hexenyl benzoates **5**, **6**, **7**,† and experimental conditions were easily found to allow the selective formation of the enol ester **5** of type **II** (Scheme 1, Table 1). The results show that complexes **1–4** are very efficient catalyst precursors for the activation of carbon–carbon triple bonds towards the addition of carboxylates, with respect to other ruthenium complexes,[2,3] which did not show catalytic activity at temperatures lower than 80 °C. More importantly, the nature of the diphosphine ligand has a tremendous influence on the rate and selectivity of the reaction. At a temperature as low as 65 °C, the 1,4-bis(diphenylphosphino)butane ligand in complex **4** gave a remarkable catalytic activity leading to a fast regiospecific addition affording stereoselectively 98% of the *Z* isomer **5**, isolated in 95% yield.

For each alkyne and acid tested, mild experimental conditions close to that of entry 4 (Table 1) could be found which

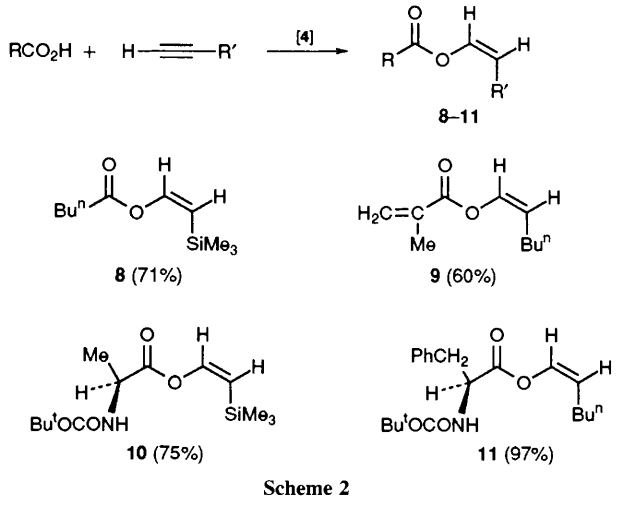
Table 1 Influence of the nature of the $Ph_2P(CH_2)_nPPh_2$ ligand on the catalytic properties of the $[Ru\{Ph_2P(CH_2)_nPPh_2\}\{\eta^3\text{-}CH_2\text{–}C(Me)=CH_2\}_2]$ complexes **1–4**[a]

Entry	Catalyst	Reaction time/h	*T*/°C	Enol ester distribution (%) 5	6	7
1	**1**	3	65	16	80	4
2	**2**	24	65	72	7	21
3	**3**	24	65	69	25	6
4	**4**	2.5	65	98	0	2
5	**4**	1.7	100	20	78	2

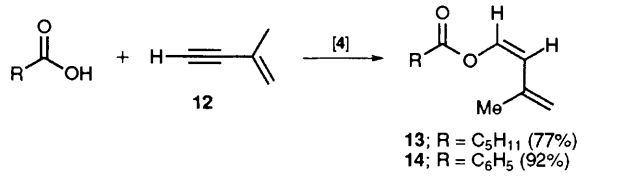
[a] *General conditions*: benzoic acid (10 mmol), hex-1-yne (10 mmol), ruthenium complex (0.1 mmol), toluene (10 ml), distribution determined by vapour phase chromatography (VPC).



Scheme 1



Scheme 2



Scheme 3

† ^1H NMR (300 MHz, $CDCl_3$) of the olefinic protons of the three isomers: **5** δ 7.25 (1 H, d, ^3J_Z 6.3 Hz, OCH), 5.01 (1 H, dt, ^3J 7.5, ^3J_Z 6.3 Hz, CHBu^n); **6** δ 4.83 (2 H, dd, ^{AB}J 1.3 Hz, $=CH_2$); **7** δ 7.28 (1 H, ^3J_E 12.4 Hz, OCH), 5.59 (1 H, dt, ^3J 7.5, ^3J_E 12.4 Hz, CHBu^n).

allowed the selective synthesis of *Z*-enol esters in good yields with 1 mol% of complex **4** (Scheme 2). The fragile trimethylsilylacetylene H–C≡C–$SiMe_3$ readily gave *Z*-(2-trimethylsilylethen-1-yl) pentanoate **8** in 71% yield at 60 °C. The unsaturated monomer **9** was simply obtained in 60% yield by addition of methacrylic acid to hexyne, but at 45 °C and without significant polymerization. The mild conditions of the activation with complex **4** made possible the selective conversion without racemization of optically pure *N*-protected amino acids into optically active *Z*-enol amino esters **10**, **11**.

The selectivity of the catalyst precursor **4** was also used for the stereoselective synthesis of functional dienes from 3-methylbut-3-en-1-yne **12**, and compounds **13** (77%) and **14** (92%) were prepared at 45 and 60 °C, respectively (Scheme 3). This reaction contrasts with the mercury(II) promoted addition of carboxylates or nucleophiles[5] at the C(2) of enynes.

The mechanism of the above reaction may involve the activation of the triple bond of the alkyne *via* η^2-coordination to the metal centre, followed by the addition of the carboxylate at C(1). The enhanced activation of terminal alkynes at low temperature by ruthenium complexes **1**–**4** is probably due to the high lability of the allylic ligands in the presence of carboxylic acids. Because a better selectivity was observed with the diphosphine ligand containing the longer chain, steric factors rather than electronic effects may be responsible for the observed regio- and stereo-selectivities, which are also very dependent on steric hindrance of both the alkyne and the carboxylic acid.

The above results show that [1,4-bis(diphenylphosphino)-butane]bis(2-methylpropenyl)ruthenium complex **4** provides a suitable route to prepare *Z*-enol esters at 40–65 °C, a step towards the mild transformation of a –C≡CH group into an aldehyde $-CH_2CHO$, rather than the classical –COMe group. This transformation, difficult to achieve,[6] is currently under investigation.

Received, 19th February 1993; Com. 3/01015E

References

1 R. C. Larock, K. Oertle and K. M. Beatty, *J. Am. Chem. Soc.*, 1980, **102**, 1966 and references cited therein.
2 T. Mitsudo, Y. Hori and Y. Watanabe, *J. Org. Chem.*, 1985, **50**, 1566; T. Mitsudo, Y. Hori, Y. Yamakawa and Y. Watanabe, *J. Org. Chem.*, 1987, **52**, 2230.
3 C. Ruppin and P. H. Dixneuf, *Tetrahedron Lett.*, 1986, **27**, 6323; C. Bruneau, M. Neveux, Z. Kabouche, C. Ruppin and P. H. Dixneuf, *Synlett*, 1991, 755; K. Philippot, D. Devanne and P. H. Dixneuf, *J. Chem. Soc., Chem. Commun.*, 1990, 1199.
4 P. F. Hudrlik, A. M. Hudrlik, R. J. Rona, R. N. Misra and G. P. Withers, *J. Am. Chem. Soc.*, 1977, **99**, 1993.
5 J. Barluenga, F. Aznar, R. Liz and M.-P. Cabal, *J. Chem. Soc., Chem. Commun.*, 1985, 1375.
6 C. Schmitz, A.-C. Rouanet-Dreyfuss, M. Tueni and J.-F. Biellmann, *Tetrahedron Lett.*, 1992, **33**,. 4911.