Diiodosamarium, an excellent catalyst precursor for Aldolisation and Michael Reactions.

Pierre Van de Weghe, Jacqueline Collin*.

Laboratoire de Synthèse Asymétrique associé au CNRS 1497, Institut de Chimie Moléculaire d'Orsay. Université Paris-Sud, 91405 Orsay, France.

Key Words : Samarium diiodide ; aldolisation reactions ; Michael additions ; ketene silyl acetals ; enol silanes ; ketones ; aldehydes .

Abstract : Sm1₂ is the precursor of efficient catalysts for the aldolisation reactions of aldehydes and ketones with enol silanes. α , β -unsaturated ketones give 1,4-additions selectively.

Diiodosamarium was introduced in 1977 as a reducing agent in organic chemistry¹. Since that time this reagent found many applications (for reviews see refs 2-4). The great majority of the examples yet investigated are dealing with *stoichiometric reactions*. However, in reports from our laboratory, some efficient *catalytic reactions* were described : Sml2 being used in situ was an excellent catalyst precursor, such as in the MPVO or Tischenko reactions⁵ (see also some recent reports of D. Evans^{6,7}), and in the epoxide rearrangement⁸. For the above reactions preformed alkoxides^{5,8} or SmlO⁸ can be used as catalysts instead of Sml2 and it is quite sure that in the latter case Sm(III) complexes formed *in situ* are the actual catalysts. Sml2 has been also employed as radical initiator in the addition of perfluoroiodides to alkenes or alkynes and polyhalogenomethanes to olefins⁹.

Presently we wish to report *examples of the catalytic use of diiodosamarium* for condensation reactions involving enol silanes. The interest of lanthanide derivatives for this type of reactions has only recently appeared. Lanthanide trichlorides catalyze aldol additions of ketene silyl acetals on aldehydes¹⁰, and other trivalent derivatives such as $|(Me_3Si)_2C_5H_3|_2YbCl^{11}$, $Ln(dppm)_3$ and $Ln(fod)_3^{12,13}$ were subsequently described as catalysts for the same reaction. Lanthanides triflates catalyze the aldolisation reaction of aldehydes with silyl enol ethers in aqueous media¹⁴. Trivalent lanthanum binaphtoxide¹⁵ and samarium bis and tris alkoxides¹⁶ have been tested as asymmetric catalysts respectively for nitroaldolisation and aldolisation reactions and enantioselectivity was observed.

We have found that aldolisation reactions of silyl ketene acetals or silyl enol ethers with aldehydes or acetophenone are performed in good yields by the use of 5 % mol eq. Sml₂ in suspension in CH₂Cl₂ (eq. (1), Table 1). In a typical experiment, 7.5 mmol (1.305 g) of trimethylsilyl ketene acetal of methyl isobutyrate 1 and 5 mmol (0.680 g) of *p*-anisaldehyde are added to a blue suspension of 0.25 mmol Sml₂(THF)₂ in 10 ml CH₂Cl₂ maintained at -78°C. Reaction mixture turns immediately yellow, and is hydrolyzed after 5 min, the product is extracted with ether and purified by column chromatography on silica gel with hexane/ethyl acetate : 90/10 as eluent (1.472 g, 95 % yield).



For the reactions of trimethylsilyl ketene acetal of methyl isobutyrate 1 with aromatic aldehydes, aliphatic aldehydes or acetophenone, reactions are performed at low temperatures and yields are high (entries 1-4). In the case of *p*-anisaldehyde the amount of catalyst can be reduced : with 2 % or 0.5 % Sml₂ reaction was carried out at the same temperature and within the same time without decrease of yield. Reactions of 1 with cyclic or acyclic ketones at room temperature do not lead to the aldolisation product (entries 5, 6). Trimethylsilyl enol ethers of acetophenone 2 and cyclohexanone 3 react at room temperature with aldehydes to give the corresponding silylated aldols in good yields (entries 7, 8).

| Entry | Carbonyl Compound | Enol silane | ፐር | t | Yield ^a |
|-------|-------------------|-------------|-----|-------|--------------------|
| T | Benzaldehyde | 1 | -78 | 5 min | 95 |
| 2 | p-Anisaldehyde | 1 | -78 | 5 min | 95 |
| 3 | n-Octanal | 1 | -20 | 4.5 h | 90 |
| 4 | Acetophenone | 1 | -20 | 2 h | 85 |
| 5 | Octan-2-one | 1 | 25 | 48 h | 0 |
| 6 | Cyclohexanone | 1 | 25 | 48 h | 0 |
| 7 | p-Anisaldehyde | 2 | 25 | 24 h | 85b |
| 8 | p-Anisaldehyde | 3 | 25 | 24 h | 85bc |

Table 1: Aldolisation reactions catalyzed by SmI2

^a Isolated yield %, see in text for experimental details, all compounds have been fully characterized spectroscopically by ¹H NMR, GC/MS, IR. ^b Yield obtained by GC and ¹H NMR analysis of the crude product. ^c Ratio syn/anti : 60/40 measured by ¹H NMR



We also examined the reaction of α,β -unsaturated ketones and α,β -unsaturated aldehydes with different enol silanes in the presence of 5 % mol eq. Sml₂ in CH₂Cl₂ (Table 2). Reactions of α,β unsaturated ketones with 1 proceed in good yields and selectivities : only 1-4 additions are observed with cyclohexenone and chalcone (eq. (2), (3)). Cinnamaldehyde gives a mixture of 1,2 and 1,4 additions with ketene silyl acetal 1 and selective 1,2 addition with the trimethylsilyl enol ethers of acetophenone 2 and cyclohexanone 3 (eq. (4)). These results are similar to those precedently reported for lanthanides catalysts. Reactions of α,β -unsaturated ketones with silyl enol ethers catalyzed by lanthanides triflates¹⁴ or Eu(dppm)₃¹² yield only Michael additions while with α,β -unsaturated aldehydes 1,2 additions¹¹ or mixtures of products¹² have been obtained.



Table 2 : Aldolisation reactions of α , β -unsaturated compounds catalyzed by Sml₂

| Entry | Carbonyl Compound | Enol silane | ፐ℃ | t | 4 : 5 ^a | Yield ^b |
|-------|-------------------|-------------|-----------|-------|-----------------------|--------------------|
| 1 | o | 1 | -20 | 5 hr | > 95 : 5 ^c | 65 |
| 2 | Ph Ph O | 1 | -20 | 5 hr | > 95 : 5 ^c | 85 |
| 3 | Ph H | 1 | -20 | 4.5 h | 50 : 50 | 9 0 |
| 4 | Ph H | 2 | 25 | 4 h | 15 : 85 | 68 |
| 5 | Ph H | 3 | 25 | 6.5 h | > 5 : 95 c,d | 52 |

^a 1,4 additions and 1,2 additions yield respectively products 4 and 5. ^b Isolated yield %, see in text for experimental details, all compounds have been fully characterized spectroscopically by ¹H NMR, GC/MS, IR. ^c Minor product was not detected by NMR.^d Ratio syn/anti : 50/50 measured by GC and ¹H NMR:

The above results show that SmI_2 in CH₂Cl₂ displays a high reactivity as a catalyst for aldolisation as well as for Michael additions. Reactions are performed in mild conditions, the catalyst is readily available and easy to use, and a small amount of catalyst is needed (5% or less). The change of colour from blue to yellow observed since the end of the addition of the reactants for every reaction, suggests that SmI_2 is not the actual catalyst, but only a catalyst precursor. This catalytic species presents a wide scope of reactions, as it induces both, aldolisations with ketene silyl acetals or silyl enol ethers, and Michael reactions with α , β unsaturated ketones.

We are currently studying some further developments of aldolisation and Michael reactions and investigating the nature of the catalytic species 18.

Acknowledgements : We are indebted to Pr Kagan for constant support and fruitful discussions.

References

- 1 Namy J.L., Girard P., Kagan H.B., New J. Chem., 1977, 1, 5-7.
- 2 Kagan H. B., Namy J. L., Tetrahedron, 1986, 42, 6573-6614.
- 3 Soderquist J.A., Aldrichimica Acta, 1991, 24, 15.
- 4 Molander, G.A., Chem. Rev., 1992, 29-68.
- 5 (a) Namy J.L., Souppe J., Collin J., Kagan H.B., J. Org. Chem., 1984, 49, 2045-2049; b) Collin J., Namy J.L., Kagan H.B., New. J. Chem., 1986, 10, 229-232.
- 6 Evans D.A., Rieger D.L., Jones T.K., Kaldor S.W., J. Org. Chem., 1990, 55, 6260-6268.
- 7 Evans D.A., Kaldor S.W., Jones T.K., Clardy J., Stout T.J., J. Am. Chem. Soc., 1990, 110, 7001-7031.
- 8 Prandi J., Namy J. L., Menoret G.; Kagan H. B., J. Organometal. Chem., 1985, 285, 449-460.
- a) Lu X., Ma S., Zhu J., Tetrahedron Lett., 1988, 29, 5129-5130; b) Ma S., Lu X., Tetrahedron, 1990, 46, 357-364; c) Ma S., Lu X., J. Chem. Soc. Perkin Trans. I, 1990, 2031-2033.
- 10 Vougioukas A.E., Kagan H.B., Tetrahedron Lett., 1987, 28, 5513-5516.
- 11 Gong L., Streitwieser A., J. Org. Chem., 1990, 55, 6235-6236.
- 12 Mikami K., Terada, M., Nakai T., J. Org. Chem., 1991, 56, 5456-5459.
- a) Mikami K., Terada M., Nakai T., *Tetrahedron Assym.*, 1991, 2, 993-996; b) Gu J.H., Terada M., Mikami K., Nakai T., *Tetrahedron Lett.*, 1992, 33, 1465-1468; c) Terada M., Gu J.H., Deka D.C., Mikami K., Nakai, *Chem. Lett.*, 1992, 29-32.
- 14 a) Kobayashi S., Chem. Lett., 1991, 2087-2090; b) Kobayashi S., Hachiya I., Tetrahedron Lett.,
 1992, 33, 1625-1628.
- 15 Sasai H., Suzuki T., Arai S., Arai T., Shibasaki, J. Am. Chem. Soc., 1992, 114, 4418-4420.
- 16 Makioka Y., Takaki K., Fujiwara Y., Rare Earths 92, Kyoto, June 1992.
- 17 Kobayashi S, Hachiya I., Takahori T., Araki M., Ishiatani H., Tetrahedron Lett., 1992, 33, 6815-6818.
- 18 For recent examples of catalyzed aldolisation and Michael reactions, see a) Grieco P.A., Cooke R.J., Henry K. J., VanderRoest J.M., *Tetrahedron Lett.*, **1991**, *31*, 4665-4668 ; b) Reetz M.T., Fox D.N.A., *Tetrahedron Lett.*, **1993**, *34*, 1119-1122 ; c) Odenkirk W., Whelan J., Bosnich B., *Tetrahedron Lett.*, **1992**, *33*, 5729-5732.

(Received in France 24 March 1993; accepted 20 April 1993)