

CATALYSIS OF THE MICHAEL REACTION

Pierre Laszlo* and Pascal Pennetreau

Institut de Chimie Organique
Université de Liège au Sart-Tilman
4000 Liège, Belgium

Abstract : Two nearly equivalent procedures have been evolved for catalysis of the Michael reaction : (i) potassium t-butoxide deposited on xonotlite; and (ii) alumina-supported potassium fluoride. These catalysts will undergo 150+ turnovers and enable Michael additions to be run at room temperature or below in good yields.

MICHAEL reactions form a new C-C bond between a carbanionic donor synthon d and an acceptor synthon a : the latter, an activated olefin, is typically an α,β -unsaturated ketone, which makes the addition vinylogous to aldol addition. Hence, an even number of interposed carbons separate the nucleophile and the electrophile. During the course of the reaction, electronic charge migrates from carbon in the donor to a better acceptor atom, usually oxygen, in the electrophile. A sufficiently stabilized carbanion is required : base serves to form the donor from the activated methylene precursor. The importance of Michael additions stems also from their being component parts of Robinson annelations¹⁻³. Side reactions to be avoided are aldol addition (a¹ rather than a³ synthon), and coupling of the carbanion with its activated methylene precursor.

We have a general program at improvement of important organic reactions, such as Diels-Alder cycloadditions⁴⁻⁶, to make them efficient and selective at ambient temperature or below, using only low-cost reagents and materials. We latched upon the Michael reaction, because it is one of the sacred cows of organic chemistry : should it be left alone ? It is nearly a century-old (1887) : it is ample time to devise catalysts for it, we feel.

Rational design of a catalyst has to answer the need here for a Brönsted base, which could be further improved by providing it with neighboring storage areas in which to dump the abstracted protons : we thought of inorganic supports of the metallic oxide type, with their numerous oxygens for this ancillary role; the primary basic function could be fulfilled, we figured, by doping them with strongly basic anionic centers.

Two solutions were evolved :

- A. use alumina⁷ (a solid acid which contains intrinsic basic sites already used in aldol reactions^{8,9}) and boost the basicity by adsorption of fluoride ions from KF;
- B. use the new calcium aluminosilicate xonotlite¹⁰, a basic support also, which we have made more basic yet by adsorption of *t*-butoxide ions from $\text{KOC}(\text{CH}_3)_3$. The catalyst is prepared by dissolving *t*-BuOK (3,6 or 9 g) in *t*-BuOH (200 ml); xonotlite (15g) is added and the mixture is stirred vigorously for 5 minutes. The flask is connected to a rotary evaporator and *t*-BuOH is eliminated under reduced pressure, on a water bath at 60°C. The catalyst is further dried for one night in an oven at 120°C; it can be stored at room temperature and is stable for several months.

Results, using both procedures, are indicated below (Table 1).

<u>donor</u>	<u>acceptor</u>	<u>reaction conditions</u>	<u>yields^a</u>
acetylacetone (50mM)	methylvinylketone (50mM)	200mg B(6/15) ^b , THF ^c , r.t., 4d	79%
ethylacetoacetate (50mM)	methylvinylketone (50mM)	200mg B(3/15), THF, r.t., 3d	70%
diethylmalonate (50mM)	methylvinylketone (50mM)	200mg B(3/15), THF, r.t., 3d	70%
acetylacetone (50mM)	acrolein (50mM)	200mg B(3/15), THF, 0°, 24h	74% ^{**}
ethylacetoacetate (50mM)	acrolein (50mM)	100mg B(3/15), THF, 0°, 24h	62% ^{**}
diethylmalonate (50mM)	acrolein (50mM)	200mg B(9/15), THF, 0°, 4d	60% ^{**}
dimedone (10mM)	methylvinylketone (10mM)	50mg A ¹¹ , THF, r.t., 3d	100%

a. Isolated yields, except^{**}, from GC integration

b. y/15 = t-BuOK/xonotlite (w/w)

c. in CH₂Cl₂, 90% yields are achieved after 20h of reaction at r.t.

Table 1 : Michael additions with catalysis by basic inorganic supports.

Based upon the quantity of the catalyst used, a minimum of 150 catalytic cycles are effected. We feel that this method is a significant improvement over existing methods, including some recent attempts at catalysis^{12,13}.

Acknowledgments :

We thank Dr. A. Mathy of this laboratory for devising the t-BuOK doping procedure for xonotlite, and the Eternit company for the gift of samples of xonotlite. We are grateful to Programmation de la Politique Scientifique, Brussels, for generous support of this work (Action Concertée 82/87-34).

References :

1. W.S. Johnson, J. Szmuszkowicz, E.R. Rogier, H.I. Hadler, and H. Wynberg, J. Am. Chem. Soc., **78**, 6285 (1956).
2. B.P. Mundy, J. Chem. Ed., **50**, 110 (1973).
3. M.E. Jung, Tetrahedron, **32**, 3 (1976).
4. P. Laszlo and J. Lucchetti, Tetrahedron Lett., **25**, 1567 (1984).
5. P. Laszlo and J. Lucchetti, Tetrahedron Lett., **25**, 2147 (1984).
6. P. Laszlo and J. Lucchetti, Tetrahedron Lett., **25**, 4387 (1984).
7. G.H. Posner, Angew. Chem. Int. Ed. Engl., **17**, 487 (1978).
8. V.A. Bell and H.S. Gold, J. Catal., **79**, 286 (1983).
9. D. Villemin, J. Chem. Soc. Chem. Commun., p. 1092 (1983).
10. An hydrothermally synthesized calcium silicate, $\text{Ca}_6\text{Si}_6\text{O}_{17}(\text{OH})_2$, with a BET specific surface of $60 \text{ m}^2\text{.g}^{-1}$ and particle size peaking at 75-100 μ (Promaxon registered trademark).
The structure consists of double chains of silicate units, regularly cross-linked to one another, with two Q^2 groups to every Q^3 bridgehead.
E. Lippmaa, M. Mägis, A. Samoson, G. Engelhardt, and A.-R. Grimmer, J. Am. Chem. Soc., **102**, 4889 (1980).
11. J. Yamawaki and T. Ando, Chem. Lett., p. 755 (1979).
12. J. Yamawaki, T. Kawate, T. Ando, and T. Hanafusa, Bull. Chem. Soc. Jpn., **56**, 1885 (1983).
13. J.H. Clark, D.G. Cork, and M.S. Robertson, Chem. Lett., p. 1145 (1983).

(Received in France 11 March 1985)