Tetrahedron Letters,Vol.29,No.19,pp 2321-2324,1988 0040-4039/88 $3.00 + .00
Printed in Great Britain Pergamon Press plc

OXIDATION OF ALKYNES INTO CONJUGATED ACETYLENIC KETONES WITH TERT-BUTYL HYDROPEROXIDE CATALYZED BY CHROMIUM^{VI} OXIDE

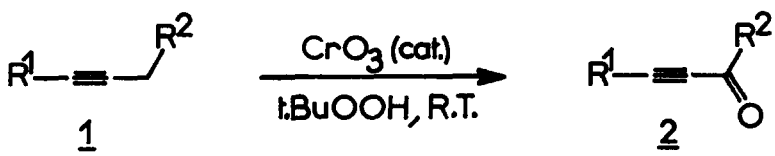
Jacques MUZART and Olivier PIVA*

Laboratoire de Photochimie, Unité Associée au CNRS n° 459
Université de Reims Champagne-Ardenne, 51062 Reims Cédex

Summary : Using t.BuOOH with catalytic amounts of CrO_3 and TsOH, regioselective α-oxidation of alkynes to conjugated ynones was observed at room temperature with yields superior to those of stoichiometric chromium procedures. Yields were slighty decreased in the absence of p.toluenesulfonic acid.

Chromium^{VI} oxide-pyridine complex (Sarett's reagent) remains the most reliable reagent for direct oxidation of alkynes into conjugated acetylenic ketones (1-3) but an excess up to 22 equiv. of Cr^{VI} is required and low yields are often obtained. An alternative approach of this transformation, which uses tert.butyl hydroperoxide associated to 0.5 equiv. of selenium dioxide, leads to a mixture of acetylenic alcohols and ketones where the former are the major products (4,5). With these procedures, the elimination of toxic chromium- or selenium- containing residues is cumbersome. It is singular that, unlike olefins (6), catalytic α-oxidation of acetylenes has not been developped (3).

Recently, we reported benzylic and allylic oxidations with t.BuOOH catalyzed by Pd^{II} or Cr^{VI} compounds (7-9). We have now observed that catalytic amounts of chromium^{VI} oxide induce efficiently the α-oxidation of alkynes by t.BuOOH.



1 2

a) R^1=Ph, R^2=$(CH_2)_2CH_3$ b) R^1=Ph, R^2=CH_3
c) R^1=CH_3, R^2=$(CH_2)_5CH_3$ d) R^1=$(CH_2)_5CH_3$, R^2=CH_3
e) R^1=$(CH_2)_2CH_3$, R^2=CH_2CH_3 f) R^1=$(CH_2)_3CH_3$, R^2=$(CH_2)_2CH_3$;
g) R^1=H, R^2=$(CH_2)_8CH_3$.

A preliminary experiment was performed under the catalytic conditions we used previously (9): 1-phenyl 1-hexyne 1a (1 mmole) was added at room temperature to a mixture of 70% t.BuOOH (7 equiv.) and CrO_3 (0.05 equiv.) in methylene chloride (table, run 1). After stirring for 21h., filtration of the mixture through a plug of alumina followed by preparative thin-layer chromatography led to starting material 1a (35%) and 6-phenyl-5-hexyn-4-one 2a (41%). Switching from

CH_2Cl_2 to benzene as solvent increased greatly the process efficiency (run 2). Use of anhydrous t.BuOOH (10) instead of aqueous t.BuOOH afforded similar results when benzene was used as the reaction solvent (run 3), while poor results were observed in CH_2Cl_2 (run 4). When a small amount of p.toluenesulfonic acid was added to the initial reaction mixture, yield of 2a rose to 62% (run 5). Reducing the quantity of both chromium catalyst and t.BuOOH to respectively 0.01 equiv. and 2 equiv. did not decrease the yield dramatically (runs 6,7).

The examples summarized in table attest to the generality and regioselectivity of this reaction. When the acetylene bears one methylene and one methyl substituent, regiospecific oxidation of the former was observed (run 11) (13). When the acetylene bears one hexyl and one ethyl group, only the methyl ketone 2d was isolated (runs 12, 13). Symmetric alkynes such as 1e or 1f afforded selectively the monoketone which was sometimes accompagnied by the diketone (runs 14-16) (14) ; by contrast, oxidation of both sides of such acetylenic group was the predominant pathway when using the Sharpless procedure (5). Surprisingly, the 1-dodecyne 1g reacted under the present catalytic conditions (runs 18,19) while α-oxidation of a terminal triple bond was not observed in using large excess over stoichiometric of Cr^{VI} (1).

Propargylic alcohol could be a putative intermediate in the α-oxidation of 1 into 2 since we have recently shown the chromium-catalyzed oxidation of alcohols into ketones by t.BuOOH (16). Ketone 2a was indeed obtained from 6-phenyl-6-hexyn-4-ol 3 under the present conditions (run 20). So, a reactive pathway for α-oxidation of alkynes into acetylenic ketones could involve two overlapping catalytic cycles. The former shown in continuous lines in the scheme would lead to the acetylenic alcohol : arguments for tert.butyl-μ-peroxo-chromium intermediate A has been previously developped (9,16) and formation of transient species B by homolysis of a Cr-peroxy bond is a way reminiscent of that proposed by Mimoun for hydroxylation of hydrocarbons by peroxo and alkylperoxidic complexes (17). The second catalytic cycle (summarized in the scheme, dotted arrows- - -) would transform the alcohol into the ketone as we recently proposed (16). However, we cannot exclude formation of propargyl chromium ester D from C without intervention of alcohol intermediate (see scheme, dotted arrows•••••).

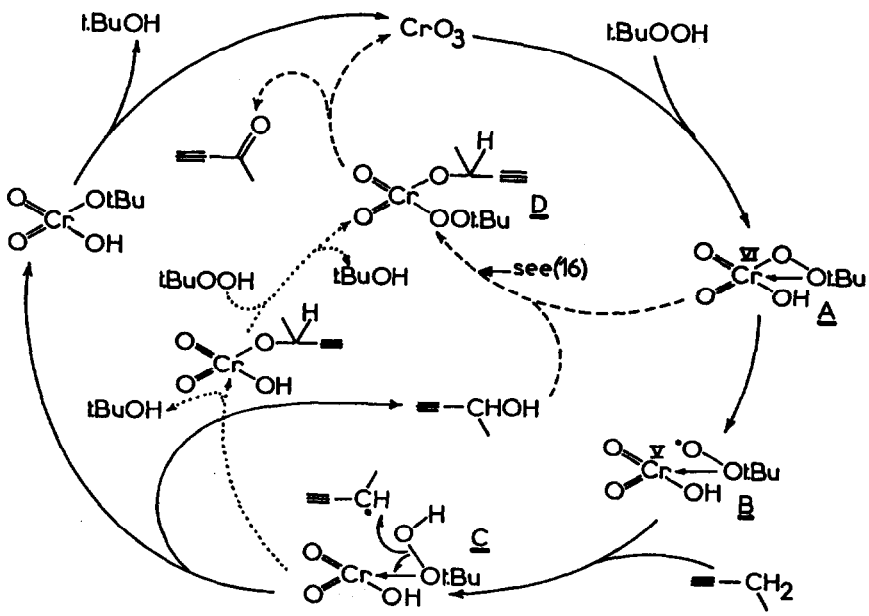


Table : Oxidations by CrO_3-t.BuOOH at room temperature

Run	S.M.	Equiv. of CrO_3	Solvent	t.BuOOH[a] equiv.	Equiv. of TsOH, H_2O	Time h	Isolated Products, % 1	2
1	1a	0.05	CH_2Cl_2	A, 7	0	21	35	41
2		0.05	PhH	A, 7	0	42	15	57
3		0.05	PhH	B, 7	0	44	15	56
4		0.05	CH_2Cl_2	C, 7	0	17	18	17
5		0.05	PhH	B, 7	0.05	44	12	62
6		0.01	PhH	B, 2	0	66	26	46
7		0.01	PhH	B, 2	0.02	66	22	55
8	1b	0.05	PhH	B, 7	0	17	9	51
9		0.05	PhH	B, 7	0.1	18	10	56
10		0.01	PhH	B, 2	0.02	46	33	40
11	1c	0.05	PhH	B, 7	0.1	20	9	47
12	1d	0.05	PhH	B, 7	0.1	21	7	57
13		0.02	PhH	A, 4	0.04	92	13	53
14	1e	0.05	PhH	B, 7	0	47	b	40[c]
15		0.01	PhH	B, 2	0	70	14	28
16		0.01	PhH	B, 2	0.02	52	b	52[d]
17	1f	0.05	PhH	B, 7	0.1	63	5	61
18	1g	0.05	PhH	B, 7	0.1	85	44	33
19		0.01	PhH	B, 2	0.02	72	62	21
20	3	0.04	PhH	B,10	0.08	4	e	57

a) A : 70% t.BuOOH ; B : anhydrous solution of t.BuOOH in benzene (M = 2.7) ; C : anhydrous solution of t.BuOOH in CH_2Cl_2 (M = 3.1). b) not determinated. c) 4-octyn-3,6-dione was also isolated (19%). d) 4-octyn-3,6-dione was also isolated (5%). e) 3 was isolated (9%).

The role of TsOH remains unclear. Although it is not necessary, it allows generally better yields for these oxidations ; it could increase the efficiency of the reactions between substrate (starting alkyne or intermediate alcohol) and chromium intermediates (18).

To our knowledge, the results presented herein constitutes the first report of a catalytic procedure for α-oxidation of alkynes. Its efficiency allows yields superior to those of stoichiometric chromium methods (1,2). In all cases, a single oxygenation product predominates and as these catalytic reactions are simple to perform (19), the present catalytic procedure should represent a useful oxidation method in organic synthesis.

References and notes

1) J.E. SHAW and J.J. SHERRY, Tetrahedron Lett., 1971, 4379.
2) W.B. SHEATS, L.K. OLLI, R. STOUT, J.T. LUNDZEN, R. JUSTUS and W.G. NIGH, J. Org. Chem., 1979, 44, 4075.
3) a) R.A. SHELDON and J.K. KOCHI "Metal-Catalyzed Oxidations of Organic Compounds", Acad. Press, New York, 1981, p. 154, 307
b) G. CAINELLI and G. CARDILLO, "Chromium Oxidations in Organic Chemistry", Springer-Verlag, Berlin, 1984, p. 47
c) F. FREEMAN in "Organic Syntheses by Oxidation with Metal Compounds", Ed. by W.J. MISS and C.R.H.I. DE JONGE, Plenum Press, New York, 1986, p. 52.
4) M.A. UMBREIT and K.B. SHARPLESS, J. Amer. Chem. Soc., 1977, 99, 5527.
5) B. CHABAUD and K.B. SHARPLESS, J. Org. Chem., 1979, 44, 4202.
6) For a recent review of metal-catalyzed allylic oxidations of olefins : J. MUZART, Bull. Soc. Chim. Fr., 1986, 65.
7) J. MUZART, J.P. PETE and A. RIAHI, J. Organomet. Chem., 1987, 331, 113.
8) J. MUZART, Tetrahedron Lett., 1986, 27, 3139.
9) J. MUZART, Tetrahedron Lett., 1987, 28, 2131, 4665.
10) Anhydrous t.BuOOH was prepared by known methods (5,11): solvent (CH_2Cl_2 or PhH) and 70% aqueous t.BuOOH were swirled in a separatory funnel, then the organic layer was dried over $MgSO_4$ and stored over molecular sieves 4 Å. Molarity was determinated by N.M.R. titration(12).
11) A.J. BLOODWORTH, K.H. CHAN and C.J. COOKSEY, J. Org. Chem., 1986, 51, 2110.
12) a) K.B. SHARPLESS and T.R. VERHOEVEN, Aldrichimica Acta, 1979, 12, 63
b) J.G. HILL, B.E. ROSSITER and K.B. SHARPLESS, J. Org. Chem., 1983, 48, 3607.
13) No aldehydic proton was detected in the N.M.R. spectra of the crude product obtained after filtration of the reaction mixture on alumina and evaporation of solvents.
14) Acetylenic α,α'-diketones were unstable (5,15) and remained minor compounds..
15) K. BOWDEN, I.M. HEILBRON, E.R.H. JONES and B.C.L. WEEDON, J. Chem. Soc., 1946, 39.
16) J. MUZART, Tetrahedron Lett., 1987, 28, 2133.
17) a) H. MIMOUN, L. SAUSSINE, E. DAIRE, M. POSTEL, J. FISCHER and R. WEISS, J. Amer. Chem. Soc., 1983, 105, 3101
b) H. MIMOUN, P. CHAUMETTE, M. MIGNARD and L. SAUSSINE, Nouv. J. Chim., 1983, 7, 467
c) E. DAIRE, H. MIMOUN and L. SAUSSINE, Nouv. J. Chim., 1984, 8, 271.
18) We have observed that the yield of oxidation of indanol-1 was increased from 77% under the previously published conditions (16) to 90% when using CrO_3 (0.05 equiv.), TsOH (0.1 equiv.), t.BuOOH (7 equiv.) in benzene for 4h.
19) ***Caution*** : t.BuOOH presents an explosion hazard when concentrated and heated. For large scale reactions, excess of t.BuOOH has to be reduced during work-up (4, 5, 11, 16, 20). For run 13 performed on 10 mmoles scale, Na_2SO_3 was used as reducing agent.
One referee noted that addition of CrO_3 to t.BuOOH could lead to dangerous decomposition of this hydroperoxide. Under our experimental conditions, we always added t.BuOOH to a suspension of CrO_3 in CH_2Cl_2 (9,16) ; this procedure seemed to be safer.
20) R.D. MAIR and R.T. HALL in "Organic Peroxides", Ed. by D. SWERN, Wiley Interscience, New York, Vol. 2, 1971, p. 535.

(Received in France 12 February 1988)