Tetrahedron Letters,Vol.25,No.38,pp 4219-4222,1984 0040-4039/84 $3.00 + .00
Printed in Great Britain

SELECTIVE OXIDATION OF SATURATED HYDROCARBONS AT SECONDARY POSITIONS

Derek H.R. Barton, Jean Boivin, Nubar Ozbalik* and Kathy M. Schwartzentruber

Institut de Chimie des Substances Naturelles, C.N.R.S.,
91190 Gif-sur-Yvette, France.

The selectivity in the oxidation of saturated hydrocarbons by oxygen in pyridine-acetic acid in presence of an iron catalyst and zinc is strongly dependant on the oxygenation of the reaction mixture; using air and slow stirring, it is possible to attack adamantane and *trans*-1,4-dimethylcyclohexane almost exclusively at the secondary positions.

We recently reported[1] a system for the oxidation of saturated hydrocarbons that comprised pyridine-acetic acid containing a soluble iron complex as catalyst and with zinc as a source of electrons and oxygen as oxidant. Such a system gives a high turnover in catalyst and superior yields of oxidised products to comparable systems.[1]

Of the hydrocarbons so far oxidised[2] a marked tendency for attack at secondary positions was observed, but with some substitution in primary groups. There was little attack at tertiary positions except for adamantane (1). This hydrocarbon plays a key role in our arguments. If we define C^2/C^3 as the ratio of secondary substituted products (alcohol and ketone) to tertiary substitution (alcohol) then the statistical number is 3. Values of less than 3 indicate preferential attack at the tertiary position and hence radical chemistry. Values above 3 indicate a different chemical mechanism.

We have now examinated the radical autoxidation of adamantane in pyridine acetic acid at 80° with benzoyl peroxide as initiator. A C^2/C^3 value of 0.85 was observed in agreement with the scanty literature data.[3] If we suppose that all the tertiary alcohol results from radical autoxidation then we can calculate the percentage of secondary alcohol and ketone produced by this mechanism. We can then determine the percentage miminum non-chain oxidation reaction.

Already in previous work[2] there was an indication that the ratio C^2/C^3 depended on the flow rate of oxygen. We now show (Table 1) that air gives a higher C^2/C^3 than oxygen and that the slower the flow rate of the air the higher is C^2/C^3. The minimum non-radical reaction can be more than 90%.

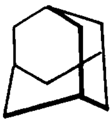
A small amount of water (6.6%) also increases C^2/C^3 by suppressing the formation of tertiary alcohol (entries 7 and 8).

The simplest way to carry out the oxidation now becomes under an atmosphere of air in an open flask at room temperature (20°) (Table 2). Here C^2/C^3 depends on the rate of stirring. We have also recovered the unused zinc and calculated the electron yield, that is the % of electrons which are usefully used in oxidising the adamantane assuming the reactions :

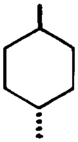
$$\begin{array}{lllllllllll} & {-}\!\!\!>\!C\text{-}H & + & O_2 & + & 2e^- & + & 2H^{\oplus} & \longrightarrow & {-}\!\!\!>\!C\text{-}OH & + & H_2O \\ \text{and} & >\!CH_2 & + & 2O_2 & + & 4e^- & + & 4H^{\oplus} & \longrightarrow & >\!C{=}O & + & 3H_2O \end{array}$$

In order to test the selectivity of our modified experimental conditions we have oxidised commercially available trans-1,4-dimethylcyclohexane (2). The major product was trans-2,5-dimethylcyclohexanone (3) in 14.2% yield. The yield and structure were confirmed by the identity of the 2,4-dinitrophenylhydrazone derivative with an authentic specimen. A small amount of the aldehyde (4) (1.3%, characterised as its 2,4-dinitrophenylhydrazone)[4] was formed. No tertiary alcohol (5) was detectable and an authentic specimen was not changed at all under the experimental conditions (including g.l.c. analysis). The acid (6)[4] and the alcohol (7) were not formed and the two secondary alcohols (8) were not detectable when compared (g.l.c.) to authentic specimens.

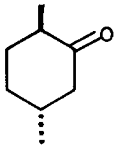
These results confirm the high selectivity of the Gif system for secondary attack on saturated hydrocarbons. An obvious hypothesis for the selectivity that we observe is the formation (and reaction with oxygen) of iron-carbene complexes. This remains to be tested further.



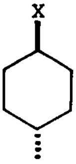
(1)



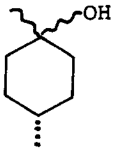
(2)



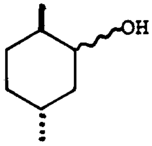
(3)



(4) X = CHO
(6) X = CO_2H
(7) X = CH_2OH



(5)



(8)

Table 1[1]

Entry	Flow rate of air ml/min	mmoles O_2 passed	Adamantan- %			Total %	C^2/C^3	% of O_2 reacted	Minimum non-radical reaction %
			1-ol	2-ol	2-one				
1	2.1	4.7	0.25	0.6	5.6	6.45	24.8	2.8	93
2	17.1	38.4	1.20	2.1	12.2	15.50	11.9	0.8	86
3	21.2	47.7	1.15	1.9	11.7	14.75	11.8	0.6	85
4	21.8	49.0	1.40	1.9	12.2	15.50	10.1	0.6	83
5	28.5	64.0	1.40	2.0	12.5	15.90	10.4	0.5	84
6	30.0	67.5	1.45	1.8	12.1	15.35	9.6	0.45	82
7[2]	17.4	39.1	0.60	0.9	13.6	15.10	24.2	0.8	93
8	22.0	49.5	0.95	1.1	14.4	16.45	16.3	0.7	89

1) Adamantane (272 mg, 2 mmole), $[\mathrm{Fe^{II}Fe_2^{III}O(OAc)_6Pyr_3}]_2\mathrm{Pyr}$[1], zinc (1.307 g, 20 mmole) and AcOH (12.3 ml, 40 mmole) were stirred in pyridine (30 ml) at 40° for 4 hrs.

2) The solvent was pyridine containing water (6.6%, v/v).

Table 2[1]

Agitation (Scale 1 to 10)	Adamantan- %			Total	C^2/C^3	electron yield %	minimum non radical reaction %
	1-ol	2-ol	2-one				
1	0.65	0.5	11.4	12.55	18.3	8	90
3	1.00	1.0	13.1	15.10	14.1	5.6	88
5	1.25	1.2	14.2	16.65	12.3	6.2	86

1) Same conditions as in entries 7 and 8 (Table 1) but at room temperature (20°).

Acknowledgement. We thank B.P. (France) for generous financial support and Drs. D.J.H. Smith and G. E. Morris for helpful suggestions.

References

1 D.H.R. Barton, M.J. Gastiger and W.B. Motherwell, *J.C.S. Chem. Comm.*, 731 (1983); see also *idem*, *ibid*, 41 (1983).

2 D.H.R. Barton, R.S. Hay-Motherwell and W.B. Motherwell, *Tetrahedron Letts.*, 1979 (1983).

3\. G.W. Smith and H.D. Williams, *J. Org. Chem.*, *26*,2207 (1961).

4\. H. Gerlach, *Helv. Chim. Acta*, *49*, 1291 (1966).

(Received in France 12 June 1984)