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A VERSATILE METHOD FOR PREPARATION OF O-ALKYLPEROXYCARBONIC ACIDS: EPOXIDATION WITH ALKYLOXYCARBONYLIMIDAZOLES AND HYDROGEN PEROXIDE

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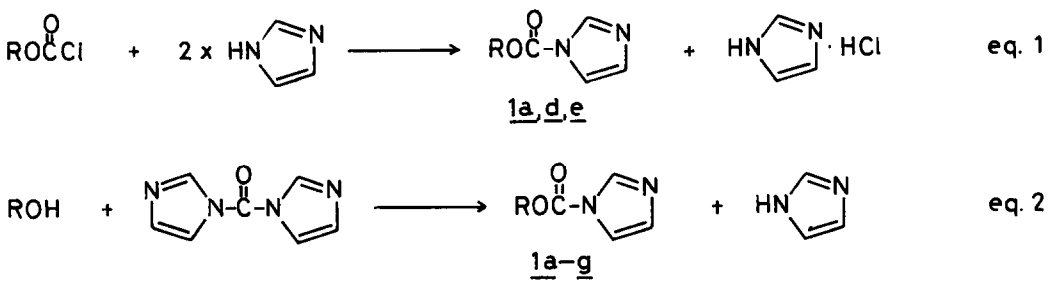
Summary : A variety of O-alkylperoxycarbonic acids (2) were conveniently prepared in situ by utilizing alkyloxycarbonylimidazoles (1) as their precursors. Epoxidation of alkenes with such peroxy-acids was studied and their reactivities were compared with those of peroxycarboxylic acids.

Although O-alkylperoxycarbonic acids are expected to be effective oxygenating agents, they have so far attracted little attention and only a few examples have been reported[1, 2]. This fact may partly be due to their instability compared with the corresponding peroxycarboxylic acids, and may also be due to laboriousness in their preparations.

We report in this paper a new convenient epoxidation method with a variety of O-alkylperoxycarbonic acids generated in situ in biphasic solvent system in which alkyloxycarbonylimidazoles (1) and aqueous hydrogen peroxide (aq. H_2O_2) were reacted under essentially neutral condition.

Alkyloxycarbonylimidazoles (1a-g) were easily prepared either by reaction of imidazole (two equivalents) with the corresponding alkylchloroformates in benzene (eq. 1) (method a), or by treatment of the corresponding alcohols in anhydrous $CHCl_3$ or CH_2Cl_2 with one equivalent or slight excess N,N'-carbonyldiimidazole (eq. 2) (method b)[3]. In both cases imidazole present after reaction was removed by washing the solution with water. Evaporation of the solvent gave usually almost pure imidazolides, and they could be further purified by chromatography, distillation or by recrystallization. The imidazolides (1a-g) used for the present study are listed in Table 2.

Scheme 1



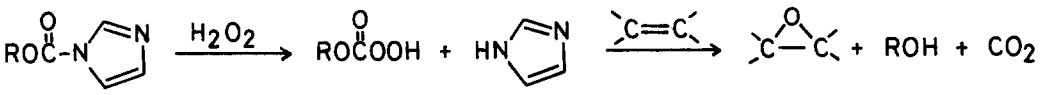
Such imidazolides were stable enough to be stored at room temperature without special precaution. They were however expected to react readily with H_2O_2 affording the corresponding peroxycarbonic acids[4]. The imidazolides tested in the present study were, indeed, found to be very sensitive to perhydrolysis, and when their CH_2Cl_2 solutions were stirred with 35 % aq.

H_2O_2 at room temperature, they disappeared within a few minutes except in the case of 1c[5], whereas they were stable to hydrolysis surviving for as long as several weeks on stirring their solutions with water.

This biphasic system was then applied to the epoxidation of alkenes : The reaction was carried out by addition of 35 % aq. H_2O_2 into the CH_2Cl_2 solution of a mixture of an alkene and an imidazolide followed by stirring at room temperature.

Although the isolation of O-alkylperoxycarbonic acids (2) has not been attempted, these reactions should conceivably follow the two-steps process shown in Scheme 2. The overall procedure was conducted cleanly under essencially neutral condition, and epoxides were isolated by simple work up.

Scheme 2



1 2

The results obtained from the epoxidation of several alkenes by using ethyloxycarbonylimidazole (1a), and of β-methylstyrene (3) and cholesterylacetate (4) by using a variety of imidazolides (1a-g) are summarized in Table 1 and 2.

In a typical preparative experiment, to 4 (1.0 g) in CH_2Cl_2 (47 ml) were added 1f (1.0 g) and 35 % aq. H_2O_2 (0.5 ml), and after 20 minutes stirring additional 1f (0.9 g) and aq. H_2O_2 (0.5 ml). After 24 hours stirring at room temperature the organic layer was separated, washed with aq. $NaHCO_3$, dried (Na_2SO_4) and concentrated (epoxides 92 % by GC, α-epoxide/β-epoxide 87/13). Silica gel column chromatography afforded α-epoxide (780 mg) and β-epoxide (150 mg) with the recovery of 4 (77 mg).

Such a two-phase epoxidation of alkenes by O-ethylperoxycarbonic acid prepared *in situ* from ethylchloroformate and aq. H_2O_2 was recently reported[2]. Our result using 1a (Table 1) was shown to be comparable to the reported data, although imidazolides (1) seem to be more susceptible to perhydrolysis than the corresponding alkylchloroformates. And the results shown in Table 2 demonstrated significant structural effect on their reactivities, which suggest that variation of R could provide further utility of such peroxy-acids. From this point of view imidazolides (1) could be very useful precursors of a variety of percarbonic acids, since such imidazolides can be very easily prepared by the method b (eq. 2) from almost all kinds of hydroxy compounds.

In the epoxidation of cyclic allylic alcohols by peroxycarboxylic acids a strong directive influence of the hydroxy group is observed, and the observation is reasonably explained in terms of a transition state such as A (Scheme 3) involving hydrogen bonding between the hydroxy group and peroxy-acid. In such epoxidation by O-alkylperoxycarbonic acids, however, several alternative transition states were conceivable because of the presence of alkoxy oxygen atom which could also perticipate to intra- and inter-molecular hydrogen bonding. We decided, therefore, to examine the stereochemical course of the epoxidation of allylic and homoallylic

Table 1. Tow-Phase Epoxidation of Alkenes with Ethyloxycarbonylimidazole (1a) / H_2O_2[a]

alkene	method[b]	reaction time (h)	yield of epoxide (%)[c]
cyclohexene	A	2	75
	B	1	95
1-methylcyclohexene	A	2	78
	B	4	90
norbornene	B	3	77
β-methylstyrene	B	3.5	66
cholesterylacetate	A	2	80 (78/22)[d]
	B	2.5	97 (79/21)[d]

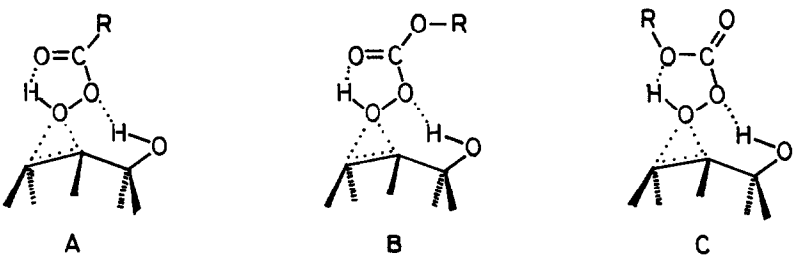
[a] All the experiments were carried out in a biphasic system with 0.5 M alkene solution in CH_2Cl_2 and 35 % aq. H_2O_2 at room temperature. [b] Method A; molar ratio of alkene/1a/H_2O_2 = 1/1.5/10. Method B; molar ratio of alkene/1a/H_2O_2 = 1/3/15. [c] Determined by gas chromatography. [d] Ratio of α-epoxide/β-epoxide.

Table 2. Epoxidations of β-Methylstyrene (3) and of Cholesterylacetate (4) with various Alkyloxycarbonylimidazoles (1a-g) / H_2O_2[a]

R		alkene	method[b]	reaction time (h)	yield of epoxide (%)[c]
CH_3CH_2	1a	3	A	3.5	71
		4	B	2.5	97 (78/22)[d]
$(CH_3)_2CH$	1b	3	A	5	80
		4	A	3	100 (81/19)[d]
$(CH_3)_3C$	1c	3	A[e]	24	84
		4	A[e]	8	100 (75/25)[d]
$PhCH_2$	1d	3	A	3	95
		4	A	1	100 (81/19)[d]
CCl_3CH_2	1e	3	A	4	85
		4	A	1	100 (85/15)[d]
$(CF_3)_2CH$	1f	3	A	1	66
		4	A	1	88 (87/13)[d]
Ph	1g	3	A	2	71
		4	A	2	92 (73/27)[d]

[a] Unless specified otherwise all the reactions were carried out in a biphasic system with 0.5 M alkene solution in CH_2Cl_2 and 35 % aq. H_2O_2 at room temperature. [b] Method A; molar ratio of alkene/1/H_2O_2 = 1/3/4.5. Method B; molar ratio of alkene/1/H_2O_2 = 1/3/15. [c] Determined by gas chromatography. [d] Ratio of α-epoxide/β-epoxide. [e] Reaction was carried out in 0.1 M alkene solution.

Scheme 3



A B C

Table 3. Ring Size and Stereoselectivity of Epoxidation of Cyclic Allylic and Homoallylic Alcohols

reagent	2-cyclohexenol epimer ratio		2-cycloheptenol epimer ratio		2-cyclooctenol epimer ratio		cholesterol epimer ratio	
	cis %	trans %	cis %	trans %	cis %	trans %	cis %	trans %
1a + H_2O_2[a]	92	8	63	37	0	100	17	83
1c + H_2O_2[a]	100	0					26	74
1f + H_2O_2[a]	92	8						
MCPBA[6]	95	5	61	39	0.2	99.8	5	95

[a] The reactions were carried out in a biphasic system with 0.5 M alkene solution in CH_2Cl_2 and 35 % aq. H_2O_2 at room temperature. Molar ratio of alkene/1/H_2O_2 = 1/3/4.5. Yields were almost quantative.

alcohols with peroxycarbonic acids prepared according to our procedure, and the result was compared with that obtained from the epoxidation of the same alkenes with m-chloroperbenzoic acid (MCPBA)[6]. The data shown in Table 3 suggest that, in both peroxycarboxylic and peroxycarbonic acids, the same kind of directing influence is controlling the steric courses of these reactions and, hence, also in the epoxidation of allylic alcohols by peroxycarbonic acid, involvement of such transition states as B or C is likely.

As was pointed out in the previous papers[1, 2], peroxycarbonic acids should provide a useful alternative to peroxycarboxylic acids for the epoxidation and other oxygen transfer reactions, and the present method can offer many different such reagents. However, for the optimization of the product yields in this procedure further experimental devices should be required.

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4. Alkyloxycarbonylimidazoles react with alcohols to give dialkylcarbonates[3], and H_2O_2 is a better nucleophile than normal alcohols.
5. Under the same reaction condition 1c survived for 8 hours.
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