

FREE RADICAL ADDITION OF α -BROMOCARBOXYLIC ACIDS TO OLEFINS
LEADING TO γ -BUTYROLACTONES

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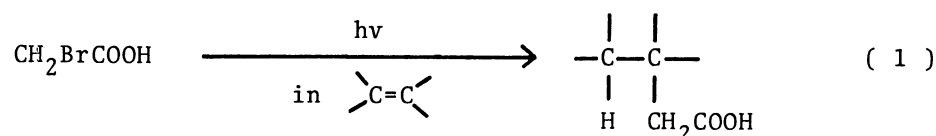
Benzoyl peroxide-catalyzed free radical addition of bromoacetic, α -bromopropionic, and α -bromobutyric acids to olefins took place under mild conditions to afford γ -alkyl-, γ -alkyl- α -methyl-, and γ -alkyl- α -ethyl- γ -butyrolactones in good yields.

There has been considerable interest in the γ -butyrolactone construction, since γ -butyrolactones are sometimes used for flavor and additives for foods. They also act as precursors for biologically active α,β -butenolides¹⁾ or α -methylene- γ -butyrolactones.²⁾

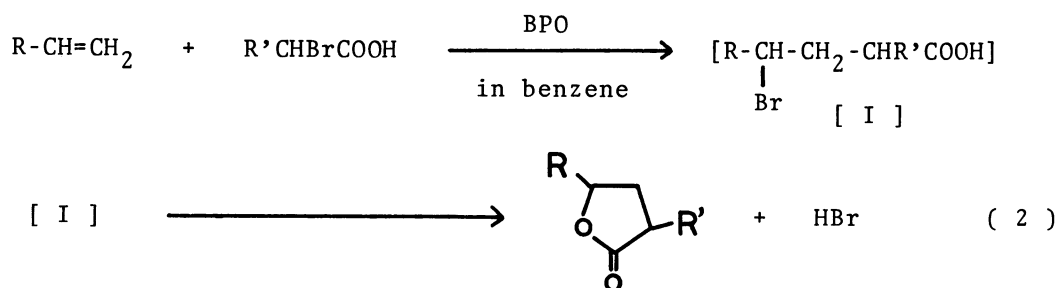
Conventional preparation of γ -butyrolactones usually involves multi-step sequences³⁾ and not always convenient. More recently, Heiba et al.⁴⁾ proposed one-step γ -butyrolactone synthesis consisting of the addition of a carboxylic acid with an α -hydrogen atom across to the double bond of an olefin. However, the method necessitates stoichiometric amount (2 equiv/mol of lactone) of various metal oxidants such as higher valent metal salts of manganese, cerium, and vanadium. Therefore, exploitation of a facile method for the γ -butyrolactone construction is highly desirable.

In view of the well-known fact that peroxide-induced radical addition of α -bromo esters to olefins gives 1:1 adducts in good yields,⁵⁾ it might be anticipated that the free radical addition of α -bromocarboxylic acids to olefins would take place resulting in the formation of γ -bromocarboxylic acids which in turn will afford γ -butyrolactones. However, N. Kharasch et al.⁶⁾ reported recently that photolysis of bromoacetic acid in excess cyclohexene or 1-hexene afforded only the debrominated aliphatic carboxylic acid in high yield (cyclohexylacetic acid or

n-octyric acid), according to eq 1.



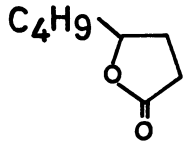
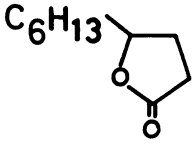
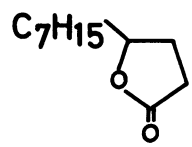
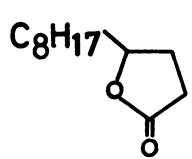
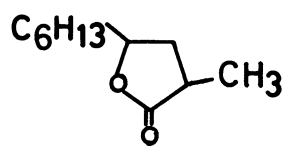
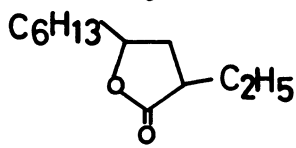
We found that the benzoyl peroxide-catalyzed free radical addition of α -bromocarboxylic acids to olefins (ca. 0.8 equiv) did take place smoothly to give γ -butyrolactones as outlined in eq 2, and we wish to report hereby this reaction since it constitutes a novel and convenient route to γ -butyrolactones.



Typically, to a mixture of 1-octene (5.6 g, 49.4 mmol), bromoacetic acid (8.3 g, 59.7 mmol), and benzene (15 ml) was added at reflux with stirring a solution of benzoyl peroxide (1.2 g, 4.9 mmol) in benzene (15 ml) for a period of 1 hr under nitrogen atmosphere and the mixture was further heated for additional 5 hr. GLC analysis of the resulting mixture disclosed that γ -hexyl- γ -butyrolactone was formed in 72% yield based on the 1-octene charged. The mixture was washed with water and dried over magnesium sulfate. After concentration, vacuum distillation gave the γ -butyrolactone as a colorless liquid boiling at $97^\circ\text{C}/0.6 \text{ mmHg}^7)$ (5.8 g, 68% yield, $n_D^{20} 1.4495^5)$). Structure determination was performed by IR and NMR spectra. In this reaction, the formation of n-capric acid was not significant (6.5% yield by GLC).

The reaction of α -bromopropionic acid and α -bromobutyric acid with 1-octene also gave the expected lactones in reasonable yields and the results are summarized in the Table. Although direct one-step synthesis of γ -butyrolactones by the reaction of bromoacetic acid with olefins in the presence of potassium bromide⁸⁾ or ferrous chloride⁹⁾ has been reported, the former reaction requires vigorous conditions ($170^\circ\text{-}190^\circ\text{C}$) and the latter is associated with rather low yield (at most 30%).

Table. Reaction of terminal olefins with α -bromocarboxylic acids¹⁰⁾

Entry	Olefin	α -Bromocarboxylic acid	Lactone	Yield % ^a
1	1-Hexene	CH_2BrCOOH		65 (58)
2 ^b	1-Octene	CH_2BrCOOH		72 (68)
3	1-Nonene	CH_2BrCOOH		73 (58)
4	1-Decene	CH_2BrCOOH		77 (54)
5 ^c	1-Octene	$\text{CH}_3\text{CHBrCOOH}$		79 (45)
6 ^{b,c}	1-Octene	$\text{CH}_3\text{CH}_2\text{CHBrCOOH}$		42 (31)
7 ^d	1-Hexene	$\text{CH}_2\text{BrCHBrCOOH}$	—	0

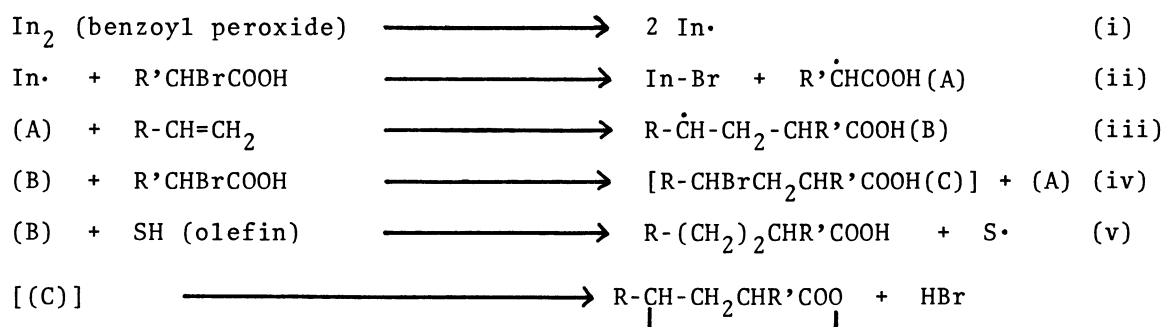
a) GLC yields. Isolated yields based on the olefin charged are shown in parentheses.

b) Experiments by using molar ratio of olefin/halo acid = 1/3 gave similar yield.

c) Fifteen mol% of benzoyl peroxide was used.

d) Only 1-hexene was consumed.

Finally, it should also be noted that the present reaction can be understood readily by a mechanism involving the radical chain carrying steps (iii, iv). The γ -bromocarboxylic acid (C) initially formed is thermally unstable and will give the γ -butyrolactone under the conditions employed. The formation of the debrominated carboxylic acids observed by N. Kharasch et al.⁶⁾ is undoubtedly due to the attack of radicals such as (B) on mobile hydrogens of an olefin solvent which was present in much larger quantities in their systems (v).



References and Notes

1. Y. S. Rao, Chem. Rev., 1964, 353 ; 1976, 625.
2. P. A. Grieco, Synthesis, 1975, 67.
3. R. P. Linstead and H. N. Rydon, J. Chem. Soc., 1933, 580.
4. E. I. Heiba and R. M. Dessau, J. Am. Chem. Soc., 93, 995 (1971); E. I. Heiba, R. M. Dessau, and P. G. Rodewald, J. Am. Chem. Soc., 96, 7977 (1974).
5. M. S. Kharasch, P. S. Skell, and P. Fisher, J. Am. Chem. Soc., 70, 1055 (1948), n_D^{20} 1.4489.
6. N. Kharasch, P. Lewis, and R. K. Sharma, J. Chem. Soc., Chem. Commun., 1967, 435.
7. 1 mmHg = 13.5951 X 980 X 10⁻² Pa.
8. T. Kishimoto, H. Ishihara, and Y. Matsubara, Bull. Chem. Soc. Jpn., 50, 1897 (1977).
9. M. Watanabe, K. Okamoto, I. Imada, and H. Morimoto, Chem. Pharm. Bull., 26, 774 (1978).
10. We found that benzoyl peroxide was the most effective catalyst for the reaction among those examined such as benzoyl peroxide, dichlorotris(triphenylphosphine)-ruthenium (II), di-*t*-butyl peroxide, cuprous chloride, and azobisisobutyronitrile.

(Received January 9, 1981)