Notes

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Studies on Ketene and Its Derivatives. XCII.[1] Reaction of Diketene with Benzaldehyde, Cinnamaldehyde, and β-Phenylcinnamaldehyde

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Reaction of diketene with benzaldehyde (**1**) in the presence of sulfuric acid gives α-benzylideneacetoacetic acid (**5**). Similarly, reaction of diketene with cinnamaldehyde (**2**) and β-phenylcinnamaldehyde (**3**) gives 2-acetyl-5-phenyl-2,4-pentadienoic acid (**6**) and 2-acetyl-5,5-diphenyl-2,4-pentadienoic acid (**7**), respectively.

Keywords——diketene; acetoacetic acid derivatives; α-benzylideneacetoacetic acid; α-cinnamylideneacetoacetic acid; 2,4-pentadienoic acid derivatives; β-lactone intermediate

It is a well documented fact that diketene reacts with ketones in the presence of acidic catalysts such as *p*-toluenesulfonic acid giving 2,2-disubstituted 6-methyl-4H-1,3-dioxin-4-one.[3] Diketene also reacts with aldehydes, however, the product is variant depending on the reaction conditions, especially on the catalyst. For instance, reaction of diketene with benzaldehyde (**1**) in the presence of sodium acetate gives rise to benzalacetone (**4**).[4] The use of aluminum oxide as a catalyst results in the formation of cyclic adducts, 1,3-dioxin-4-one derivatives.[5] Furthermore, ethyl 5-hydroxy-5-phenyl-3-oxo-pentanoate was obtained in 95% yield by the reaction of diketene with benzaldehyde in the presence of titanium chloride followed by ethanolysis.[6]

As a continuation of our study of some potential uses of diketene, we now report the reaction of diketene with benzaldehyde in the presence of sulfuric acid to give α-benzylideneacetoacetic acid.

When benzaldehyde (**1**) was allowed to react with diketene in the presence of conc. sulfuric acid, an acidic product (**5**) was obtained, which was soluble in sodium bicarbonate solution and was converted to benzalacetone (**4**) on heating. The elemental and spectral analyses provided its structure being α-benzylideneacetoacetic acid (**5**). NMR spectral study suggested the acid (**5**) existed in the mixture of (*Z*) and (*E*) isomers in the ratio of 3 : 8. Methylation of compound (**5**) with diazomethane gave rise to the methyl ester (**8**), whose NMR spectrum indicated that the (*Z*) and (*E*) isomers existed in the same ratio (3 : 8) as in the case of the acid (**5**).

The ester (**8**) was identified unequivocally by the comparison of its infrared (IR) and nuclear magnetic resonance (NMR) spectra with those of an authentic sample prepared from methyl acetoacetate and benzaldehyde according to the literature.[7,8]

1) Part XCI: T. Kato, M. Sato, and Y. Suzuki, *Chem. Lett.*, **1978**, 697.
2) Location: *Aobayama, Sendai 980, Japan.*
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8) The 1 : 1 ratio of *cis* and *trans* isomers was reported.

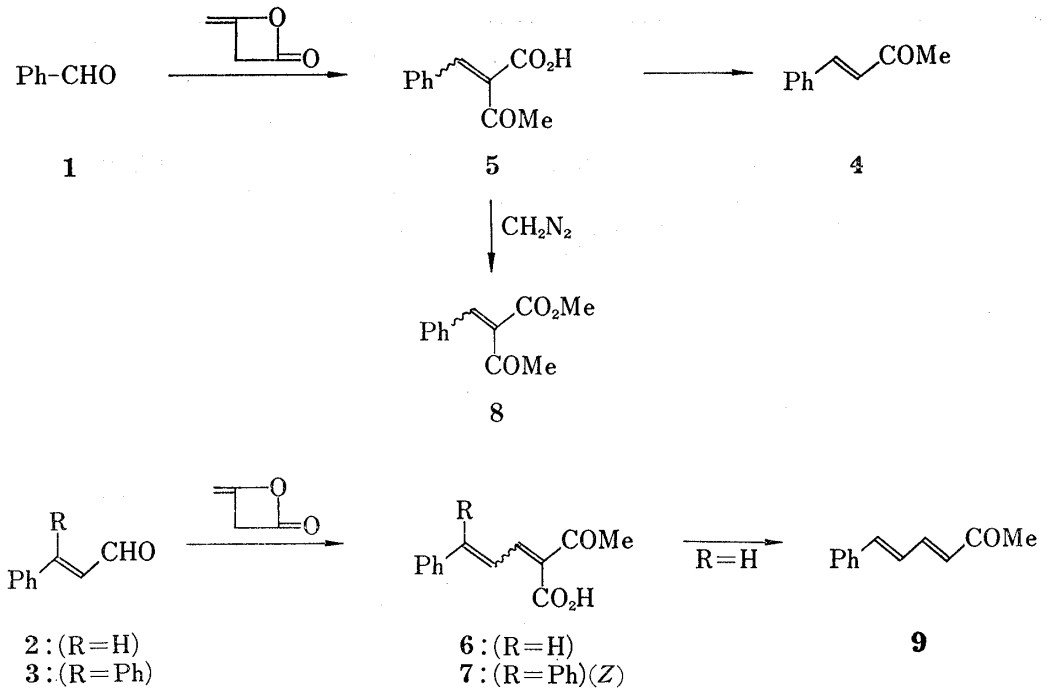

Chart 1

Similarly, cinnamaldehyde (**2**) reacted with diketene to give the acid (**6**), heating of which in pyridine afforded the decarboxylated product (**9**). Compound (**9**) was characterized by the comparison of spectral data and mixed melting point test with an authentic sample of (*E*, *E*)-6-phenyl-3,5-hexadien-2-one (**9**).[9] The configuration of the acid (**6**) was not determined.

β-Phenylcinnamaldehyde (**3**) reacted with diketene similarly to give the corresponding (*Z*)-carboxylic acid (**7**), which was identified by the comparison with an authentic sample prepared according to the literature.[10]

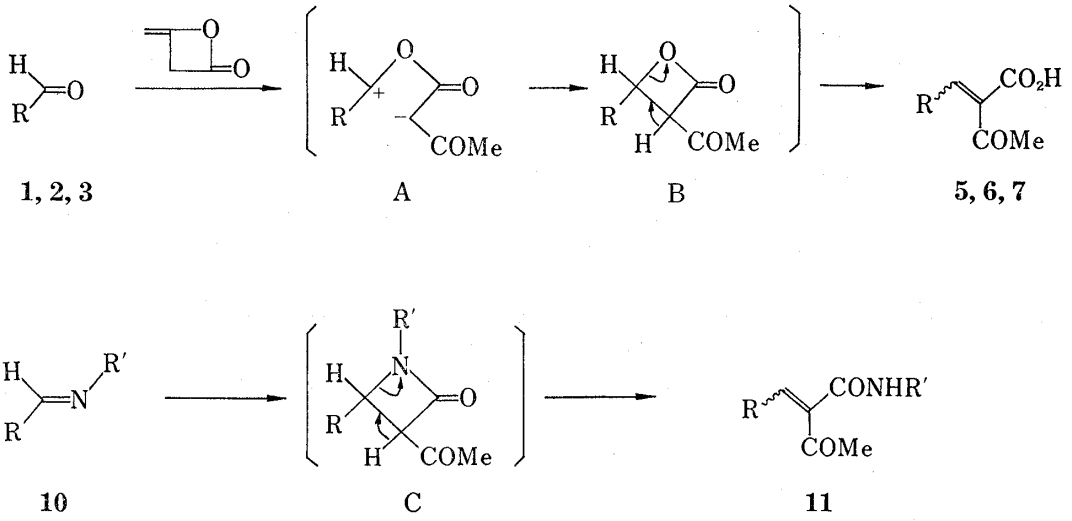

Chart 2

9) *a*) A.F. Kluge and C.P. Lillya, *J. Org. Chem.*, 36, 1988 (1971); *b*) J.L. Plati, W.H. Strain, and S.L. Warren, *J. Am. Chem. Soc.*, **65**, 1273 (1943).
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It is reported that one of the typical reactions of diketene involves addition of the carbonyl carbon of diketene to the nucleophilic terminus of the double bond accompanied with ring closure to give cyclic (mostly heterocyclic) compounds.[11] Concerning the formation of the acids (**5**,**6** and **7**) a likely pathway is shown in Chart 2. Namely, addition of the carbonyl carbon of diketene to the aldehyde oxygen accompanied with ring opening gives rise to the dipolar intermediate A, which cyclizes to give the oxetanone intermediate B. Ring opening of the intermediate B affords the acids (**5**,**6** and **7**). Such a mechanism had to be considered in view of the reported formation of the 2-alkylideneacetoacetamide (**11**) by the reaction of Schiff base (**10**) with diketene, in which reaction the azetidinone intermediate C corresponding to the intermediate B is proposed.[12]

Experimental

α-Acetylcinnamic Acid (**5**)——A solution of benzaldehyde (**1**) (5.3 g, 0.05 mol), diketene (4.2 g, 0.05 mol), and 2 drops of conc. sulfuric acid in ether (30 ml) was allowed to stand at 0° in a refrigerator for 3 days. The solution was extracted with 5% sodium bicarbonate. The aqueous solution was acidified with 10% hydrochloric acid. An oily substance separated was extracted with ether. The ether extract gave a crystalline substance. Recrystallization from benzene gave the product (**5**) as colorless prisms, mp 103—110°. Yield, 2.6 g (27%). *Anal.* Calcd. for $C_{11}H_{10}O_3$: C, 69.49; H, 5.30. Found: C, 69.51; H, 5.34. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3200—2600, 1715, 1700, 1630. NMR ($CDCl_3$) δ: 2.39 (s, (*E*)-CH_3) and 2.51 (s, (*Z*)-CH_3) total of 3H, 7.50 (5H, s, arom.-H), 7.74 (s, (*Z*)-vinyl H) and 7.94 (s, (*E*)-vinyl H) total of 1H, 11.47 (1H, s, (*Z*) and (*E*) CO_2H), ((*Z*):(*E*)=3:8).

Methyl 3-Acetylcinnamate (**8**)——To a solution of the acid (**5**) (0.38 g) in ether (20 ml), was added a solution of diazomethane in ether until yellow coloration appeared. The reaction mixture was condensed, and the oily residue was distilled giving the product (**8**) as a pale yellow oil, bp 112—115° (1 mmHg) (lit.[7] bp 140° (4 mmHg)), whose NMR data were in good agreement with those reported in the literature.[7] Yield, 0.39 g (96%).

Benzalacetone (**4**)——Compound (**5**) (114 mg) was placed in a test tube, and was heated at 150° on an oil bath for 30 min. The oily residue was dissolved in petroleum ether. The petroleum ether soluble fraction gave 85 mg (97%) of benzalacetone.

2-Acetyl-5-phenyl-2,4-pentadienoic Acid (**6**)——To a solution of cinnamaldehyde (**2**) (13.2 g, 0.1 mol) and a few drops of conc. sulfuric acid in ether (40 ml), was added diketene (8.4 g, 0.1 mol) under ice-cooling. The mixture was kept at 0° for 3 days. The mixture was extracted with 5% sodium bicarbonate. The alkaline solution was acidified with 10% hydrochloric acid. The mixture was extracted with $CHCl_3$. The $CHCl_3$ solution was dried, and condensed to give a crystalline residue. Recrystallization from ether gave the product (**6**) as yellow needles, mp 124—125°. Yield, 4.7 g (32%). *Anal.* Calcd. for $C_{13}H_{12}O_3$: C, 72.21; H, 5.59. Found: C, 72.22; H, 5.70. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3220—2800, 1730, 1720. NMR ($CDCl_3$) δ: 2.54 (3H, s, $COCH_3$), 7.17—7.67 (6H, m, arom., and C_5-H), 7.80 (d, J=11.5 Hz, C_3-H), 8.50 (1H, dd, J=11.5 Hz, J=15 Hz, C_4-H), 11.7 (1H, br, CO_2H).

6-Phenyl-3,5-hexadien-2-one (**9**)——A solution of compound (**6**) (216 mg) in pyridine (20 ml) was refluxed for 45 min. The mixture was condensed *in vacuo*, and the residue was extracted with hexane. The hexane solution was condensed to give a crystalline substance. Recrystallization from hexane gave the product (**9**) as pale yellow prisms, mp 66—67°, undepressed on admixture with an authentic sample prepared according to the literature.[9] Yield, 53 mg (31%).

2-Acetyl-5,5-diphenyl-2,4-pentadienoic Acid (**7**)——A solution of β-phenylcinnamaldehyde (**3**) (0.5 g, 2.4 mmol), diketene (0.2 g, 2.4 mmol) and several drops of conc. sulfuric acid in ether (15 ml) was kept in a refrigerator (0°) for 3 days. The mixture was washed with 5% sodium bicarbonate. The washing was acidified with 10% hydrochloric acid. The mixture was extracted with $CHCl_3$. The $CHCl_3$ extract gave the product (**7**), yellow prisms (from ether), mp 130—131°, undepressed on admixture with an authentic sample.[10] Yield, 0.4 g (56%).

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