Formation of Cyclic Carbonates in the Reaction of 1,2-Ditertiary Diols with Acetic Anhydride and 4-(Dimethylamino)pyridine†

Vidya Bhushan, Tushar K. Chakraborty, and Srinivasan Chandrasekaran*

Department of Chemistry, Indian Institute of Technology, Kanpur 208 016, India

Received October 14, 1983

The reaction of 1,2-ditertiary diol **1a** with acetic anhydride and 4-(dimethylamino)pyridine (DMAP) at high concentrations in the absence of solvent has been found to give rise to cyclic carbonate **2a**. The reaction has been generalized with a few other 1,2-ditertiary diols (**1b–d**). Based on the different products isolated in these reactions, apart from a small amount of normal acetylation products, various mechanisms have been proposed and examined. Tertiary alcohols have been found to give monoacetoacetates in addition to the acetates, under the same reaction conditions. Detailed investigations have prompted us to suggest the intermediacy of ketene and diketene in these reactions.

4-(Dimethylamino)pyridine (DMAP) has long been used as an efficient catalyst in acylations and related reactions in various fields. The general applicability of DMAP catalysis has been compiled in two exhaustive reviews,[1,2] which have stimulated further interest in its use. There is an interesting early report of the formation of acetoacetates during the attempted acylation of 17-α-hydroxy steroids with excess of acetic anhydride and DMAP in pyridine.[1] This observation prompted us to study in detail the mode of reaction of pinacols under similar conditions employing a higher concentration of 4-(dimethylamino)-pyridine and acetic anhydride.

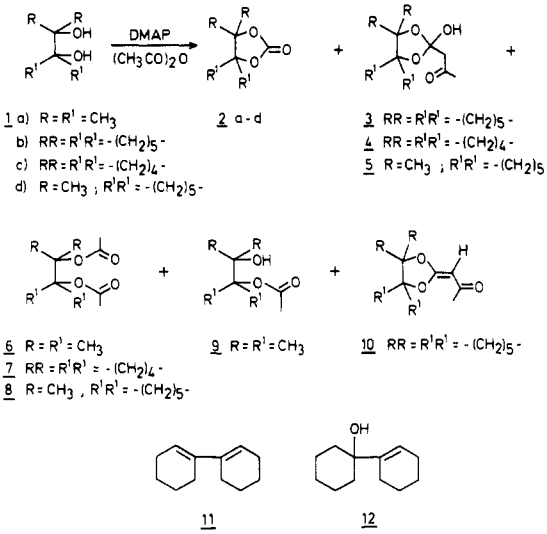
Results

With a view to examining the behavior of pinacols with acetic anhydride and 4-(dimethylamino)pyridine at high concentrations, the representative substrate, 2,3-dihydroxy-2,3-dimethylbutane (**1a**), was treated with DMAP (1 equiv) and acetic anhydride (2.2 equiv) at ca. 85 °C for 3 h. A colorless crystalline compound was isolated, mp 179–180 °C (51%), which was identified as the cyclic carbonate **2a**, 2-oxo-4,4,5,5-tetramethyl-1,3-dioxolane.[3] The other products isolated in the reaction were characterized as 2-acetoxy-3-hydroxy-2,3-dimethylbutane (**9**, 26%) and 2,3-diacetoxy-2,3-dimethylbutane (**6**, 17%), mp 64–65 °C (lit.[4] mp 65 °C). Acetone was also found to be formed as a byproduct in the reaction (2,4-dinitrophenylhydrazone,[5] mp 127–128 °C).

In order to examine the generality of the above reaction, 1,2-ditertiary diols such as 1,1′-dihydroxybicyclohexane (**1b**) and 1,1′-dihydroxybicyclopentane (**1c**) have been studied under identical reaction conditions. The pinacol **1b** gave the cyclic carbonate, 2-oxo-4,4:5,5-bis(pentamethylene)-1,3-dioxolane (**2b**, 21%), mp 178–179 °C, 2-acetonylidene-4,4:5,5-bis(pentamethylene)-1,3-dioxolane (**10**, 15%), and 2-acetonyl-2-hydroxy-4,4:5,5-bis(pentamethylene)-1,3-dioxolane (**3**, 17%) along with the recovered starting material, and acetone was formed as the byproduct (characterized as 2,4-dinitrophenylhydrazone) (Scheme I).

The monoacetoacetate **3a** was thermally labile and when a gas chromatographic analysis on a SE-30 column at 120 °C was attempted, it seemed to decompose giving rise to five different components. A GC–MS analysis indicated the presence of 1,1′-bicyclohexane (**11**, M^+ = 162), 1-hydroxycyclohexyl-1′-cyclohexene (**12**, M^+ = 180), 1,1′-dihydroxybicyclohexane (**1b**, M^+ = 198), 2-oxo-4,4:5,5-bis(pentamethylene)-1,3-dioxolane (**2b**, $M^+ - 44 = 180$), and 2-acetonylidene-4,4:5,5-bis(pentamethylene)-1,3-dioxolane (**10**, M^+ = 264).

Scheme I



On the other hand, the pinacol **1c** under analogous conditions yielded 2-oxo-4,4:5,5-bis(tetramethylene)-1,3-dioxolane (**2c**, 24%), mp 89–90 °C, 1,1′-diacetoxy-1,1′-bicyclopentane (**7**, 32%), 2-acetonyl-2-hydroxy-4,4:5,5-bis(tetramethylene)-1,3-dioxolane (**4**, 16%), and a small amount of the unchanged pinacol **1c**. In this reaction also, acetone was formed as a byproduct.

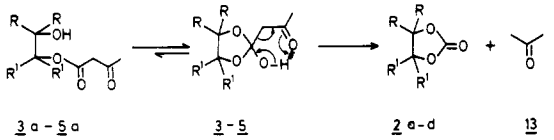
The similarity in the behavior of the symmetrical pinacols **1a–c** toward acetic anhydride and 4-(dimethylamino)pyridine prompted us to examine the behavior of an unsymmetrical pinacol, 2-(1-hydroxycyclohexyl)-propan-2-ol (**1d**) under analogous reaction conditions. As expected, the reaction afforded a mixture of products identified as 2-oxo-4,4-(tetramethylene)-5,5-dimethyl-1,3-dioxolane (**2d**, 34%), mp 112–112.5 °C, 2-(1-acetoxycyclohexyl)prop-2-yl acetate (**8**, 17%), and 2-acetonyl-2-hydroxy-4,4-(pentamethylene)-5,5-dimethyl-1,3-dioxolane (**5**, 28%).

† Dedicated to Professor S. Swaminathan, University of Madras, on his 60th birthday.

(1) Höfle, G.; Steglich, W.; Vorbrüggen, H. *Angew. Chem., Int. Ed. Engl.* **1978**, *17*, 569.
(2) Scriven, E. F. V. *Chem. Soc. Rev.* **1983**, *12*, 129.
(3) Sarel, S.; Phoryles, L. A.; Ben-Shoshan, R. *J. Org. Chem.* **1959**, *24*, 1873.
(4) Levina, R. Y.; Fainzil'berg, A. A.: Itenberg, P. V. *Dokl. Akad. Nauk SSSR* **1950**, *75*, 39; *Chem. Abstr.* **1951**, *45*, 4637c.
(5) "Dictionary of Organic Compounds", 5th ed.; Chapman and Hall: Florida, 1982.

0022-3263/84/1949-3974$01.50/0

Scheme II



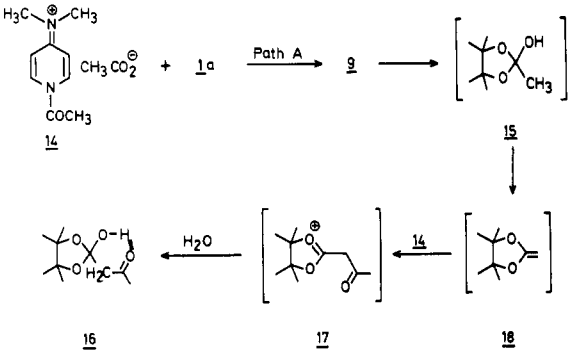
In all the cases of 1,2-ditertiary diols studied, it has been observed that apart from a small amount of normal acetylation products, the cyclic carbonates and the monoacetoacetates are the major reaction products. The formation of acetone in these reactions is also noteworthy. The monoacetoacetates gave the cyclic carbonates upon standing for a long time or warming. The formation of the rather unusual product, the cyclic carbonate in these reactions of 1,2-ditertiary diols with acetic anhydride and DMAP needed mechanistic probing.

Discussion

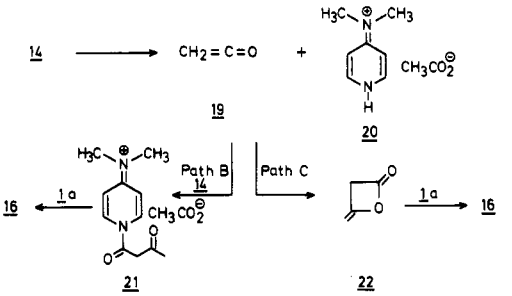
The acylation reactions catalyzed by DMAP have been suggested to proceed through the intermediacy of *N*-acetyl-4-(dimethylamino)pyridinium acetate (**14**) formed by the initial attack of the highly nucleophilic DMAP on the acylating agent, such as acetic anhydride (nucleophilic catalysis). The neighboring acetate anion causes an increase in the reaction rate by abstracting a proton from the nucleophile (general base catalysis).[1] An alternative mechanism suggests that **14** is not an intermediate but might be forming in a bypass to the main mechanistic pathway, consisting of an anhydride-tertiary alcohol complex (e.g., acetic anhydride–*tert*-butyl alcohol complex) formation.[6] However, both these mechanisms fail to explain the formation of cyclic carbonates and monoacetoactates obtained in our reactions.

The isolation of monoacetoacetates **3a–5a** in the reactions of 1,2-ditertiary diols studied coupled with the fact that these monoacetoacetates were transformed into cyclic carbonates upon heating suggest that the formation of cyclic carbonates might proceed via the corresponding monoacetoacetates. In analogy with the well-known mechanism of the decarboxylation of acetoacetic acid,[7] the formation of cyclic carbonate and acetone could be visualized from the cyclic tautomer of the monoacetoacetate, which is in equilibrium with the monoacetoacetate (Scheme II). This is further supported by the fact that the cyclic carbonates have been obtained in the transesterification reaction of ethyl acetoacetate and 1,2-ditertiary diols in the presence of a base such as sodium methoxide.[8] This was independently confirmed by us when cyclic carbonate **2a** was isolated in 50% yield in the reaction of pinacol **1a** with ethyl acetoacetate at ca. 140 °C in the presence of anhydrous sodium acetate. The hydroxyl and the ketone absorptions in the IR spectra of monoacetoacetates (see Experimental Section) further support the existence of equilibrium between the monoacetoacetates and their cyclic tautomers. The mass spectra of the monoacetoacetates **3a–5a** showed a fragment with

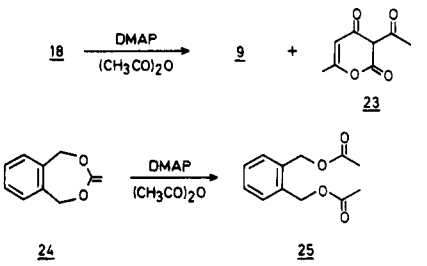
Scheme III



Scheme IV



Scheme V



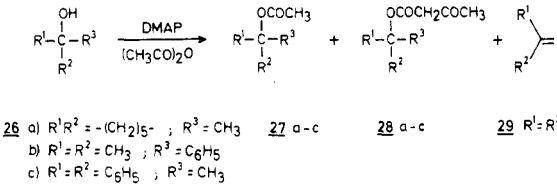
m/e $M^+ - 18$, indicating that dehydration is an important mode of fragmentation, which in turn could occur easily from the cyclic orthoester. Isolation of α,β-unsaturated carbonyl compound **10** in the reaction of pinacol **1c** with DMAP and acetic anhydride further substantiates the fact that it is most likely the product of dehydration of the cyclic tautomer **3**. On the basis of all these experimental evidences, different mechanistic pathways may be proposed for the formation of the 2-acetonyl-2-hydroxy-1,3-dioxolane system **3–5**.

The path "A" utilizes the well established species **14** to form the monoacetate **9** which can cyclize to give the orthoester **15**. This mode of cyclization has been demonstrated earlier by Hine et al. in the case of the monotrifluoroacetate of pinacol **1a**.[9] The cyclic orthoester **15**, on dehydration can give rise to the ketene cyclic acetal **18**, which may react with **14**, leading to the formation of **16** in the presence of an equivalent amount of water (Scheme III).

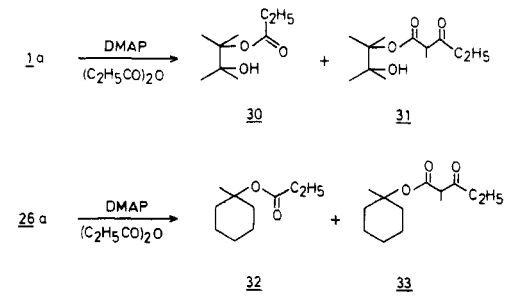
An alternative mode for the formation of the cyclic orthoester **16** involves the intermediacy of ketene (Scheme IV) which in turn can come from *N*-acetyl-4-(dimethyl-

(6) Guibe'-Jampel, E.: le Corre, G.; Wakselman, M. *Tetrahedron Lett.* **1979**, 1157.
(7) Wasserman, H. H. In "Steric Effects in Organic Chemistry", Newman, M. S., Ed.; Wiley: New York, 1956, p 349.
(8) (a) Daev, N. A.; Dashunin, V. M. *Khim. Nauka Prom.* **1957**, *2*, 667; *Chem. Abstr.* **1958**, *52*, 6169. (b) Daev, N. A.; Dashunin, V. M.; Chizov, O. S. *Izv. Akad. Nauk SSSR, Ser. Khim.* **1969**, *5*, 1158; *Chem. Abstr.* **1969**, *71*, 49192u.
(9) Hine, J.; Ricard, D.; Perz, R. *J. Org. Chem.* **1973**, *38*, 110.

Scheme VI



Scheme VII



amino)pyridinium acetate (**14**). Ketene on reaction with **14** may give *N*-acetoacetyl-4-(dimethylamino)pyridinium acetate (**21**), which may yield the monoacetoacetate upon treatment with **1a** (path "B").

Yet another pathway (path "C") to rationalize the unusual products formed in the reaction of 1,2-ditertiary diols with acetic anhydride and DMAP at high concentration would be via the intermediacy of diketene (**22**) obtained from the dimerization of ketene formed from **14**. The pinacol **1a** on reaction with diketene can form the monoacetoacetate (Scheme IV).

In order to test the validity of the mechanisms proposed experiments were carried out with the ketene cyclic acetals **18**[10] and **24** (Scheme V).[11] When 2-methylene-4,4,5,5-tetramethyl-1,3-dioxolane (**18**) was treated with acetic anhydride and DMAP at 80 °C for 3 h, followed by the addition of an equivalent amount of water, two products identified as the monoacetate **9** and dehydroacetic acid **23**, mp 111–112 °C (mixture melting point), were isolated whereas 1,5-dihydro-3-methylene-2,4-benzodioxepin (**24**) under identical reaction conditions yielded 58% of the diacetate **25**, mp 35 °C (mixture melting point[11] 35 °C).

Thus, path "A" involving the ketene cyclic acetal as an intermediate in the formation of monoacetoacetate could be safely ruled out since neither the monoacetoacetate nor the products derived from it could be isolated in the reaction of authentic ketene acetals under the same reaction conditions. The isolation of dehydro acetic acid **23** as one of the products could possibly be explained by invoking "ketene" as an intermediate, as visualized in path "B" or path "C". Ketene dimerization to diketene and diketene dimerization to dehydroacetic acid under basic conditions are well documented in the literature.[12]

With a view to testing the intermediacy of 1-acetoacetyl-4-(dimethylamino)pyridinium acetate (**21**), ketene generated independently through a ketene generator[13] was allowed to react with a solution of *N*-acetyl-4-(dimethylamino)pyridinium chloride[14] in dichloromethane in the presence of a catalytic amount of DMAP at room temperature. The ^{1}H NMR spectrum of this mixture did not show the formation of *N*-acetoacetyl-4-(dimethylamino)pyridinium chloride and it failed to react with 1-methylcyclohexanol (**26a**) to give the acetoacetate **28a**.

The isolation of dehydroacetic acid **23** in the reaction of acetic anhydride and DMAP with ketene cyclic acetal **18** possibly suggests that diketene, precursor to **23**, might have come from acetic anhydride and DMAP according to our mechanistic pathway "C". With a view to confirming this, acetic anhydride and DMAP were mixed in equivalent amounts and left to stand at room temperature for 2 days. Dehydoacetic acid was the only isolable product from the crude mixture.

In order to substantiate the intermediacy of diketene in these reactions, 1-methylcyclohexanol (**26a**) (Scheme VI) was treated with acetic anhydride and DMAP under identical reaction conditions in the absence of solvent at 85 °C for 4 h which afforded 1-methylcyclohexyl acetate (**27a**) and 1-methylcyclohexyl acetoacetate (**28a**) in the ratio of 10:3.1 along with a small amount of unchanged starting material.

In order to examine the generality of this reaction with tertiary alcohols, experiments were carried out with other carbinols such as 2-phenylpropan-2-ol (**26b**) and 1,1-diphenylethanol (**26c**). When **26b** was treated with acetic anhydride and DMAP (2.2:1 equiv) at 85 °C for 4 h, a mixture of two products were obtained, purification of which by flash chromatography yielded the acetate **27b** and the acetoacetate **28b** in the ratio of 2.2:1. However, when 1,1-diphenylethanol (**26c**) was treated under analogous conditions with acetic anhydride and DMAP, 1,1-diphenylethyl acetate (**27c**) and 1,1-diphenylethylene (**29**) were the only products obtained. The olefin **29** might have been derived by a facile elimination reaction of the acetoacetate **28c**.[15]

The formation of acetoacetates in the case of tertiary alcohols examined provides strong evidence for the intermediacy of diketene in such reactions. Jampel et al. have observed earlier in their UV studies of a solution of acetic anhydride and DMAP, that the absorption at 312 nm slowly disappears and a new peak appears at 282 nm, analogous to that of the 4-(dimethylamino)pyridinium acetate.[6] It is very likely that the disappearance of the peak at 312 nm might be due to the decomposition of *N*-acetyl-4-(dimethylamino)pyridinium acetate, giving rise to ketene. A recent report[16] on the triethylamine-catalyzed Perkin reaction, where ketene intermediate has been proposed, is in good agreement with our diketene mechanism.

With a view to examining the generality of the reaction with anhydrides, the pinacol **1a** was treated with 4-(dimethylamino)pyridine and propionic anhdyride (1:2.2 equiv) under identical reaction conditions. The product was found to be a mixture of monopropionate **30** (Scheme VII) and 2-methyl-3-oxopentanoate **31** in the ratio of 3.5:1, respectively. When **26a** was treated with propionic anhydride and DMAP under identical conditions, a mixture of monopropionate **32** and 2-methyl-3-oxopentanoate **33** was obtained in the ratio of 2.8:1, respectively. In contrast to the reaction of pinacol **1a** with acetic anhydride and DMAP, no cyclic carbonate **2a** was isolated in the reaction with propionic anhydride and DMAP at high concentration. This only suggests that the cyclization of **31** to give the orthoester may be difficult in the latter case, which

(10) Taskinen, E.; Pentikäinen, M.-L. *Tetrahedron* **1978**, *34*, 2365.
(11) Crewe, R.; Struve, A. *Chem. Ber.* **1963**, *96*, 2819.
(12) Blake P. In "The Chemistry of Ketenes, Allenes, and Related Compounds", Patai, S., Ed.; Wiley: New York, 1980; Part I, p 331.
(13) Williams, J. W.; Krinitsky, G. A. "Organic Syntheses"; Wiley: New York, 1962; Collect. Vol. III, p 508.
(14) Wakselman, M.; Guibé'-Jampel, E. *Tetrahedron Lett.* **1970**, 1521.
(15) Frisell, C.; Lawesson, S.-O. *Ark. Kemi* **1961**, *17*, 401.
(16) Kinastowski S.; Nowacki A. *Tetrahedron Lett.* **1982**, *23*, 3723.

is necessary for the formation of carbonate.

In summary, the mechanistic pathway "C" invoking the intermediacy of ketene and subsequent dimerization to diketene, in the reaction of DMAP and acetic anhydride at high concentrations, seems more plausible, considering the following facts: (i) The formation of cyclic carbonates and monoacetoacetates in the reaction of pinacols could be rationalized conveniently. (ii) The formation of acetoacetates in the case of simple tertiary alcohols could be explained. (iii) The formation of products apart from simple propionates could be understood in the reaction of **1a** and **26a** with propionic anhydride and DMAP. (iv) Finally, isolation of dehydroacetic acid could be accounted for.

Experimental Section

Instrumentation. Infrared spectra were obtained with a Perkin-Elmer Model 377 and 580 spectrophotometers. Proton magnetic resonance spectra were measured with Jeol PMX-60, Varian EM-390, and Varian HA-100 spectrometers; chemical shifts are expressed in parts per million downfield from internal reference, tetramethylsilane. Mass spectra were obtained with a VG Micromass 7070F mass spectrometer at an ionizing voltage of 70 eV. Melting points and boiling points are uncorrected.

Materials. (Dimethylamino)pyridine (DMAP) was obtained from Aldrich Chemicals Co. (mp 108–110 °C) and was used without further purification. Commercial grade solvents were distilled prior to use. Petroleum ether used was the fraction 60–80 °C. Acetic anhydride was distilled from phosphorus pentoxide immediately before use.

The compounds 2,3-dihydroxy-2,3-dimethylbutane (**1a**, mp 46–46.5 °C),[17] 1,1′-dihydroxybicyclohexane (**1b**, mp 124–125 °C),[18] 1,1′-dihydroxybicyclopentane (**1c**, mp 111.5–112 °C),[18] 2-(1-hydroxycyclohexyl)propan-2-ol (**1d**, mp 82 °C),[18] 1-methylcyclohexanol (**26a**, bp 55–56 °C (10 mmHg)),[19] 2-phenylpropan-2-ol (**26b**, bp 87–89 °C (9 mmHg)),[20] and 1,1-diphenylethanol (**26c**, mp 78–79 °C)[20] were prepared by the reported procedures. The ketene cyclic acetal **18** (bp 40 °C (10 mmHg))[10] was prepared by the dehydrobromination of 2-(bromomethyl)-4,4,5,5-tetramethyl-1,3-dioxolane (bp 92–94 °C (11 mmHg)) by potassium *tert*-butoxide in *tert*-butyl alcohol, which in turn was prepared by the transesterification of anhydrous acetone, pinacol, and bromoacetaldehyde diethyl acetal in the presence of a catalytic amount of *p*-toluenesulfonic acid. The ketene cyclic acetal **24** was prepared by the literature procedure.[11] Anhydrous acetone pinacol was prepared by azeotropic removal of water from pinacol hydrate in refluxing benzene by means of a Dean–Stark water separator.

General Procedure. All reactions were performed in oven-dried apparatus. Reaction mixtures were stirred magnetically. Purification of the products was performed by using 100-200 mesh Acme silica gel. Flash chromatography was performed by using Acme thin-layer chromatography silica gel.

Reaction of Pinacol 1a with Acetic Anhydride and DMAP. To a mixture of acetic anhydride (0.45 g, 4.4 mmol) and DMAP (0.244 g, 2 mmol) was added **1a** (0.236 g, 2 mmol). The reaction mixture was heated with stirring at ca. 85 °C for 3 h. The reaction was quenched by adding a few drops of methanol followed by water (10 mL). After stirring for 10 min, it was extracted with dchloromethane (3 × 20 mL). The organic layer was washed with water (10 mL) followed by brine (10 mL) and dried over anhydrous magnesium sulfate. The solvent was evaporated under reduced pressure to afford a brown oil which was chromatographed over silica gel to give 0.05 g of **6** (17%, elution with petroleum ether), mp 64–65 °C (lit.[4] mp 65 °C), 0.06 g of **9** (26%, elution with 1:1 ether–petroleum ether), 0.11 g of **2a** (51%, elution with 1:9 ether–petroleum ether), mp 179–180 °C (lit.[3] mp 180–181 °C), and 0.06 g of unreacted starting material (elution with 1:5 ether–petroleum ether). Monoacetate **9**: IR (CCl_4) 3470, 1735 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.3 (s, 6 H), 1.4 (s, 6 H), 1.95 (s, 3 H), 3.26 (s, 1 H, D_2O exchangeable); mass spectrum, m/e 145 ($M^+ - CH_3$).

In a repeat reaction, a condenser with ice water circulation was set downwards for distillation with a receiver containing 2,4-dinitrophenylhydrazine solution in methanol. An orange yellow precipitate of 2,4-dinitrophenylhydrazone of acetone was separated in the receiver which was filtered and recrystallized (aqueous ethanol), mp 127–128 °C (lit.[5] mp 128 °C).

Reaction of Pinacol 1b with Acetic Anhydride and DMAP. The reaction was carried out as above with **1b** (0.792 g, 4 mmol), acetic anhydride (0.88 g, 8.8 mmol), and DMAP (0.488 g, 4 mmol). A brown oily solid obtained after the workup was purified by flash chromatography (elution with 1:9 ether–petroleum ether) to give 0.05 g of **10** (15%), 0.07 of **2b** (21%), mp 178–179 °C, 0.07 g of **3** (17%), and 0.5 g of recovered **1b**. α,β-Unsaturated carbonyl compound **10**: IR (CCl_4) 1680, 1640 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.2 (m, 20 H), 2.6 (s, 3 H), 4.8 (s, 1 H); mass spectrum, m/e 264 (M^+); exact mass calcd for $C_{16}H_{24}O_3$ 264.1726, found 264.1720. Anal. Calcd for $C_{16}H_{24}O_3$: C, 72.69; H, 9.15. Found: C, 72.54; H, 9.40. Carbonate **2b**: IR (KBr) 1780 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.0–2.2 (br, m); mass spectrum, m/e 224 (M^+); exact mass calcd for $C_{13}H_{20}O_3$ 224.1416, found 224.1418. Anal. Calcd for $C_{13}H_{20}O_3$: C, 69.61; H, 8.99. Found: C, 69.42; H, 8.50. Orthoester **3**: IR (thin film) 3440, 1730, 1700 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.0–1.89 (m, 20 H), 2.25 (s, 3 H), 3.5 (s, 2 H), 4.18 (s, 1 H, D_2O exchangeable); mass spectrum, m/e 264 ($M^+ - 18$); exact mass calcd for $C_{16}H_{26}O_4$ (M − 18) 264.1726, found 264.1717. Anal. Calcd for $C_{16}H_{26}O_4$: C, 68.06; H, 9.28. Found: C, 68.36; H, 9.44.

Reaction of Pinacol 1c with Acetic Anhydride and DMAP. Reaction was carried out under identical conditions with **1c** (0.34 g, 2 mmol), acetic anhydride (0.44 g, 4.4 mmol), and DMAP (0.244 g, 2 mmol) for 4 h. Flash chromatography of the crude product afforded 0.1 g of **7** (32%, elution with petroleum ether), 0.05 g of **4** (16%, elution with 1:19 ether–petroleum ether), 0.06 g of **2c**, mp 89–90 °C (24%, elution with 1:19 ether–petroleum ether), and 0.12 g of the starting material (elution with 3:17 ether–petroleum ether). Diacetate **7**: IR (CCl_4) 1730 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.25–2.0 (m, 16 H), 2.04 (s, 6 H). Orthoester **4**: IR (thin film) 3415, 1735, 1705 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.4–2.0 (m, 16 H), 2.08 (s, 5 H), 4.33 (s, 1 H, D_2O exchangeable); mass spectrum, m/e 254 (M^+). Carbonate **2c**: IR (KBr) 1780 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.6–2.2 (m); mass spectrum, m/e 196 (M^+); exact mass calcd for $C_{11}H_{16}O_3$ 196.1100, found 196.1106. Anal. Calcd for $C_{11}H_{16}O_3$: C, 67.32; H, 8.22. Found: C, 67.25; H, 8.64.

Reaction of Pinacol 1d with Acetic Anhydride and DMAP. Reaction was performed under similar conditions with **1d** (0.316 g, 2 mmol), acetic anhydride (0.44 g, 4.4 mmol), and DMAP (0.244 g, 2 mmol) to afford 0.06 g of **8** (17%, elution with 1:19 ether–petroleum ether), 0.09 g of **2d** (34%, elution with 1:9 ether–petroleum ether), mp 112–112.5 °C, 0.1 g of **5** (28%, elution with 1:9 ether–petroleum ether), and 0.085 g of recovered pinacol (elution with 3:17 ether–petroleum ether). Diacetate **8**: IR (thin film) 1735 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.09 (s, 6 H), 1.16–1.43 (m, 10 H), 1.53 (s, 6 H); mass spectrum, m/e 182 ($M^+ - CH_3COOH$). Carbonate **2d**: IR (KBr) 1780 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.36 (s, 6 H), 1.44–2.04 (m, 10 H); mass spectrum, m/e 184 (M^+); exact mass calcd for $C_{10}H_{16}O_3$ 184.1100, found 184.1096. Anal. Calcd for $C_{10}H_{16}O_3$: C, 65.19; H, 8.75. Found: C, 65.34; H, 8.97. Orthoester **5**: IR (thin film) 3440, 1735, 1710 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.13–1.66 (m, 10 H), 1.53 (s, 6 H), 2.01 (s, 3 H), 2.23 (s, 2 H), 2.92 (s, 1 H, D_2O exchangeable).

Reaction of Ketene Cyclic Acetal 18 with Acetic Anhydride and DMAP. To a mixture of acetic anhydride (0.408 g, 4 mmol) and DMAP (0.244 g, 2 mmol) was added **15** (0.568 g, 4 mmol). The reaction mixture was heated to 80–90 °C with stirring for 2 h. Water (0.07 mL) was added and the heating was continued for two more hours. The crude product obtained after the usual workup was purified by flash chromatography to yield 0.1 g of **9** (15%, elution with 1:19 ether–petroleum ether) and 0.07 g of **23**, mp 111–112 °C (mixture melting point 111–112 °C, elution with 1:19 ether–petroleum ether).

Reaction of 24 with Acetic Anhydride and DMAP. The compound **24** (0.648 g, 4 mmol) was treated under identical conditions with acetic anhydride (0.408 g, 4 mmol) and DMAP

(17) Adams, R.; Adams, E. W. "Organic Syntheses"; Wiley: New York, 1961; Collect. Vol. I., p 459.
(18) Corey, E. J.; Danheiser, R. L.; Chandrasekaran, S. *J. Org. Chem.* **1976**, *41*, 260.
(19) Nevitt, T. D.; Hammond, G. S. *J. Am. Chem. Soc.* **1954**, *76*, 4124.
(20) (a) Klages, A. *Chem. Ber.* **1902**, *35*, 2637. (b) Klages, A. *Chem. Ber.* **1902**, *35*, 2646.

(0.244 g, 2 mmol) as done with **18**. The crude product upon flash chromatography yielded 0.45 g of the diacetate **25** (58%), mp 35 °C (mixture melting point, elution with petroleum ether).

Reaction of 26a with Acetic Anhydride and DMAP. To a mixture of acetic anhydride (0.44 g, 4.4 mmol) and DMAP (0.244 g, 2 mmol) was added the carbinol **26a**. The reaction mixture was heated with stirring at 85–90 °C for 4 h. The crude product obtained after the usual workup gave 0.18 g of **27a** (71%, elution with petroleum ether), 0.05 g of **28a** (15%, elution with 1:19 ether–petroleum ether), and 0.04 g of **26a**. The products were compared with the authentic samples.

Reaction of 26b with Acetic Anhydride and DMAP. The reaction was carried out under identical conditions as above with **26b** (0.272 g, 2 mmol), acetic anhydride (0.44 g, 4.4 mmol), and DMAP (0.244 g, 2 mmol). The crude product upon flash chromatography yielded 0.17 g of **27b** (66%, elution with petroleum ether) and 0.08 g of **28b** (18%, elution with 1:19 ether–petroleum ether). The products were compared and confirmed with the authentic samples.

Reaction of 26c with Acetic Anhydride and DMAP. The tertiary alcohol **26c** (0.396 g, 2 mmol) was treated under identical conditions as earlier with acetic anhydride (0.44 g, 4.4 mmol) and DMAP (0.244 g, 2 mmol). The crude product upon purification by flash chromatography yielded 0.13 g of **29** (52%, elution with petroleum ether), 0.158 g of **27c** (46%, elution with petroleum ether), and 0.11 g of unreacted starting alcohol (elution with 1:19 ether–petroleum ether). The products were compared with the authentic samples.

Reaction of Pinacol 1a with Propionic Anhydride and DMAP. To a mixture of propionic anhydride (0.858 g, 6.6 mmol) and DMAP (0.366 g, 3 mmol) was added **1a** (0.354 g, 3 mmol). The reaction mixture was heated with stirring at ca. 80 °C for 4 h. The crude product upon flash chromatography lead to 0.3 g of **30** (71%, elution with 1:19 ether–petroleum ether), 0.085 g of **31** (15%, elution with 1:19 ether–petroleum ether), and 0.07 g of unreacted pinacol (elution with 1:5 ether–petroleum ether). Compound **30**: IR (thin film) 1730 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.06 (t, 3 H, J = 7.5 Hz), 1.1 (s, 6 H), 1.4 (s, 6 H), 2.23 (q, 2 H, J = 7.5 Hz), 2.9 (s, 1 H, D_2O exchangeable). Compound **31**: IR ($CHCl_3$) 1735 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.03 (t, 3 H, J = 7.5 Hz), 1.1 (s, 6 H), 1.27 (d, 3 H, J = 6 Hz), 1.45 (s, 6 H), 2.47 (q, 2 H, J = 7.5 Hz), 3.35 (q, 1 H, J = 6 Hz).

Reaction of 26a with Propionic Anhydride and DMAP. The tertiary alcohol **26a** (0.228 g, 2 mmol) was added with stirring to a mixture of propionic anhydride (0.572 g, 4.4 mmol) and DMAP (0.244 g, 2 mmol). The crude product upon flash chromatography yielded 0.2 g of **32** (75%, elution with petroleum ether), 0.07 g of **33** (21%, elution with petroleum ether), and 0.05 g of unreacted alcohol (elution with 1:19 ether–petroleum ether). Compound **32**: IR (thin film) 1730 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.1 (t, 3 H, J = 7 Hz), 1.43 (s, br, 13 H), 2.23 (q, 2 H, J = 7 Hz). Compound **33**: IR (CCl_4) 1710, 1730 cm^{-1}; ^1H NMR (CCl_4) δ 1.1 (t, 3 H, J = 6 Hz), 1.3 (d, 3 H, J = 6 Hz), 1.5 (s, br, 13 H), 2.5 (q, 2 H, J = 6 Hz), 3.37 (q, 1 H, J = 6 Hz).

Registry No. **1a**, 76-09-5; **1b**, 2888-11-1; **1c**, 5181-75-9; **1d**, 1124-96-5; **2a**, 19424-29-4; **2b**, 87122-14-3; **2c**, 91328-29-9; **2d**, 91328-31-3; **3**, 91328-26-6; **4**, 91328-40-4; **5**, 91328-32-4; **6**, 5781-64-6; **7**, 91328-28-8; **8**, 91328-30-2; **9**, 20127-81-5; **10**, 91328-27-7; **15**, 76937-02-5; **18**, 69814-59-1; **23**, 520-45-6; **24**, 80649-14-5; **25**, 14019-65-9; **26a**, 590-67-0; **26b**, 617-94-7; **26c**, 599-67-7; **27a**, 16737-30-7; **27b**, 3425-72-7; **28a**, 91328-33-5; **28b**, 91328-34-6; **29**, 612-00-0; **30**, 91328-35-7; **31**, 91328-36-8; **32**, 91328-37-9; **33**, 91328-38-0; DMAP, 1122-58-3; $(CH_3CO)_2O$, 108-24-7; $(C_2H_5CO)_2O$, 123-62-6; 2-(bromomethyl)-4,4,5,5-tetramethyl-1,3-dioxolane, 91328-39-1.

Kinetic Study of the Reaction of *N*-(2,4-Dinitrophenyl)imidazole with Piperidine and *n*-Butylamine

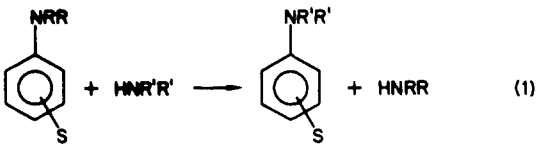
Elba B. de Vargas and Rita H. de Rossi*

Instituto de Investigaciones en Físico-Química de Córdoba (INFIQC), Departamento de Química Orgánica, Facultad de Ciencias Químicas, Universidad Nacional de Córdoba, Sucursal 16-C.C. 61, 5016 Córdoba, Argentina

Received March 21, 1984

The reaction of *N*-(2,4-dinitrophenyl)imidazole, **1**, with piperidine and *n*-butylamine was studied. The reaction with piperidine is catalyzed by hydroxide ion and by the amine while the reaction with *n*-butylamine is weakly catalyzed by hydroxide ion. The hydrolysis of the substrate competes with the aminolysis reaction. The base catalysis in the reaction of **1** with piperidine is shown to be a consequence of rate-limiting deprotonation of the zwitterionic intermediate complex, followed by spontaneous (noncatalyzed) leaving group expulsion. On the other hand, the small rate aceleration observed in the reaction of butylamine as well as the catalysis of the hydrolysis reaction by *n*-butylamine and piperidine is considered of unclear origin.

Aryl transfer from one amine to another as in eq 1 is considered to be a difficult reaction because the amine nucleophile usually adds to an unsubstituted ring position.[1]



(1)

However, we have found that imidazole is a moderately good leaving group for nucleophilic aromatic substitution[2,3] and (2,4,6-trinitrophenyl)imidazole reacts quite easily with *n*-butylamine,[3] although when piperidine is the nucleophile, the predominant reaction is the hydrolysis of the substrate[4] indicating that piperidine cannot compete with OH^-. This result is quite unexpected since piperidine is usually a better nucleophile than HO^- and *n*-butylamine.[5] We attribute the anomalous behavior of piperidine to steric crowding at the transition state for the formation of the zwitterionic intermediate.

(1) de Rossi, R. H.; Nuñez, A. *J. Org. Chem.* **1982**, *47*, 319 and references cited therein.

(2) de Rossi, R. H.; de Vargas, E. B. *J. Am. Chem. Soc.* **1981**, *103*, 1533.
(3) de Vargas, E. B.; de Rossi, R. H. *Tetrahedron Lett.* **1982**, *23*, 4423.
(4) Unpublished results from this lab.
(5) Bernasconi, C. F.; *MTP Int. Rev. Sci.: Org. Chem. Ser. One* **1973**, *3*, 33.

0022-3263/84/1949-3978$01.50/0