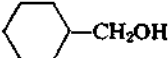
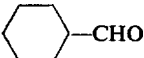
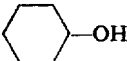
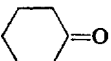
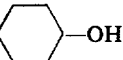
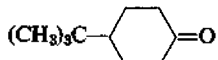


TABLE 2: Oxidation of Alcohols Using Diisopropyl Sulfide and Dimethyl Sulfide with NBS

Alcohols	Aldehydes or ketones	% Yield* using diisopropyl sulfide		% Yield* using dimethyl sulfide	
		at 0°C	at -78°C	at 0°C	at -78°C
CH ₃ (CH ₂) ₁₁ OH	CH ₃ (CH ₂) ₁₀ CHO	23	43	87	68
		18	60	83	85
		5	63	78	75
(CH ₃) ₃ C- 	(CH ₃) ₃ C- 	22	77	73	76

* Determined GLC analysis on a column of 10 % UCW-982.

2 h. The temperature control is important for the yield and the selectivity of this oxidation reaction and the reaction temperature should be kept 0°C or -78°C throughout the reaction.

On the basis of the result obtained in the present work, it is apparent that the steric factor, the reaction temperature, and the counteranion of the sulfonium salt are critical for the selectivity. However, the remarkable selectivity shown in the present oxidation process using di-*s*-butyl sulfide or *t*-butyl methyl sulfide with NCS at 0°C or -78°C can not be easily rationalized. Perhaps the iminosulfonium salt and the alkoxy-sulfonium salt might be in equilibrium and the equilibrium constant might be very sensitive to the bulkiness of the dialkyl sulfide, the reaction temperature, and the counteranion of the sulfonium salts.

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1, 1, 3, 3-Tetramethylguanidine. An Efficient and Selective Catalyst for the Benzoylation of Alcohols

Sunggak Kim[†] and Heung Chang

Department of Chemistry, Korea Advanced Institute of Science and Technology, Seoul 131, Korea

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The benzoate group is one of the widely used hydroxy protective groups in organic synthesis.¹ The most commonly used reagent, benzoyl chloride/pyridine, often requires longer reaction times at elevated temperature and may cause side reactions in complex molecules under forcing conditions due to the acidic nature of the reaction medium. In general, benzoylation using benzoic anhydride/pyridine or triethylamine does not proceed to completion, even after prolonged stirring at elevated temperature. Thus, several synthetic methods have been reported in the literature, which proceed under relatively mild conditions.²

In connection with our studies on the use of amidines and related compounds as functional group transfer agents, we have recently reported that the use of 1,1,3,3-tetramethylguanidine (TMG)³ as a catalyst is very effective for the *t*-butyldimethylsilylation of alcohols.⁴ We now wish to report that TMG is an efficient and selective catalyst for the benzoylation of alcohols (eq. 1).

First, the relative rates of benzoylation of phenethyl alcohol using equimolar amounts of TMG and benzoic anhydride at room temperature were examined in several solvents such as methylene chloride, tetrahydrofuran, acetonitrile, and

TABLE I: Benzoylation of Alcohols

$$\text{ROH} + (\text{C}_6\text{H}_5\text{CO})_2\text{O} + \text{Et}_3\text{N} \xrightarrow[\text{DMF}]{0.2 \text{ eq. TMG}} \text{R-O-COC}_6\text{H}_5$$

ROH	Temp, °C	Time, h	Yield, % ^a
C ₆ H ₅ CH ₂ CH ₂ OH	r.t	0.8	94 ^b
	r.t	12	97
C ₆ H ₅ CH ₂ OH	r.t	12	85
CH ₃ (CH ₂) ₇ OH	r.t	12	93
CH ₂ =CHCH ₂ OH	r.t	12	85
CH ₃ (CH ₂) ₅ CH(OH)CH ₃	60	12	95
C ₆ H ₅ CH(OH)CH ₃	60	12	96
Cyclohexanol	60	12	87
(CH ₃) ₃ COH	90	24	<5 ^b

^a The yields refer to isolated products. ^b 1.1 equiv of TMG was used.

dimethylformamide. Among solvents employed, dimethylformamide was found to be the most effective and the benzoylation was complete within 1 h: acetonitrile (1.5 h for completion), methylene chloride (3 h), tetrahydrofuran (3 h), and toluene (3 h). Thus, remaining benzoylations have been performed on several structurally different alcohols in dimethylformamide using 0.2 equiv of TMG and 1 equiv of triethylamine.

Table 1 includes several experimental results and illustrates the efficiency, the applicability, and the scope of this procedure. Primary alcohols such as benzyl alcohol and *n*-octanol, upon treatment with equimolar amounts of benzoic anhydride and triethylamine in the presence of 0.2 equiv of TMG, yielded the corresponding benzoates in high yields at room temperature in 12 h. However, benzoylation of secondary alcohols such as 2-octanol and cyclohexanol proceeded slowly at room temperature, indicating approximately 30 % completion of the reaction in 12 h. Benzoylation of secondary alcohols required a gentle heating at 60°C for 12h for completion of the reaction. As we expected, benzoylation of a tertiary alcohol, *t*-butyl alcohol, did not occur, even after prolonged stirring at elevated temperature.

In view of the fact that secondary alcohols are reluctant

to benzoylation at room temperature using this procedure, it is expected that selective benzoylation of primary alcohols in the presence of secondary alcohols may be feasible. Indeed, the benzoylation of an equimolar mixture of phenylethanedio, benzoic anhydride, and triethylamine in the presence of 0.2 equiv of TMG in dimethylformamide at room temperature in 12h afforded a 92: 6: 2 mixture of the primary benzoate, the secondary benzoate, and the bis-benzoate, which was determined by column chromatographic separation.⁵ Furthermore, similar high regioselectivity was realized with 1,3-butanediol.^{6,7}

References and Notes

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- (5) Reaction of phenethanediol with an equimolar mixture of benzoic anhydride and 4-dimethylaminopyridine in methylene chloride at room temperature for 3 h yielded a 73:12:15 mixture of the primary benzoate, the secondary benzoate, and the bis-benzoate, respectively.
- (6) The product ratio was 93:2: 5 mixture of the primary benzoate, the secondary benzoate, and the bis-benzoate, respectively.
- (7) Further studies on the use of TMG in organic synthesis are progress and will be published in detail in due course.