the elemental halogens. In fact from the linear equation

$$X_{hal} = 0.317\ b.p._{hal} - 18.5°$$

our X_{hal} values may be calculated with no deviation of as much as 2°.

While it is not usually possible to predict the boiling points of unknown organic compounds with the accuracy found in the present case, we believe that organic chemists frequently overlook gross deviations between expected and actual boiling points. In one of the most striking examples known to us, a liquid boiling at 14.5° is reported to be $Br_2C(OCH_3)_2$,[6] a compound that should boil at around 200°.

Acknowledgments. The authors would like to express their gratitude to the Rich Electronic Computer Center for use of the computer, to Dr. J. C. Currie for aid in the use of a program, and to Dr. William F. Atchison for advice and assistance in all phases of computer work.

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Triethylamine Salts in the Preparation of Esters from Active Halogen Compounds

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Received March 29, 1856

The formation of acyloxy derivatives from compounds which contain halogen substituents adjacent to a carbonyl group or aromatic ring has long been utilized for the preparation of solid derivatives of carboxylic acids.[1,2] Favored reagents have been compounds such as *p*-nitrobenzyl halides[1] and substituted phenacyl halides.[2] More recently, this type reaction has been useful in the field of corticoid hormones for the introduction of C_{21}-oxygen functions into 20-ketosteroids *via* the corresponding C_{21}-iodo derivatives.[3]

Typical conditions have involved treatment of the halogen compound with the sodium or potassium salt of the desired acid in solvents such as acetone, alcohols, or (for acetoxy derivatives) acetic acid. The choice of solvents has been necessarily limited by wide differences in the solubilities of the two reactants and, frequently, varying amounts of water have been incorporated to give increased solubility of the salt component.[1–5] In steroid preparations anhydrous conditions have often been used, necessitating a large excess of the acetate salt and prolonged refluxing of the resulting heterogeneous reaction mixture. Recent improvements include the use of dry acetone and potassium acetate freshly prepared from potassium bicarbonate and acetic acid[4] and the use of potassium acetate in a mixture of acetone, water, and acetic acid such that homogeneity is obtained.[5]

Salts other than those of the alkali metals in this type reaction apparently have received little attention. Methylammonium salts have been mentioned,[2b] catalytic amounts of triethylamine in the presence of a sodium salt have been used,[6] and there is at least one example of the use of a triethylammonium salt in benzene.[7]

The present study demonstrates a general utility for triethylammonium salts in this type reaction, making possible the preparation of the desired esters in excellent yields and high purity in a variety of solvents. The reaction is carried out by mixing the solvent, acid, and triethylamine in appropriate quantities and adding the halogen compound. The resulting clear solution is allowed to stand at room temperature or refluxed depending on the reactivity of the halogen compound and the solvent

TABLE I

Esters from Active Halogen Compounds Using Triethylammonium Salts in Acetone[a]

Halide, 0.02 mole; Acid, 0.175 mole; $(C_2H_5)_3N$, 0.109 mole

Acid	Ester Yield, %[b,c]	M.P., °C. Obs.[c]	Lit.
	PHENACYL BROMIDE		
Benzoic	85	119–121	118.5[e]
Benzilic	87	121–125	125.5[f]
Salicylic	86	106–108	110[g]
	p-PHENYLPHENACYL BROMIDE		
Acetic	86	109–111	111[h]
Benzoic	93	168–170	167[e]
	p-NITROBENZYL CHLORIDE		
Acetic	54[d]	78–79	78[h]
Benzoic	68[d]	85–87	88–89[e]

[a] Unless otherwise stated the reactions proceeded in one hour at room temperature. [b] Based on starting halide. [c] The reported yields and physical constants represent the crude products obtained directly from the reaction mixture. [d] Refluxed two hours in the presence of 0.2 g. of sodium iodide. [e] Ref. 8, p. 146. [f] Ref. 8, p. 156. [g] Ref. 8, p. 158. [h] Ref. 8, p. 180.

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(1) Reid, *J. Am. Chem. Soc.*, **39**, 124 (1917).

(2) (a) Reid, *et al.*, *J. Am. Chem. Soc.*, **41**, 75 (1919); **42**, 1043 (1920). (b) Drake and Bronitsky, *J. Am. Chem. Soc.*, **52**, 3715 (1930).

(3) See for example: Romo, Rosenkranz and Sondheimer, *J. Am. Chem. Soc.*, **76**, 5169 (1954); Djerassi and Lenk, *J. Am. Chem. Soc.*, **75**, 3493 (1953).

(4) Rosenkranz, Pataki, Kaufmann, Berlin, and Djerassi, *J. Am. Chem. Soc.*, **72**, 4084 (1950).

(5) Ruschig, *Chem. Ber.*, **88**, 878 (1955).

(6) Tharp, *et al.*, *Ind. Eng. Chem.*, **39**, 1300 (1947).

(7) Cromwell and Starks, *J. Am. Chem. Soc.*, **72**, 4108 (1950).

(8) Huntress and Mulliken, *Identification of Pure Organic Compounds, Order I*, John Wiley & Sons, Inc., New York, 1941.

used. In this fashion 85–93% yields of esters of a variety of acids were obtained from phenacyl bromides in acetone after one hour at room temperature. With the less reactive *p*-nitrobenzyl chloride, it was necessary to add a catalytic amount of sodium iodide and to reflux for two hours in order to obtain 50–70% yields of esters. The results from these simple halides are shown in Table I. In the steroid series, similar conditions were used to prepare 3,21-dihydroxy-Δ^5-pregnene-20-one 21-acetate in 88.5% yield from the corresponding 21-iodo derivative.

The results from a study of variations in reaction conditions as applied to the preparation of phenacyl benzoate from phenacyl bromide, benzoic acid, and triethylamine are shown in Table II. Equally good results were obtained in solvents other than acetone, although the reaction appeared to be somewhat slower. In each case, however, the reaction mixture was homogeneous until the crystallization of triethylammonium bromide began. It is noteworthy that a large excess of the salt is not required (compare Runs 1 and 2) and that a large excess of triethylamine over the acid apparently is not deleterious (Run 3).

TABLE II

PHENACYL BENZOATE FROM PHENACYL BROMIDE AND TRIETHYLAMMONIUM BENZOATE

Phenacyl bromide, 0.02 mole; reaction time, one hour

Run	C_6H_5COOH Moles	$(C_2H_5)_3N$ Moles	Ml. of Solvent[a]	Temp., °C.	Yield, %[b]
1	0.175	0.109	50A	25	85
2	.0216	.0202	25A	25	92
3	.0216	.109	25A	25	90
4	.0216	.0202	25B	80[c]	85
5	.0216	.0202	25M	64[c]	94
6	.0216	.0202	25E	78[c]	94
7	.0216	.0202	25P	82[c]	92

[a] A, acetone; B, benzene; M, methanol; E, ethanol; P, 2-propanol. [b] Based on phenacyl bromide. [c] Reaction carried out under reflux.

EXPERIMENTAL[9]

3,21-Dihydroxy-Δ^5-pregnene-20-one 21-acetate. To a solution of 47 g. (0.78 mole) of glacial acetic acid and 49 g. (0.49 mole) of triethylamine in 130 ml. of acetone was added 13.2 g. (0.03 mole) of 3-hydroxy-21-iodo-Δ^5-pregnene-20-one.[5] The clear solution was refluxed for 45 minutes, cooled to room temperature and diluted slowly with 225 ml. of water. The product was filtered, washed thoroughly with water, and dried to constant weight *in vacuo.* The resulting 3,21-dihydroxy-Δ^5-pregnene-20-one 21-acetate was obtained as nearly white crystalline material weighing 9.9 g. (88.5%), m.p. 182–183°, $[\alpha]^{28}_{D}$ +43° (*c*, 1.0 in ethanol). An analytically pure sample prepared by recrystallization from acetone melted at 185–186°, $[\alpha]^{25}_{D}$ +45° (*c*, 1.0 in ethanol).

Preparation of esters (*Table I*). To a solution of 0.175 mole of the acid and 0.109 mole of triethylamine in 50 ml. of acetone was added 0.02 mole of the halogen compound. With the phenacyl bromides, precipitation of triethylammonium bromide from the clear solution usually started within a few minutes. After one hour at room temperature the mixture was slowly diluted with 100 ml. of water which first dissolved the amine salt, then caused separation of the water-insoluble product. The solid material was filtered, washed thoroughly with aqueous 5% sodium bicarbonate followed by water, and dried to constant weight *in vacuo.* The yields and melting points of the products so obtained are shown in Table I.

When the conditions described above for the phenacyl bromides were used with *p*-nitrobenzyl chloride, there was no apparent reaction. There was no precipitation of triethylammonium chloride, and 75–90 per cent of the starting halide could be recovered. While no attempt was made to determine the optimum conditions, it was found that refluxing the acetone solution for two hours in the presence of 0.2 g. of sodium iodide was sufficient to bring about at least partial conversion. The products were isolated as above, and the results are shown in Table I.

Preparation of phenacyl benzoate (*Table II*). The general procedure and isolation (except in Run 4) were as described above for the phenacyl bromides except for changes in solvent and quantities of reagents as indicated in Table II. The reactions in acetone were carried out at room temperature. Incomplete reaction after one hour at room temperature in the other solvents was indicated by the strong lachrymatory odor of phenacyl bromide. One hour at reflux temperature was apparently sufficient for complete reaction in these cases.

In Run 4, the benzene solution was cooled, washed with aqueous 5% sodium bicarbonate and water, and evaporated to dryness under reduced pressure. Trituration of the residue with the *n*-pentane gave the crystalline product as shown in Table II.

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[9] Melting points are uncorrected.

The Proton Magnetic Resonance and Structure of the Diketene-Acetone Adduct[1]

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Received March 30, 1956

In previous work there is some question regarding the molecular structure of the adduct obtained from the reaction of diketene with ketones.[2]

The infrared and ultraviolet spectra[2] and the chemical behavior[2,3] of the adduct with acetone have been interpreted as favoring structure I. On the other hand, similar evidence led to the suggestion[4] that the structure is II. We have observed the proton magnetic resonance spectrum[5] of the adduct, and obtained results which show con-

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[1] This work was supported by the Office of Naval Research and by a grant-in-aid from E. I. du Pont de Nemours and Co.

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