benzofuran is metalated more readily than dibenzothiophene. (4) Contrary to earlier work, but in agreement with Suter's experiments, phenoxathiin was not converted to dibenzofuran by heating with some metals.

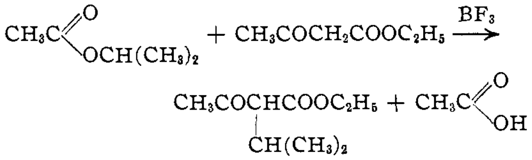
AMES, IOWA RECEIVED JUNE 13, 1940

[CONTRIBUTION FROM THE CHEMISTRY DEPARTMENT OF DUKE UNIVERSITY]

Condensations. XIV.[1] The Alkylation of Ethyl Acetoacetate with Isopropyl Acetate in the Presence of Boron Trifluoride[2]

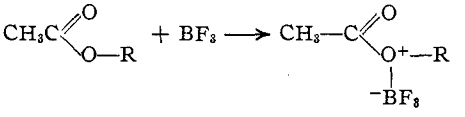
BY DAVID S. BRESLOW AND CHARLES R. HAUSER

It is well known that aliphatic esters generally alkylate rather than acylate in the Friedel–Crafts reaction. In this paper it is shown that isopropyl acetate likewise alkylates the reactive methylenic compound, ethyl acetoacetate, in the presence of boron trifluoride. The reaction may be represented as follows.

(I) 

$$CH_3C(=O)OCH(CH_3)_2 + CH_3COCH_2COOC_2H_5 \xrightarrow{BF_3} CH_3COCH(CH(CH_3)_2)COOC_2H_5 + CH_3C(=O)OH$$

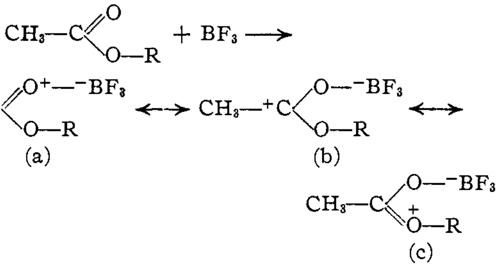
In this condensation as well as in the corresponding Friedel–Crafts reaction it is considered that the ester is activated[3] by the boron trifluoride. The mechanism of this activation may involve an attack of the reagent on either the alcohol oxygen or the carbonyl oxygen. As pointed out by Price,[4] an attack of the boron trifluoride on the alcohol oxygen of the ester would give a complex which would be analogous to that obtained from an alcohol or ether, thus

(II) 

$$CH_3C(=O)O{-}R + BF_3 \longrightarrow CH_3{-}C(=O)O^{+}(R)({}^{-}BF_3)$$

The positive charge on the oxygen atom should facilitate the release of R as a carbonium ion, which is considered to be the "active" electron-accepting component[3] in the alkylation.

An attack of the boron trifluoride on the carbonyl oxygen may also lead to the intermediate formation of R as a carbonium ion. The boron trifluoride-ester complex that would result from such an attack may be represented in several resonance forms, thus[5]

(III) 

Similar to the complex formed in (II), the resonance form (c) with the positive charge on the oxygen should lead to the formation of R as a carbonium ion ("active" intermediate). It seems possible that because of the strongly electron-attracting nature of boron trifluoride, resonance form (c) may contribute to a large extent to the structure of the coördination complex; or the complex may acquire the structure of resonance form (c) as it approaches the electron-donating component in the condensation.

Recently it has been shown[6] that, although esters apparently only alkylate in the Friedel–Crafts reaction at room temperature, at least certain esters both alkylate and acylate at higher temperatures. An attempt to effect the acylation of ethyl acetoacetate with isopropyl acetate by means of boron trifluoride at relatively high temperatures, however, has been unsuccessful.

It should be pointed out that the mechanism of activation of esters by boron trifluoride (or aluminum chloride) represented above in (III) may lead to an "active" acylating intermediate as well as an "active" alkylating intermediate.

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[1] For paper XIII of this series see THIS JOURNAL, **62**, 2457 (1940).

[2] This investigation was supported by a grant from the Duke University Research Council.

[3] See Hauser and Breslow, THIS JOURNAL, **62**, 2389 (1940).

[4] Price and Ciskowski, *ibid.*, **60**, 2499 (1938).

[5] The double-headed arrow is used to illustrate resonance forms. See especially Hammett, "Physical Organic Chemistry," McGraw-Hill Book Co., New York, N. Y., 1940.

[6] Norris and Sturgis, THIS JOURNAL, **61**, 1413 (1939); Norris and Arthur, *ibid.*, **62**, 874 (1940); Kursanov and Zel'vin, *J. Gen. Chem.* (U. S. S. R.), **9**, 2173 (1939).

This is possible if the resonance form (b) contributes appreciably to the structure of the boron trifluoride-ester complex, or if the complex acquires the structure of resonance form (b) during condensation. Thus resonance form (b) with the positive charge on the carbonyl carbon may be regarded as the "active" acylating component in acylations.

Experimental

Alkylation of Ethyl Acetoacetate with Isopropyl Acetate.—A solution of 26.0 g. (0.20 mole) of purified ethyl acetoacetate (b. p. 180–181°) and 20.4 g. (0.20 mole) of purified isopropyl acetate (b. p. 87–88°) was chilled in an ice-bath and saturated with boron trifluoride as previously described,[7] 28.0 g. (0.41 mole) of boron trifluoride being absorbed. A mixture of yellow solid and liquid formed, which turned to a clear orange solution on stirring at room temperature for thirty hours. The reaction mixture was hydrolyzed by pouring it into a solution of 80 g. of anhydrous sodium bicarbonate in 500 cc. of water. The hydrolyzed solution was extracted several times with ether and the combined ether solutions dried over "Drierite." The ether was distilled off through a short Widmer column and the residue distilled at atmospheric pressure, the fraction boiling at 201–203° being collected. It was identified as ethyl α-isopropylacetoacetate by hydrolysis to methyl isobutyl ketone as previously described.[3]

The yield of ethyl α-isopropylacetoacetate was 14.4 g. or 42.1% of the theoretical amount.

Summary

1. Ethyl acetoacetate has been alkylated with isopropyl acetate in the presence of boron trifluoride.

2. The mechanism of alkylation and of acylation by means of esters in the presence of acidic reagents is discussed.

DURHAM, NORTH CAROLINA RECEIVED JULY 17, 1940

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[7] Breslow and Hauser, THIS JOURNAL, **62**, 2385 (1940).

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE WASHINGTON BIOPHYSICAL INSTITUTE]

Photodehydrogenation of Steroids. I. 2,4-Cholestadiene

BY ROBERT P. JACOBSEN AND C. Z. NAWROCKI

An investigation of the formation and properties of certain bimolecular photodehydrogenation products of sterol and bile acid derivatives has been undertaken partly with the hope of learning more about the character of this rather unique group of compounds and partly with the idea of examining them for possible physiological activity.

During the past several years the preparation by photodehydrogenation of a number[1–12] of bisteroids[13] has been reported. In every case the key system which seems to be necessary in order that such photodehydrogenation may occur is a conjugated system of double bonds in Ring B at the 5,7- or 6,8-positions, and, in the former case, the additional requirement of a *trans* orientation[10] of the hydrogen at C_9 with respect to the methyl group at C_{10}. It seemed of particular interest to see whether compounds possessing conjugation in Ring A might undergo similar photodehydrogenation. From preliminary experiments with cholestadiene mixtures rich in 2,4-cholestadiene, this indeed appears to be the case. Although a decision regarding the structure of the hydrocarbon obtained must await further investigation, it seemed desirable in view of the recent appearance of papers by Ando[4] and Tominaga,[11] to make a preliminary report of the investigations which have been undertaken in this Laboratory.

For the photodehydrogenation of steroid dienes

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[1] Windaus and Borgeaud, *Ann.*, **460**, 235 (1928). Inhoffen, *Naturwissenschaften*, **25**, 125 (1937), has tentatively proposed a 7,7′-structure for this substance from ergosterol.

[2] Ando, *Bull. Chem. Soc. Japan*, **14**, 285 (1939).

[3] Windaus and Linsert, *Ann.*, **465**, 148 (1928).

[4] Ando, *Bull. Chem. Soc. Japan*, **14**, 482 (1939).

[5] Windaus and Langer, *Ann.*, **508**, 105 (1933).

[6] Schenck, Buchholz and Wiese, *Ber.*, **69**, 2696 (1936).

[7] Urushibara and Ando, *Bull. Chem. Soc. Japan*, **11**, 802 (1936); **12**, 495 (1937).

[8] Dimroth, *Ber.*, **69**, 1123 (1936).

[9] Wunderlich, *Z. physiol. Chem.*, **241**, 116 (1936).

[10] Haslewood, *Biochem. J.*, **33**, 454 (1939).

[11] Tominaga, *Bull. Chem. Soc. Japan*, **14**, 486 (1939).

[12] Kennedy and Spring, *J. Chem. Soc.*, 250 (1939).

[13] The prefix "bi-" is suggested as an alternative to supplant the term "pinacone" (pinacol in English usage) as applied to this group of photodehydrogenation products. To avoid confusion (see statement of Weizmann, E. Bergmann, and Hirshberg, THIS JOURNAL, **60**, 1532 (1938)) with the bimolecular reduction products of ketones the misnomer "ergopinacol" would become "biergostratrienol." The "Δ^4-cholestenone pinacone" of Windaus, *Ber.*, **39**, 518 (1906), Krekeler, Dissertation, Göttingen, 1937, and of Galinovsky and Bretschneider, *Monatsh.*, **72**, 190 (1938), is probably a true pinacol and its dissimilarity to the aforementioned group of bimolecular photodehydrogenation products is at once apparent on the basis of proposed change in nomenclature. The interesting bimolecular products of the ultraviolet irradiation of α,β-unsaturated steroid ketones [E. Bergmann and Hirshberg, *Nature*, **142**, 1037 (1938); Inhoffen and Huang-Minlon, *Naturwissenschaften*, **27**, 167 (1939); Butenandt and Wolff, *Ber.*, **72**, 1121 (1939)] may possess 4,4′-linkages or may be joined through the oxygen function at C_3. The bimolecular steroid of Petrow and Starling, *J. Chem. Soc.*, 60 (1940), is assumed to have a 6,6′-linkage between molecules.