It has been pointed out that in neutral media compounds substituted at the 4(6)-position absorbed at longer wave lengths than the correspondingly substituted 5-derivatives because the former position was conjugated with the stilbene chromophore, the latter unconjugated. With protonation at the 3-position the chromophoric system changes and the 5- becomes the conjugated and the 4(6)- the unconjugated site with respect to the new benzylideneaniline chromophore. The spectra in acid media reflect this change. For each pair the 5-substituted compound now absorbed at longer wave lengths than the 4(6)- derivative, an inversion of their former relative positions.

This seems strong evidence that there was at least some protonation at the 3-position but does not necessarily imply that all seven compounds were converted exclusively to the indoleninium salts (XXIV, $R_2 = C_6H_5$), for on the latter basis it would be difficult to explain the hypsochromic positions of the maxima of VII and IX relative to IV.[27] It seems more likely that with I, III, IV, V, VI, VIII, and X the products were predominantly the indoleninium salts but that VII and IX were converted to mixtures of the latter with the indolium salts (XXIII), $R_2 = C_6H_5$).[28] The fact that the spectra of VII and IX were more diffuse than those of the others and a broad shoulder for IX at 360–390, which might be the manifestation of a bathochromic band, supports this suggestion.

To determine whether a rate versus equilibrium phenomenon was involved, the spectra of all compounds were redetermined after three days' standing in 85% phosphoric acid. The results were inconclusive. The maxima of I, III, IV, V, VIII, and IX remained at about the same place while that of VII shifted toward the red, that of VI shifted toward the blue and that of IX disappeared completely, probably because of decomposition. Details are given in the footnotes to Table I.

Indoles undergo Mannich[16] and Michael[29] reactions at the 3-position and it is the preferred site for alkylations, acylations, and other substitution reactions,[30] indicating a high electron density at this position. Protonation at the 3-position thus is consistent with the general tendency for electrophilic reactions. Indeed, the conversion of IV to XXIVb is exactly analogous with the reaction of 2,3-disubstituted indoles with methyl iodide. The products are the 2,3,3-trisubstituted indolenines and the indoleninium salts corresponding to XXIV (H = R) are intermediates.

Acknowledgment. The authors are grateful to Drs. B. Witkop and K. Schofield for furnishing samples of the indoles and especially to Dr. E. F. Pratt for permission to publish preliminary information. Drs. L. A. Kaplan and R. E. Lyle contributed helpful discussions.

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(27) The positions of the maxima of both VII and VIII were strongly influenced by overlap with very high intensity bands showing maxima below 260 mμ so that the hypsochromic position for VIII relative to IV causes no concern. With VII the shift was too great to be ascribed to band overlap alone.

(28) Partial protonation at the imino position by VII and IX might be ascribed to stabilization of the stilbene chromophore by the substituent causing a tendency to keep that substituent in the conjugated position.

(29) W. E. Noland and P. J. Hartman, *J. Am. Chem. Soc.*, 76, 3227 (1954).

(30) *Cf.* Review by P. L. Julian, E. W. Meyer, and H. C. Printy in R. C. Elderfield, *Heterocyclic Chemistry*, Volume III, John Wiley and Sons, New York, 1952.

[CONTRIBUTION NO. 28 FROM THE EXPLORATORY RESEARCH LABORATORY, DOW CHEMICAL OF CANADA, LIMITED]

Organic Fluorine Compounds. XXVI.[1a] Acetoacetyl Fluoride[1b]

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Acetoacetyl fluoride was prepared from diketene and anhydrous hydrogen fluoride. Its properties and chemical reactivity as an acetoacetylating agent were investigated.

Acyl fluorides have been reported to be stable in cases where the corresponding chlorides or bromides are nonexistent or unstable. Formyl fluoride[2] and perchloryl fluoride[3] are representative of the high stability of acyl fluorides.

Acetoacetyl chloride has been prepared by Hurd and Kelso[4] but was found to be unstable above −20°. It could not be distilled or stored without

(1a) Part XXV, *J. Org. Chem.*, 21, 1319 (1956).

(1b) Presented at the Symposium on Recent Advances in Fluorine Chemistry, at the 138th Meeting of the American Chemical Society, September 12, 1960. New York, N. Y.

(2) A. N. Nesmeyanov and E. J. Kahn, *Ber.*, 67, 370 (1934). G. A. Olah and S. J. Kuhn, *J. Am. Chem. Soc.*, 82, 2380 (1960).

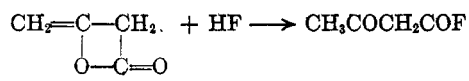
(3) A. Engelbrecht and H. Atzwanger, *Monatsheft.*, 83, 1087 (1952).

(4) C. D. Hurd and C. D. Kelso, *J. Am. Chem. Soc.*, 62, 1548 (1940).

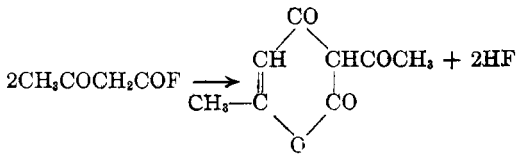
decomposition and its reactions could only be carried out at low temperatures.

We have now investigated the preparation, properties, and chemical reactivity of the previously unreported acetoacetyl fluoride.

Diketene was found to react with anhydrous hydrogen fluoride to give a 60% yield of acetoacetyl fluoride



The by-product of the reaction is dehydracetic acid, formed through condensation of acetoacetyl fluoride

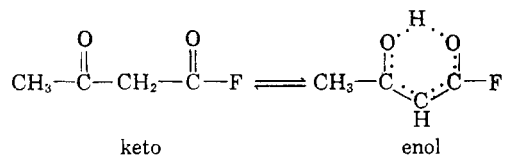


Acetoacetyl fluoride is a colorless fairly stable liquid with a somewhat sharp odor. The boiling point is 57–60° at 35 mm., 43° at 14 mm., 132–134° at atmospheric pressure with some decomposition, n_D^{25} 1.4052. At room temperature it decomposes upon standing in the course of some days to dehydracetic acid but when refrigerated it can be stored for weeks without decomposition. At first the colorless liquid turns yellow, then red. Later a solid precipitate forms (dehydracetic acid) and the whole sample becomes solid. Hydrogen fluoride liberated during the decomposition has a catalytic effect on the condensation.

The infrared spectrum of a thin liquid film (taken on a Baird double beam recording spectrometer with sodium chloride optics) gave the following bands, with tentative assignments in parentheses: 3676 w(2 × 1832), 3426 w, sh (2 × 1721), 3226 m, 2976 m (ν^a C—H), 2937 m (ν^s C—H), 1832 vs (ν C=O, —COF), 1721 vs (ν C=O, CH_3CO), 1626 s, 1425 s (δ C—H), 1412 s (δ C—H), 1366 (δ C—H), 1312 (δ C—H), 1233 s, 1200 s, 1168 s, 1121 s (ν C—F), 1110 s, sh, 1028 m, 945 w, 923 w,

The following abbreviations have been employed; w = weak, s = strong, sh = shoulder, m = medium, vs = very strong, b = broad; ν = stretching frequency (superscript a or s indicates symmetrical or antisymmetical mode), δ = bending frequency.

According to the infrared spectrum acetoacetyl fluoride is present predominantly in the keto form.



keto enol

In order to establish the quantitative keto:enol ratio in acetoacetyl fluoride, the high resolution nuclear magnetic proton resonance spectrum was taken. The proton resonance spectrum was recorded as a function of the applied magnetic field at a fixed frequency of 30.008 Mc using the modified high resolution NMR spectrometer described by Baker and Burd.[5] A comparison of the intensity of the two principal CH_3 peaks indicates a mole ratio of 0.08 enol/keto (7.41% enol, 92.59% keto).

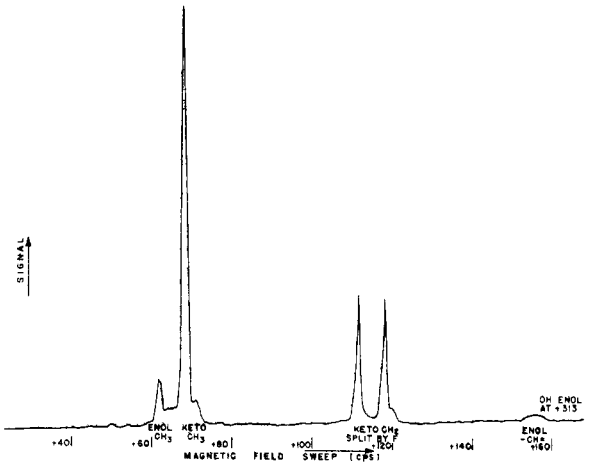
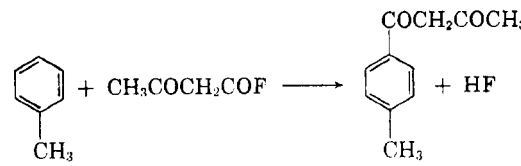


Figure 1

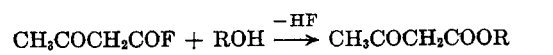
Acetoacetyl fluoride, when used as an acyl halide in attempted aromatic Friedel-Crafts acylation in the presence of boron trifluoride catalyst (most effective in acylation with other acyl fluorides) gives dehydroacetic acid as the main reaction product. Using aluminum chloride as catalyst, a 10% yield of methyl benzoylacetone was obtained in the Friedel-Crafts reaction of acetoacetyl fluoride with toluene.



Selfcondensation to dehydracetic acid is still the main reaction course.

Thus it seems that a Friedel-Crafts catalyst such as boron trifluoride promotes primarily enolization and subsequent selfcondensation by coördinating to oxygen rather than fluorine. This is made more obvious by the fact that no acetoacetylium tetrafluoroborate complex formations was observed in the system $CH_3COCH_2COF:BF_3$.

By treating acetoacetyl fluoride with alcohols in the presence of an acid binding agent, alkyl acetoacetates are formed in good yields:



(5) E. B. Baker and L. W. Burd, *Rev. Sci. Instr.*, 28, 313 (1957).

TABLE I

Amine	Acetoacetamide	B.P./Mm.	N, % Calcd.	N, % Found	Yield, %
Ethylamine	*N*-Ethyl acetoacetamide	170/18 (dec.)	10.90	10.84	70
n-Propylamine	*N*-Propyl acetoacetamide	131/1	9.77	9.69	93
i-Propylamine	*N*-*i*-Propyl acetoacetamide	105–106/0.5	9.77	9.83	91
n-Butylamine	*n*-Butyl acetoacetamide	128/0.5	8.92	8.90	86
Dicyclohexyl-amine	*N*,*N*-Dicyclohexyl aceto-acetamide	166–168/0.6	5.27	5.19	90

The known methyl, ethyl, *i*-propyl, *i*-butyl, *i*-amyl, and benzyl acetoacetate were obtained in yields varying from 68 to 86%.

Acetoacetyl fluoride reacts with primary and secondary amines to form the corresponding acetoacetamides.

$$CH_3COCH_2COF + 2RNH_2 \longrightarrow CH_3COCH_2CONHR + RNH_2.HF$$

The following previously known compounds were obtained with 56 to 87% yields: acetoacetamide, *N*-benzyl acetoacetamide, *N*-*o*-tolyl acetoacetamide, *N*-propyl acetoacetamide, and *N*-*o*-chlorophenyl acetamide. Properties of the new acetoacetamides prepared are summarized in Table I.

Acetoacetyl fluoride is hydrolyzed by water to acetoacetic acid, which itself loses carbon dioxide and gives acetone

$$CH_3COCH_2COF + H_2O \xrightarrow{-HF} CH_3COCH_2CO_2H \xrightarrow{-CO_2} CH_3COCH_3 + CO_2$$

In caustic medium the acetone formation is greatly accelerated.

EXPERIMENTAL

Diketene was purchased from the Aldrich Chemical Company, Milwaukee, Wis., and redistilled each time before use; b.p. 126–127.5°, m.p. −6.5°.

Preparation of acetoacetyl fluoride. To 100 g. (1.2 moles) of diketene 24 g. (1.2 moles) of anhydrous hydrogen fluoride was added in a silica flask, provided with a reflux condenser and protected by a calcium chloride tube from air moisture. The addition was started at −5° and as the freezing point of the diketene–acetoacetyl fluoride mixture dropped, so the temperature was lowered down to Dry Ice temperature. After the addition was completed the reaction mixture was allowed to warm up slowly to room temperature, 5 g. of anhydrous sodium fluoride was added to remove any possible excess of hydrogen fluoride. After filtering, the product was distilled *in vacuo;* yield, 81 g., 65%, b.p. 63–65°/35 mm., n_D^{25} 1.4052. From the residue 8 g. of dehydroacetic acid (m.p., 109°) was isolated.

Anal. Calcd. for $C_4H_5FO_2$ (104.08): C, 46.15; H, 4.83; F, 18.27. Found: C, 46.28; H, 4.80; F, 18.10.

Reaction of acetoacetyl fluoride with alcohols. Acetoacetyl fluoride, 5.7 g. (0.05 mole), was dissolved in 20 ml. of dry ether and 0.05 mole of the corresponding alcohol dissolved in 20 ml. ether was added at ice bath temperature. The reaction mixture was allowed to stand for 15 min. Thereafter, a solution of 3 g. of trimethylamine in 10 ml. ether was added, while the mixture was stirred with a magnetic stirrer. The precipitated amine hydrofluoride was filtered, the organic layer washed with water, dried, distilled to remove ether, and then fractionated. The following known alkyl acetoacetates were prepared: methyl (78% yield), ethyl (86%), *i*-propyl (83%), *i*-butyl (72%), *i*-amyl (79%) and benzyl (68%).

Reaction of acetoacetyl fluoride with amines. Acetoacetyl fluoride, 5.7 g. (0.05 mole), was dissolved in 20 ml. of dry ether and was added to a solution of 0.1 mole of amine dissolved in 25 ml. of ether, at ice bath temperature. The mixture was allowed to stay for 1 hr. The precipitated amine hydrofluoride was filtered. After removal of the ether, the remaining crude amine was either distilled under reduced pressure or recrystallized from ligroin or alcohol. The following known acetoacetamides were prepared: acetoacetamide (87% yield), *N*-benzyl (61%), *N*-phenyl (74%), *N*-*o*-tolyl (63%), and *N*-*o*-chlorophenyl (56%). Data of the new acetoacetamides prepared are summarized in Table I.

Friedel-Crafts acetoacetylation of toluene. Into the stirred mixture of 46 g. of toluene (0.5 mole), 50 g. of chloroform, and 33 g. of anhydrous aluminum chloride (0.25 mole), 20 g. of acetoacetylfluoride (0.2 mole) was added dropwise. The temperature was kept at 0° and the mixture stirred for 1 hr. There was strong hydrogen chloride evolution at first which gradually ceased. The mixture was then poured into ice water, the separated organic layer was washed three times with water, dried over calcium chloride, and distilled to remove the unchanged toluene. The residue was distilled under reduced pressure; b.p. 115–117°/1 mm. The infrared spectrum was identical with that of methyl benzoylacetone; yield 3.29g., 10%. From the reaction residue, 10.5 g. dehydracetic acid (b.p. 109°) was isolated.

Acknowledgment. The authors are indebted to Dr. Denys Cook of this laboratory for the assignment of the infrared spectrum and to Dr. E. B. Baker, Physical Research Laboratory, the Dow Chemical Company, Midland, Mich., for obtaining and interpreting the NMR spectrum.

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