Anal. Calcd for $C_{10}H_{12}ON_2$: C, 68.16; H, 6.86; N, 15.90. Found: C, 68.41; H, 6.60; N, 16.00.

A second fraction was isolated as a yellow solid, yield 0.25 g (0.1 mmole, 22%), mp 100–101° dec, and was identified as 3-(β-phenylhydrazino)-4-nitroso-5-cyclopropylisoxazole (IV): infrared absorption (cm^{-1}, Nujol mull), 950 s, 1010 s, 1030 s, 1310 w, 1360 s, 1600 s, 1625 s, 3040 m.

Anal. Calcd for $C_{12}H_{12}O_2N_4$: C, 59.01; H, 4.95; N, 22.94. Found: C, 59.19; H, 5.26; N, 23.12.

Reaction of Di(cyclopropanecarbonyl)furoxan (II) with 2,4-Dinitrophenylhydrazine.—A solution of 0.56 g (0.25 mmole) of II in 10 ml of methanol was heated to boiling while a solution of 0.50 g (0.25 mmole) of 2,4-dinitrophenylhydrazine in 25 ml of methanol was added. Upon addition of a few drops of concentrated HCl, the yellow mono-2,4-dinitrophenylhydrazone derivative was isolated and recrystallized a few times from alcohol: mp 118–119°; yield, 0.81 g (0.2 mmole, 80%).

Anal. Calcd for $C_{15}H_{14}O_7N_6$: C, 47.76; H, 3.51; N, 20.89. Found: C, 47.76; H, 3.50; N, 20.75.

A solution of 0.56 g (0.25 mmole) of II in 10 ml of ethanol was heated to boiling while a solution of 1.0 g (0.50 mmole) of 2,4-dinitrophenylhydrazine in 25 ml of ethanol was added. After addition of a few drops of concentrated HCl, the mixture was heated to reflux for 2 hr. The yellow solid was separated by filtration while the solution was still hot and recrystallized repeatedly from nitromethane: mp 250–251° dec; yield, 0.41 g (0.07 mmole, 28%).

Anal. Calcd for $C_{22}H_{15}O_{10}N_{10}$: C, 45.36; H, 3.12; N, 24.05. Found: C, 45.42; H, 3.53; N, 24.18.

Hydrolysis of II.—A suspension of 1.55 g (0.7 mmole) of di(cyclopropanecarbonyl)furoxan in 20 ml of 10% NaOH solution was heated in a water bath for 2 hr, then evaporated under vacunm to a small volume, acidified with 50% H_2SO_4, and extracted with ether. The combined ether extracts were washed with water and dried with anhydrous sodium sulfate. The major portion of the ether was removed, then replaced by methylene chloride, which was distilled off, followed by fractional distillation under vacuum. The middle fraction which distilled at at 94° (35 mm) was identified as cyclopropane carboxylic acid: yield, 0.5 g (71%) of colorless liquid; $n^{26}D$ 1.4350 (lit.[9] bp 182–184°; $n^{20}D$ 1.4390). This liquid was converted into the corresponding amide by a standard procedure. The colorless solid gave no depression of mixture melting point with authentic cyclopropanecarboxamide, mp 123–125°.

Registry No.—II, 15158-43-7; II bis(2,4-dinitrophenylhydrazone), 15158-44-8; III, 15158-45-9; IV, 15158-46-0.

Acknowledgment.—This work was supported by the Naval Weapons Laboratory, Dahlgren, Va., and we are grateful for this support. The authors thank Mr. Rupert D. Barefoot for obtaining the nmr spectra and to Dr. Elton Price for assistance in their interpretation.

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Studies on the Synthesis of Extended β-Carbonyl Compounds

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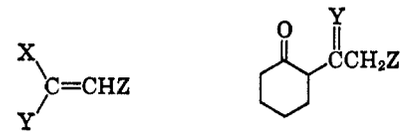
Because of the widespread occurrence of acetate-derived poly-β-carbonyl systems and related species in nature, we were prompted to investigate new approaches to the synthesis of such compounds. Although the terminal acylation of dianions derived from β-diketones has been employed[2] to achieve this end, the required conditions are incompatible with a number of sensitive functional groups. Our aim has therefore been to develop a milder and more selective synthetic method. In this Note we wish to report some successful alkylations of 1-pyrrolidinocyclohexene (I) to generate derivatives of 1,3,5-triketones.

One attractive approach to such systems would be a Michael addition of enamine I to a compound of general formula II, where X is the leaving group, Y represents a function which can be transformed to a carbonyl by hydrolysis and ketonization, and Z is a carbonyl derivative. One simple model with the required functionalization is ethyl-2,2-diethoxyacrylate (IIa).[3] However, reaction of IIa with I followed by work-up with aqueous acid produced cyclohexanone and diethyl malonate as the only detectable neutral products.



IIa, X = Y = OEt; Z = CO_2Et IIIa, Y = NH; Z = CN
b, X = $OPO(OCH_3)_2$; Y = NH_2; Z = CN b, Y = O; Z = CO_2Et

In a more successful attack, the Perkow reaction[4] of 2-bromocyanoacetamide and trimethyl phosphite afforded a compound which is assumed, on the basis of previous research,[5] to have structure IIb. Further reaction of this crude material with I followed by cautious aqueous acid hydrolysis gave a 23% yield of crystalline tricarbonyl derivative IIIa. Variations in the reagent proportions and reaction times failed to increase the yield. The analogous alkylation reaction of the adduct of diethyl bromomalonate[6] and trimethyl phosphite with I was sluggish and required refluxing for 4 hr in benzene for completion, as judged by separation of dimethyl phosphate. The products of hydrolytic work-up were diethyl malonate and cyclohexanone rather than the desired IIIb or its transformation products.

The ketoketenimines (V) derived from base-catalyzed ring opening of suitably substituted isoxazolium salts (IV)[7] suggested themselves as particularly reactive intermediates toward enamine alkylation (Chart I). In a model experiment N-ethyl-5-phenylisoxazolium fluoroborate (IVa) was treated with 1 equiv of triethylamine and an excess of I. Work-up with aqueous acetic acid afforded a 16% yield of the fluoroborate salt of VIIa probably resulting from cyclization of the intermediate VIa or a related species.

Attempts to extend this method with a simple 5-alkoxy isoxazolium salt IVb (seemingly an ideal reagent for the synthesis of β-δ-diketo esters) were frustrated

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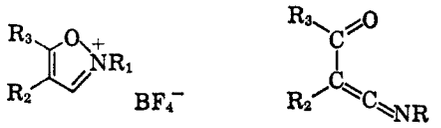
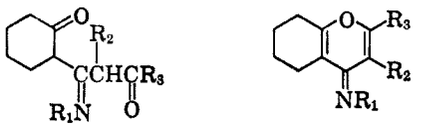
CHART I



IVa, R_1 = Et; R_2 = H; R_3 = Ph
b, R_1 = Me; R_2 = H; R_3 = OEt
c, R_1 = Me; R_2 = CO_2Et; R_3 = OEt

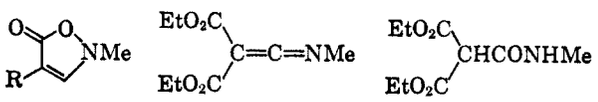
V



VIa, R_1 = Et; R_2 = H; R_3 = Ph
b, R_1 = Me; R_2 = CO_2Et; R_3 = OEt

VIIa, R_1 = Et; R_2 = H; R_3 = Ph
b, R_1 = Me; R_2 = CO_2Et; R_3 = OH

by our inability to prepare the required precursor, N-methylisoxazolone (VIIIa). Condensation of ethyl propiolate with N-methylhydroxylamine did not yield the expected VIIIa but gave instead triethyl trimesate



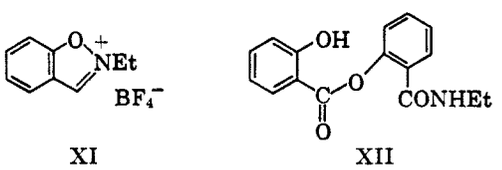
VIIIa, R = H
b, R = CO_2Et

IX

X

as the major product. The more complex 4-carboethoxy-5-ethoxyisoxazolium salt (IVc) could, however, be prepared by alkylation of the known 4-carboethoxyisoxazolone (VIIIb)[8] with triethyloxonium fluoroborate.[9] The product, an intractable gum, was shown by two experiments to contain IVc. On treatment with 1 equiv of triethylamine in dichloromethane the expected ketenimine (IX) formed as demonstrated by the appearance of a strong infrared absorption band at 4.5–4.7 μ. The isoxazolium salt (IVc) could also be converted *via* IX with aqueous sodium bicarbonate into the diester amide (X) in 22% over-all yield from VIIIb. Unfortunately the reaction of crude IVc with I followed by work-up with aqueous acid gave only traces of VIIb and none of its possible precursor (VIb).

A further attempt to extend the enamine alkylation reaction to the benzisoxazolium salt (XI)[10] met with failure. When XI was treated with excess I, there was produced, along with considerable polymeric material, an 18% yield of ester XII probably resulting



XI

XII

from reaction of an intermediate ketoketenimine with one of its own hydrolysis products.

The results reported here are mainly of theoretical interest because of the low yields. Possibly enamine I is too poor a nucleophile to alkylate the compounds studied before considerable competing side reactions can occur.

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(10) D. S. Kemp and R. B. Woodward, *Tetrahedron*, **21**, 3019 (1965).

Experimental Section[11]

2-(2-Imino-3-cyanoethyl)cyclohexanone (IIIa).—A solution of 2-bromocyanoacetamide (3.2 g, 0.02 mole)[12] in 50 ml of dry tetrahydrofuran was cooled in an ice bath and a solution of trimethyl phosphite (2.5 g, 0.02 mole) in 10 ml of tetrahydrofuran was added dropwise with stirring. The mixture was stirred for 5 min after completion of the addition and then a solution of 1-pyrrolidinocyclohexene (I,[13] 6.0 g, 0.04 mole) in 40 ml of benzene was added dropwise over 15 min with stirring and cooling in ice. A dark oil gradually separated. The mixture was allowed to stand for 1 hr at room temperature and 10 ml of water and 2.4 g (0.04 mole) of glacial acetic acid were added. The mixture was warmed for 5 min on the steam bath, cooled to room temperature, and extracted with three 10-ml portions of ether. The combined extracts were washed successively with water and 10% aqueous $NaHCO_3$ and dried ($MgSO_4$); the solvent was evaporated to give an oil which deposited clumps of needles on standing. The crystals were filtered and washed with ether to give almost colorless product (0.73 g, 23%). Recrystallization from benzene yielded analytically pure material: mp 110–112°; infrared ($CHCl_3$), 2.85, 2.93, 4.51, 5.93, and 6.28 μ; nmr, $\delta_{TMS}^{CDCl_3}$ 6.3–7.1 (2 H), 2.8–3.1, 2.5–2.8 (4 H total), and 1.5–1.9 (6 H), all poorly resolved envelopes.

Anal. Calcd for $C_9H_{12}N_2O$: C, 65.82; H, 7.37; N, 17.06; mol wt, 164. Found: C, 65.97; H, 7.56; N, 17.32; mol wt, 164 (mass spectrum).

4-Ethylimino-5,6,7,8-tetrahydroflavan (VIIa).—To a solution of 1-pyrrolidinocyclohexene (I, 6.0 g, 0.04 mole) and triethylamine (2.8 ml) in 40 ml of benzene cooled in an ice bath was added dropwise with stirring over 1 hr a solution of 2-ethyl-5-phenylisoxazolium fluoroborate (IVa,[7] 5.2 g, 0.02 mole) in 60 ml of acetonitrile. The resulting solution was allowed to stand for 16 hr at room temperature under nitrogen. The solvent was evaporated, acetic acid (3.6 ml) and water (40 ml) were added to the residue, and the mixture was warmed for 5 min on the steam bath. The solvent was removed with a rotary evaporator and the residual semisolid was dissolved in 30 ml of ethanol with heating. The mixture was cooled and the product was filtered and washed with ether to give a solid (1.8 g, 26%). Recrystallization from 95% ethanol afforded colorless needles of the fluoroborate salt: mp 179–180°, infrared ($CHCl_3$), 3.02, 6.07, and 6.25 μ.

Anal. Calcd for $C_{17}H_{20}NOBF_4$: C, 59.84; H, 5.91; N, 4.11. Found: C, 59.64; H, 5.89; N, 4.15.

The free base was prepared by shaking the fluoroborate salt (1.8 g) with a mixture of 20 ml of 10% aqueous KOH and 20 ml of ether until all solid had dissolved. The ether layer was then separated, washed with water, and dried over $MgSO_4$. Evaporation of the ether yielded an off-white solid (1.1 g). Chromatography of a benzene solution on a short column of neutral grade I alumina and recrystallization from pentane gave VIIa as colorless prisms: mp 76–77°; infrared ($CHCl_3$), 6.00 and 6.24 μ; nmr, $\delta_{TMS}^{CDCl_3}$ 7.2–7.8 (5 H, multiplets), 7.02 (1 H, singlet), 3.46 (2 H, quartet, J = 7 cps), 2.2–2.6 (4 H, envelope), 1.5–1.9 (4 H, envelope), and 1.27 (3 H, triplet, J = 7 cps).

Anal. Calcd for $C_{17}H_{19}NO$: C, 80.59; H, 7.56; N, 5.53; mol wt, 253. Found: C, 80.67; H, 7.86; N, 5.49; mol wt, 253 (mass spectrum).

2-Methyl-4-carboethoxy-5-ethoxyisoxazolium Fluoroborate (IVc).—Triethyloxonium fluoroborate[9] (0.95 g, 0.005 mole) was added to 2-methyl-4-carboethoxy-5-isoxazolone (VIIIb,[8] 0.85 g, 0.005 mole) and the mixture was warmed on a steam bath with care to exclude moisture. A homogeneous melt soon resulted and ether vapors were evolved. After heating for 5 more min

(11) All melting points were determined with a Thomas–Hoover capillary melting point apparatus and are uncorrected. Infrared spectra were run on a Beckman IR-8 spectrophotometer and calibrated against the 6.24-μ polystyrene peak. Nmr spectra were measured on a Varian A-60A spectrometer and mass spectra were determined with a Nuclide Corp. Model 12-90 Gl. 1 spectrometer.

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the mixture was freed of ether *in vacuo* yielding the isoxazolium salt as a colorless viscous oil.

A sample of crude IVc prepared on the above scale was dissolved in 20 ml of 10% aqueous $NaHCO_3$. After the vigorous evolution of carbon dioxide had subsided, the mixture was extracted with two 20-ml portions of ether, the combined ether extracts were dried over $MgSO_4$, and the solvent was evaporated cautiously to give a yellow oil which solidified on scratching under a small amount of ether, yield of amide X, 240 mg, 22%. Two recrystallizations from benzene–cyclohexane gave colorless clumps of needles: mp 89–91°; infrared ($CHCl_3$), 2.95, 5.73, and 5.95 μ; nmr, $\delta_{TMS}^{CDCl_3}$ 7.1–7.7 (1 H, envelope), 4.36 (1 H, singlet), 4.27 (4 H, quartet, J = 7 cps), 2.86 (3 H, doublet, J = 5 cps), 1.29 (6 H, triplet, J = 7 cps).

Anal. Calcd for $C_9H_{15}NO_5$: C, 49.76; H, 6.96; N, 6.45; mol wt, 217. Found: C, 50.01; H, 7.03; N, 6.47; mol wt, 217 (mass spectrum).

3-Carboethoxy-4-methylimino-3,4,5,6,7,8-hexahydrocoumarin (VIIb).—Crude 2-methyl-4-carboethoxy-5-ethoxyisoxazolium fluoroborate (IVc), prepared from (VIIIb, 2.55 g, 0.015 mole) as described above, was dissolved in 30 ml of acetonitrile and the solution was cooled in a Dry Ice–acetone bath. Triethylamine (2.25 ml, 0.015 mole) was added dropwise and then 1-pyrrolidinocyclohexene (I,[13] 2.25 g, 0.015 mole) was added in one portion. The mixture was allowed to stand for 16 hr at room temperature under nitrogen. The solvent was removed on a rotary evaporator, the residual gum was dissolved in a mixture of 30 ml of water and 1.8 ml of acetic acid, and the solution was warmed for 5 min on the steam bath. After cooling the mixture was extracted with two 30-ml portions of ether. The extracts were washed with 10% aqueous $NaHCO_3$ and dried over $MgSO_4$ and the solvent was evaporated, yielding an oil which partially crystallized on standing in an evaporating dish. The crystals were triturated with a small amount of ether, filtered, and washed with ether. The light tan prismatic needles (74 mg, 2.0%) were further purified by column chromatography on neutral grade 1 alumina using benzene as eluent. Recrystallization from cyclohexane afforded analytically pure material: mp 106–108°; infrared ($CHCl_3$), 2.90, 6.10, and 6.25 μ; nmr, $\delta_{TMS}^{CDCl_3}$ 4.45 (2 H, quartet, J = 7 cps), 3.44 (3 H, singlet), 2.3–2.8 (4 H, envelope), 1.6–2.1 (4 H, envelope), 1.45 (3 H, triplet, J = 7 cps) (the enolic proton was not detectable).

Anal. Calcd for $C_{13}H_{17}NO_4$: C, 62.13; H, 6.82; N, 5.58; mol wt, 251. Found: C, 62.11; H, 6.61; N, 5.39; mol wt, 251 (mass spectrum).

Reaction of 2-Ethylbenzisoxazolium Fluoroborate with 1-Pyrrolidinocyclohexene.—A solution of 2-ethylbenzisoxazolium fluoroborate[10] (XI, 5.4 g, 0.02 mole) in 20 ml of acetonitrile was added dropwise with stirring at room temperature over 30 min to a solution of 1-pyrrolidinocyclohexene (I,[13] 6.0 g, 0.04 mole) in 40 ml of benzene. The mixture was allowed to stand overnight at room temperature under nitrogen and the solvent was then evaporated; the gummy residue was dissolved in 20 ml of 6 N HCl and the solution was warmed for 5 min on the steam bath. The mixture turned dark and an oil separated. After cooling, the mixture was extracted with three 20-ml portions of ether, the combined extracts were washed with water and then with 10% aqueous $NaHCO_3$ and dried ($MgSO_4$), and the solvent was evaporated. The resulting oil solidified partially on standing. Chromatographic filtration through a short column of neutral grade I alumina in chloroform and two recrystallizations from cyclohexane gave almost colorless needles of XII (0.5 g, 18%): mp 133–134°; infrared, ($CHCl_3$) 2.91, 3.07, 5.91, and 6.02 μ; nmr, $\delta_{TMS}^{CDCl_3}$ 6.8–8.2 (8 H, multiplet), 6.2–6.7 (1 H, envelope), 3.33 (2 H, quintet, poorly resolved), 1.0 (3 H, triplet, J = 6.5 cps).

Anal. Calcd for $C_{16}H_{15}NO_4$: C, 67.36; H, 5.30; N, 4.91; mol wt, 285. Found: C, 67.34; H, 5.07; N, 5.24; mol wt, 285 (mass spectrum).

Registry No.—IIIa, 15129-05-2; VIIa, 15129-06-3; VIIa fluoroborate salt, 12167-68-9; VIIb, 15129-07-4; X, 15129-21-2; XII, 15129-08-5.

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Reactions of Benzyl Halides with Nickel Carbonyl in Various Media

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Recently a number of reports have been published on the reactions of nickel carbonyl with some active halides, such as allylic halides,[1] propargyl halides,[2] or aryl iodides.[3] The types of the reaction products, however, differ with the change in the properties of the ogranic group in the halides. For example, allyl halides form linear dimers on reaction with nickel carbonyl in alcohols or in aprotic solvents. The reactions are considered to proceed *via* π-allylnickel complexes. These π-allylnickel complexes have been shown to react with other organic halides to yield coupling products[4] and also to react with acetylene and carbon monoxide,[5] acrylonitrile,[6] benzaldehyde, acrolein, cyclopentanone, or styrene oxide.[4] Although carbonylation of allyl halides can only be accomplished under high pressure of carbon monoxide, as reported by Bauld, iodobenzene is carbonylated with nickel carbonyl to give esters of benzoic acid in alcoholic solvents and benzil and α,α'-dibenzoyloxystilbene in aprotic solvents. These carbonylation products were considered to be produced by the alcoholysis or thermal decomposition of the postulated intermediate, benzoylnickel carbonylate, $C_6H_5Ni(CO)_nI$, which contains a benzoyl–nickel σ bond. Since the ordinary alkyl halides were reported not to react with nickel carbonyl,[3] it is interesting to select benzyl halide series for reactions with nickel carbonyl. We have carried out the reactions of nickel carbonyl with benzyl halides in various solvents and obtained new types of results (Table I).

As indicated in Table I, carbon monoxide insertion occurred in the polar nonaromatic solvents, whereas almost no insertion occurred in the aromatic solvents. The reactivity of benzyl halides in the carbonylation increased in the order chloride < bromide < iodide and the increasing polarity of the solvent results in the increasing reactivity. Benzyl bromide and iodide were converted mainly into ethyl phenylacetate in ethanol and, when the reaction between benzyl iodide and nickel carbonyl was carried out in tetrahydrofuran, the fission of the tetrahydrofuran ring occurred to give 4-iodo-*n*-butyl ester of phenylacetic acid in a 62% yield. In polar aprotic solvents, such as N,N-dimethylformamide, dimethyl sulfoxide, or acetonitrile, dibenzyl ketone was obtained in an excellent yield, but neither α-diketone nor its derivative (enediol diester) was obtained. It is noteworthy that, when the

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(3) N. L. Bauld, *Tetrahedron Letters*, 1841 (1963).

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