293. Trimers of Aliphatic Monosubstituted Ketenes from Acid Chlorides

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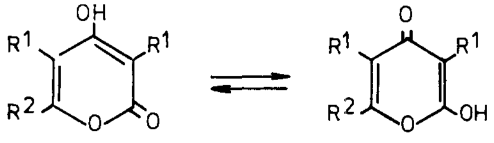
Summary

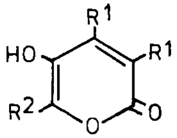
A new synthesis of trimers of aliphatic monosubstituted ketenes from acid chlorides is described. The structures of the products are shown to be alkyl substituted γ-hydroxy-α-pyrones by NMR. and mass spectroscopy. ^{13}C-NMR. studies indicate, that an acetanilide/aluminum-chloride complex catalyses the formation of the products.

Introduction. – To acylate acetanilide excessive amounts of $AlCl_3$ were used [1] [2] instead of the nearly stoichiometric amounts [3] needed for acylating aromatic compounds with acid chlorides. On caproylating acetanilide in trichloroethylene [4], it was found that using less than 1.8 mol $AlCl_3$/1 mol acetanilide leads to the formation of a compound of the simplest formula $C_6H_{10}O$ melting at 69° instead of the expected *p*-acetamino-phenylpentyl ketone. With more $AlCl_3$ the ketone was obtained. These facts lead us to suspect that the $AlCl_3$ is involved in a reaction other than the *Friedel-Crafts* acylation. We decided therefore, to elucidate the structure of the $C_6H_{10}O$ compound and investigate this reaction.

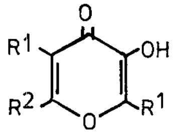
Results. – The mass spectrum of the above compound showed a molecular mass of 294.219 corresponding to a molecular formula $C_{18}H_{30}O_3$ (calc. 294.2194). The most prominent fragments were formed by loss of C_3H_7 (base peak), C_3H_6, C_4H_8, subsequent decarbonylation, elimination of C_2H_4 and again of C_3H_6, indicating several alkyl groups. The presence of alkyl groups was verified by the ^{1}H-NMR. spectrum, which showed unresolved multiplets, at 0.9 ppm for 9 protons (3CH_3 groups), at 1.4 ppm for 14 protons (7CH_2 groups) and at 2.5 ppm for 6 protons (3 deshielded CH_2 groups). Thereby 13 carbon atoms and 29 protons of the molecular formula appear to be accounted for by 3 alkyl groups. The last proton showed up in the NMR. spectrum as a singlet at 8.8 ppm and is ascribed to an OH group as indicated by the IR. spectrum which showed a broad association band extending up to 3600 cm^{-1}. This leaves us with 5 carbon atoms and 2 oxygen atoms. At least 1 carbonyl group is present as indicated by a split band at 1670 cm^{-1} in the IR. spectrum. The gathered structural features amount to a tetrasubstituted pyrone structure, especially when the information obtained from the ^{13}C-NMR. spectrum is taken into consideration. This showed 5 low field signals (167.2, 166.3, 159.1, 112.9 and 103.6 ppm) for carbon atoms not directly bound to protons (as seen from off resonance spectra) and proton bearing alkyl carbon atoms in the range between 32 and 14 ppm. Furthermore, the molecular formula corresponds to a trimer of the dehydrohalogenated acid chloride. The above facts suggest that the compound $C_{18}H_{30}O_3$ has one of the following structures (Ia–IVa).



I II



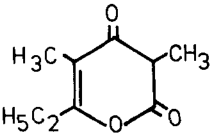
III



IV

	a	b
R^1 =	$(CH_2)_3CH_3$	CH_3
R^2 =	$(CH_2)_4CH_3$	CH_2CH_3

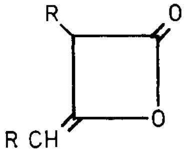
The lower homologue 6-ethyl-3,5-dimethyl-2,4-dioxo-3,4-dihydro-2*H*-pyran (V) was synthesized by *Wedekind & Haeussermann* [5] and reported to melt at 151°.



V

Therefore, we repeated the above reaction with propionyl chloride and obtained a product melting at 153–154° of the simplest formula C_3H_4O as shown by elemental analysis. Its mass spectrum showed the expected molecular mass of 168 for $C_9H_{12}O_3$ and as major degradation pathways decarbonylation and loss of CH_3 and C_2H_4. By analogy the structures (Ib–IVb) were suggested, while structures (Ib–IIIb) were favoured by the mass spectrometric fragmentation pattern. Structure IVb contains a potential acetyl group which usually yields a very abundant ion at *m/e* 43. However the spectrum of this compound shows no significant fragment of this mass. A clear differentiation between the suggested structures was possible on the basis of the ^{13}C, ^{1}H couplings. The multiplicities of the 3 low field lines (4, 7, 9 *cf.* exper. part) exclude structures IIIb and IVb. Therefore we suggest the tautomeric structures Ib and IIb for this compound. The exchange of the OH proton with D_2O causes upfield shifts of 0.21 ppm, 0.11 ppm, 0.11 ppm and 0.06 ppm for the lines at 166.80, 107.57, 98.56 and 167.56 ppm indicating that the OH group is bound to the carbon atom at 166.80 ppm [6] [7]. This signal is a septet in the nondecoupled spectrum, thus showing that the tautomer Ib is favoured in $CDCl_3$ solution.

The compounds Ia and Ib were obviously formed by the condensation of 3 molecules of the acid chloride through the elimination of 3HCl. Whether a ketene is first formed is an open question. This type of trimers was reported to be obtained in low yields beside the β-lactone type dimers (VI) by the dehydrohalogenation of aliphatic acid chlorides with triethylamine [8].



VI

Since no amine was used in the reaction mixture and our experiments showed that neither $AlCl_3$ nor acetanilide alone could catalyse the reaction and since the trimers of monosubstituted ketene were formed in good yields, then another catalyst must have been formed *in situ*. This could only be a sort of $AlCl_3$/acetanilide complex. The effect of changing the ratio of $AlCl_3$ to acetanilide on the formation of the monosubstituted ketene trimer (Ia) and the 4-acetamino-phenylpentyl ketone (VII) is shown in *Table* .

Table. *Effect of $AlCl_3$/acetanilide ratio on the formation of ketene trimer Ib and the ketone VII*

Mol ratio $AlCl_3$/acetanilide	Amount of products in the reaction mixture after 1 h[a]) Ib%	VII%
1.1	4.3	–
1.5	11.2	3.2
1.6	19.1	5.9
1.8	0.5	16.4
2.0	0.2	25.2
2.5	–	35.2

[a]) Relative peak area of products in the reaction mixture as determined by GLC.

The results in *Table* show that $AlCl_3$ is first bound by the acetanilide and the resulting complex catalyses the formation of trimers of monosubstituted ketenes. As soon as the amount of $AlCl_3$ is in excess of what is needed for the complex formation, the free $AlCl_3$ catalyses the competing *Friedel-Crafts* reaction. The interaction between acetanilide and $AlCl_3$ was investigated by ^{13}C-NMR. spectroscopy. Successive addition of $AlCl_3$ to a solution of acetanilide in deuterioacetone showed the dependence of the chemical shifts on the relative concentrations (*Figure*). The maximum

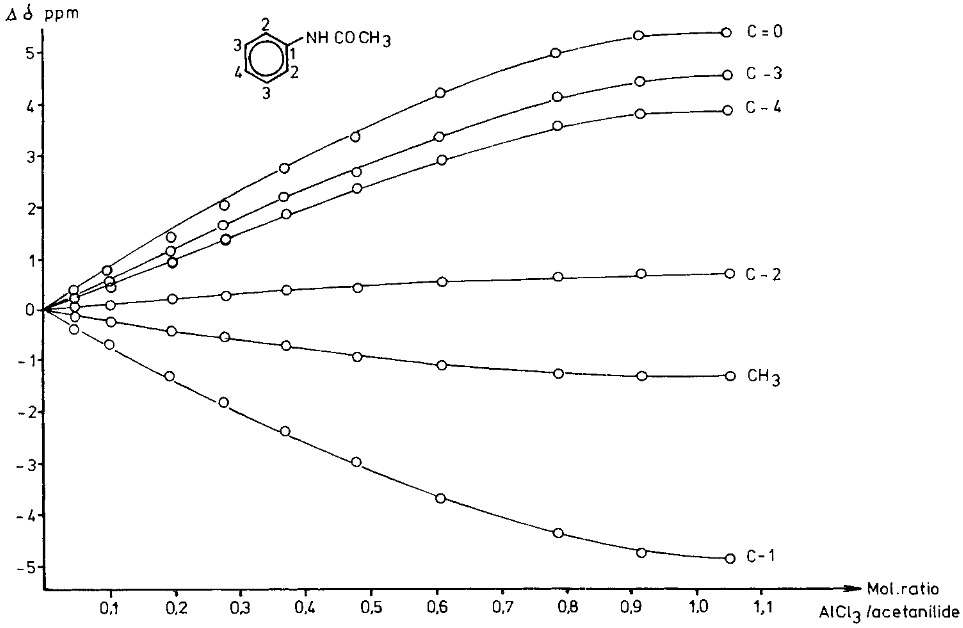


Figure. *Influence of $AlCl_3$ on the ^{13}C-chemical shifts in acetanilide* (solvent: acetone-d_6, conc. of acetanilide: ~1 mol/l)

values of the induced shifts were observed at a molar concentration ratio of 1:1 ($AlCl_3$/acetanilide). At this concentration the carbonyl carbon was deshielded by more than 5 ppm, while C(1) was shielded by more than 4.5 ppm. These results show clearly that there is an association between acetanilide and $AlCl_3$.

This reaction provides a new route for the synthesis of aliphatic monosubstituted-ketene trimers in good yields.

Experimental Part

General remarks. ^1H-NMR. spectra were recorded on *Varian* HA-100MHz using tetramethylsilane (TMS) as internal standard. Chemical shifts are reported in δ (ppm). For each signal the multiplicity (with the following abbreviations: *s* = singlet, *d* = doublet, *t* = triplet, *qa* = quartet, *m* = multiplet, br. = broad), the relative intensity and the assignment is given. ^{13}C-NMR. spectra were recorded on a *Bruker-Spectrospin* HFX-90/B-SC-FFT-12 spectrometer at 22.628 MHz. Chemical shifts are reported in δ (ppm) relative to TMS as internal reference, coupling constants *J* in Hz. The uncertainties of the reported chemical shifts are ±0.05 ppm, those of the coupling constants ±1.2 Hz. For each signal the multiplicity observed in the off-resonance decoupled spectrum is given. – IR. spectra were recorded on a *Perkin-Elmer* 281 IR. spectrophotometer. – Mass spectra were determined on a *Hitachi* RMU-6M instrument at 70 eV ionizing electron energy, source temp. 180°, accurate mass measurements on a *AEI*-MS5074. The most important ions are reported as *m/e* values with relative intensities (% base peak) in parenthesis.

Synthesis of the monosubstituted ketene trimers. The $AlCl_3$ (*Merck*, sublimed and powdered) was added portionwise to a stirred suspension of 13.5 g acetanilide (0.1 mol) in 150 ml trichloroethylene so that the reaction temperature did not exceed 30°. The acid chloride (0.12 mol) was then added through a dropping funnel under stirring and the mixture heated to reflux. The reaction mixture was refluxed for 2 h, then poured on ice and extracted with $CHCl_3$. The organic phase was washed with water and extracted with NaOH solution. The alkaline extract was acidified with HClsolution and extracted with ether. The etheral extract was washed neutral, dried over Na_2SO_4 and the ether driven off. The so obtained crystalline product was crystallized from aceton (yield: 50% of the theoretical calculated on basis of the acid chloride).

The analysis was made by GLC. on a 3% OV 25 column (1 m) programmed from 150 to 270° at a heating rate of 8°/min (N_2: 40 ml/min).

3,5-Dibutyl-4-hydroxy-6-pentyl-2-pyrone (*Ia*). – IR. (KBr): 2500–3600/br. (OH), 1670, 1650, 1565, 1535, 1200. – ^1H-NMR. ($CDCl_3$): 0.9/*m*, 9H (3 × CH_3); 1.4/br.*m*, 14H (7 × CH_2); 2.5/*m*, 6H (3 × CH_2–C=); 8.8/*s*, 1H (OH). – ^{13}C-NMR. ($CDCl_3$): 14.0/*qa*, 14.1/*qa*, 22.4/*t*, 22.7/*t*, 23.4/*t*, 24.5/*t*, 27.3/*t*, 30.6/*t*, 31.5/*t*, 23.1/*t*, 103.6/*s*, 112.9/*s*, 152.9/*s*, 166.3/*s*, 167.2/*s*. – MS.: 294 ($M^{+\cdot}$, 37) 279 (5), 266 (7), 265 (21), 252 (93), 251 (100), 238 (22), 224 (20), 223 (93), 210 (11), 209 (23), 197 (35), 196 (18), 195 (15), 181 (10), 179 (14), 178 (24), 167 (30), 154 (14), 153 (27), 125 (25), 99 (43).

6-Ethyl-4-hydroxy-3,5-dimethyl-2-pyrone (*Ib*). – IR. ($CHCl_3$): 3000–3600/br. (OH), 1680, 1580, 1200. – ^1H-NMR. ($CDCl_3$): 1.2/*t*, 3H (CH_3); 2.00/*s*, 3H and 2.04/*s*, 3H (2 × CH_3); 2.55/*qa*, 2H (CH_2); 9.0/br.*s*, 1H (OH). – ^{13}C-NMR. ($CDCl_3$): 8.79/*qa* and 9.71/*qa* (CH_3–C=); 11.60/*qa* (CH_3); 24.28/*t* (CH_2); 98.56/*s* (C(3)); 107.57/*s* (C(5)); 159,84/*s* (C(6)); 166.80/*s* (C(4)); 167.56/*s* (C(2)). The following multiplicities and coupling constants were observed for the low field signals in the nondecoupled spectrum: 98.56/*qa*, J = 6.0), 107.57/*m*, 159.84 (9-line system as indicated by the intensity ratio of the 7 detected lines, J = 5.0) 166.80 (7-line system as indicated by the intensity ratio of the 5 detected lines, J = 4.0) 167.56/*qa*, J = 4.5. – ^{13}C-NMR. ($CDCl_3 + D_2O$): 8.79, 9.71, 11.60, 24.28, 98.45, 107.46, 159.84, 166.59, 167.50. – MS.: 168 ($M^{+\cdot}$, 70); 140 (47), 125 (100), 113 (40), 112 (12), 111 (11), 83 (59), 57 (31), 56 (22), 55 (12), 43 (35), 41 (10), 39 (12), 29 (28), 28 (11), 27 (25).

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REFERENCES

[1] *F. Kunkel*, Ber. deutsch. chem. Ges. *33*, 2641 (1900).

[2] *R. Steinsträsser & L. Pohl*, Z. Naturforsch. *26b*, 577 (1971).

[3] *G. A. Olah*, 'Friedel-Crafts and related reactions', vol. III, part 1, p. 16, Interscience Publishers, N.Y. 1964.

[4] *M. A. Osman*, Z. Naturforsch. *31b*, 801 (1976).

[5] *E. Wedekind & J. Haeusermann*, Ber. deutsch. chem. Ges. *41*, 2297 (1908).

[6] *D. H. Hunter, A. L. Johnson, J. B. Stothers, A. Nickon, J. L. Lambert & D. F. Covey*, J. Amer. chem. Soc. *94*, 8582 (1972).

[7] *F. W. Wehrli*, Chem. Commun. *1975*, 663.

[8] *D. G. Farnum, J. R. Johnson, R. E. Hess, T. B. Marshall & B. Webster*, J. Amer. chem. Soc. *87*, 5191 (1965).