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THE α:β RATIO IN THE ACETYLATION OF FURAN AND THE "EXTENDED SELECTIVITY TREATMENT" FOR ELECTROPHILIC SUBSTITUTIONS AT THE BETA POSITION OF THE FURAN RING

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In a previous study on the acetylation of furan[1] we were able only to estimate that the percentage of the 3-substituted isomer would be smaller than 0.1%. This problem has now been approached with more accurate analytical techniques, so that we can give the correct values for the α:β reactivity ratios in the acetylation reaction, under three different experimental conditions.

The reactions were carried out in the same conditions used in the acetylations of thiophen,[2] i.e. with acetic anhydride in the presence of 1/100 mole of $SnCl_4$, or acetyl trifluoroacetate, in 1,2-dichloroethane, at 25° and 75°C. The mixtures were worked up as usual and analysed by G.L.C. on a model 900 Perkin Elmer Fractometer, particularly suitable for trace analyses, equipped with a flame ionisation detector, using a 1.5 mx1/8" column packed with a mixture of about 2:1 w/w of bentone and didecylphtalate on Chromosorb.

The separation of the acetyl isomers was a difficult task to achieve: this stationary phase proved to be the only suitable among many others examined.

The isomer distributions and the α:β ratios are listed in Table 1. It is interesting to observe that the values of the ratios are considerably larger than the reported ones for the thiophene ring:[2] hence furan shows a greater "selectivity of position" as well as a greater sensitivity to substituent effect.[3,4]

Table 1

Isomer distributions and α:β reactivity ratios in the acetylation of furan

Reaction conditions	β (%)	α:β
Ac_2O and $SnCl_4$ in DCE at 25°	0.0147	6,800
Ac_2O and $SnCl_4$ in DCE at 75°	0.125	800
Acetyl trifluoroacetate in DCE at 75°	0.0170	6,000

The validity of the gas chromatographic results was tested by the use of a different analytical procedure. The value for the reaction of furan with Ac_2O and $SnCl_4$ at 25° was determined by a technique involving the combination of the isotope dilution method with preparative scale gas chromatography, according to the procedure described in a previous paper.[5] In this case the reaction was carried out with C^{14}-labeled acetic anhydride and the activity of the acetylfurans (subjected to a rigorous purification using a specially modified[5] model C gas chromatograph from C. Erba, Milano, Italy) was measured with a Nuclear Chicago Mark 1 Scintillation Spectrometer. The α:β ratio obtained in this way (6,600) was in good agreement with that reported in Table 1.

Since the partial rate factor α_f for this reaction is known,[6,7] a value for β_f can be calculated therefrom, 4.7×10^3. The partial rate factors available for electrophilic substitutions and related reactions at the β position of the furan ring are summarized in Table 2. Our value is the only one which refer to a conventional electrophilic substitution, in which a proton is substituted; all the other regard "displacement" or side-chain reactions in which a carbon ion is formed in the transition state. The data, of Table 2 can be used to test the "Extended selectivity treatment" for the electrophilic reactions at the beta position of the furan ring. Recently the same treatment was successfully applied to both the positions of thiophen,[2] and to the alpha position of furan[7] and selenophen.[12]

Plotting the log β_f, derived from Table 2, against the reaction constants ρ for benzene derivatives, a satisfactory straight line passing through the theoretical origin is obtained ($r = 0.979$, $s = 0.38$).

Table 2

Beta partial rate factors for electrophilic reactions of furan

Reaction	ρ	β_f	Ref.
Acetylation, Ac_2O, $SnCl_4$, DCE, 25°	-9.1	4.7×10^3	this work
Solvolysis of 1-arylethyl-p-nitrobenzoates 80% EtOH, 75°	-6.0	2.9×10^2	3
Solvolysis of 1-arylethylacetates 30% EtOH, 25°	-5.7	6.8×10^2	8
Protodesilylation, $HClO_4$, MeOH, 50°	-4.3	1.17×10^2	9
Protodemercuration, HCl, 10% EtOH, 70°	-2.4	1.5×10^2	10
Pyrolysis of 1-arylethylacetates, 327°	-0.66	1.9	11

From the slope a substituent constant σ^+_β, relative to the structural change caused by the substitution of an oxygen atom for a CH=CH in the benzene ring, may be calculated. The value obtained, -0.44, compared with the other σ^+ values (see Table 3), shows that the β position of furan is the least reactive among those considered but always much more reactive than a position of benzene.

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Table 3

A summary of the substituent constants σ^+ derived from the application of the extended selectivity relationship to the electrophilic substitutions of furan and thiophen[a]

Compound	σ^+_α	σ^+_β
Thiophen	-0.79	-0.52
Furan	-0.93	-0.44

a) data from this work and Refs 2 and 7.

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