ELECTROPHILIC SUBSTITUTION REACTIONS OF 2-FURYLCYCLOPROPANES

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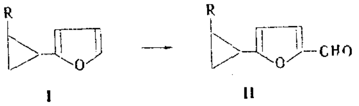
2-Furylcyclopropanes undergo typical electrophilic substitution reactions. In acetylation and Vilsmeier formylation, the substituent enters the 5 position of the furan ring without involvement of the three-membered ring; this may serve as a convenient method for the synthesis of 2-formyl- and 2-acetyl-5-cyclopropylfurans.

The similarity in the chemical properties of cyclopropanes and olefins is well known [1,2]. In particular, cyclopropane derivatives quite readily react with electrophilic reagents with opening of the three-membered ring [1,3] and this hinders the synthesis of functional derivatives of arylcyclopropanes [3].

The behavior of furylcyclopropanes, which are difficult-to-obtain and highly reactive compounds [4,5], during acetylation and Vilsmeier formylation was investigated in the present study. The literature contains practically no data on the behavior of furylcyclopropanes in substitution reactions. It is known only that 1-methyl-2-(2-furyl)- and 1-cyclopropyl-2-(2-furyl)cyclopropanes undergo substituent addition without opening of the three-membered ring [6,7].



a R=H; b $R=CH_3$; c $R=C_6H_5$

We have found that the formylation of substituted furylcyclopropanes Ia-c leads to the corresponding aldehydes without involvement of the three-membered ring. The reaction proceeds quite smoothly, and the yields of aldehydes IIa-c are 45, 63, and 62%, respectively.

Strong absorption at 1670-1680 cm^{-1} was observed for all of these aldehydes; this indicates conjugation of the aldehyde group with the furan ring. The absorption bands at 1600 and 1520 cm^{-1} in the spectra of aldehydes IIa and IIb can be assigned to the absorption of the furan ring. Cole [8] has pointed out the presence in the IR spectra of cyclopropane derivatives of an absorption band at 1017-1025 cm^{-1}, which was also observed in the spectra of aldehydes II. The strong absorption at 3000-3200 cm^{-1} corresponds to the stretching vibrations of the C–H bonds of the furan and cyclopropane rings.

The UV spectrum of aldehyde IIc is also in agreement with the structure assigned to it, since it contains maxima at 218 ($\log \varepsilon$ 3.99) and 304 nm ($\log \varepsilon$ 4.04).

A multiplet at 0.8 ppm (4H of the cyclopropane ring), a multiplet at 1.8-2.3 ppm (1H of the cyclopropane ring), two doublets at 6.23 and 7.1 ppm (protons in the 3 and 4 positions of the furan ring, AX system with J_{AX} 3.0 Hz), and a singlet at 9.08 ppm (1H of the aldehyde group) are observed in the NMR spectrum of IIa (on the δ scale). The J_{AX} value of 3 Hz is characteristic for coupling of the β protons and shows that, as one should expect, electrophilic attack is directed to the α position.

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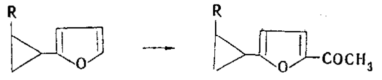

I III

a R = H; b R = CH$_3$

The acetylation of furylcyclopropanes by the Hartough–Kosak method [9] gives lower yields of the corresponding ketones than of the aldehydes (30 and 36% for IIIa and IIIb). The structures of the ketones obtained were proved by the IR and NMR spectra.

Thus furylcyclopropanes undergo the typical electrophilic substitution reactions – acetylation and Vilsmeier formylation – and recall alkylfurans with respect to their behavior in these reactions.

EXPERIMENTAL

5-(2-Methyl-1-cyclopropyl)furfural (IIb). A 14.5-g (0.1 mole) sample of phosphorus oxychloride was added dropwise at –2°C to 7.3 g (0.1 mole) of dimethylformamide in such a way that the temperature did not rise above 10°. The mixture was then stirred at 0° for 30 min, after which 12.2 g (0.1 mole) of freshly distilled 2-(2-methyl-1-cyclopropyl)furan was added in the course of 30 min at no higher than 5-10°. The mixture was stirred at 0-5° for 30 min, at room temperature for another 30 min, and poured into 100 ml of acetic acid. The resulting mixture was neutralized with saturated sodium carbonate solution and allowed to stand overnight. It was then extracted with four 25-ml portions of ether, and the ether extracts were dried with calcined sodium sulfate. The ether was removed by distillation, and the residue was vacuum distilled in a stream of nitrogen to give 9.6 g of aldehyde IIb with bp 93-95° (3 mm), n_D^{20} 1.5510 and d_4^{20} 1.2667. Found,%: C 71.6; H 6.8. $C_9H_{10}O_2$. Calculated,%: C 71.9; H 6.7. The 2,4-dinitrophenylhydrazone was obtained as dark red crystals with mp 212-213.5° (from ethyl acetate). Found,%: C 54.8; H 4.3; N 17.2. $C_{15}H_{14}O_5N_4$. Calculated,%: C 54.5; H 4.3; N 17.0. The NMR spectrum of aldehyde IIb contains a multiplet at 0.7-2.3 ppm (4H of the cyclopropane ring and a doublet of the CH$_3$ group at 1.05 ppm, which stands out above the overall multiplet), signals of the protons in the 3 and 4 positions of the furan ring (7.36 and 6.3 ppm), and the signal of an aldehyde proton (9.48 ppm).

5-Cyclopropylfurfural (IIa). This compound was similarly obtained in 45% yield and had bp 115° (12 mm), n_D^{20} 1.5659, and d_4^{20} 1.1264. Found,%: C 70.5; H 6.1. $C_8H_8O_2$. Calculated,%: C 70.6; H 5.9. The 2,4-dinitrophenylhydrazone was obtained as brown crystals with mp 186-188° (from ethyl acetate). Found,%: C 53.3; H 4.2. $C_{14}H_{12}O_5N_4$. Calculated,%: C 53.2; H 3.8.

5-(2-Phenyl-1-cyclopropyl)furfural (IIc). This compound was similarly obtained in 62% yield and had bp 127° (0.06 mm) and mp 101-102° (from alcohol). Found,%: C 79.5; H 5.8. $C_{14}H_{16}O_2$. Calculated,%: C 79.3; H 5.7. The 2,4-dinitrophenylhydrazone was obtained as an orange powder with mp 183-184° (from ethyl acetate). Found,%: C 60.9; H 4.2. $C_{20}H_{16}O_5N_4$. Calculated,%: C 61.2; H 4.1. The NMR spectrum of aldehyde IIc contains signals of a three-membered ring at δ 1.2-1.6 (two protons) and 1.8-2.3 ppm (2H), a doublet of one of the β protons of the furan ring at 6.0 ppm, a signal of phenyl protons, which overlaps the signal from the second β proton of the furan ring, at 6.8-7.5 ppm, and a singlet of an aldehyde proton at 9.45 ppm.

2-(2-Methyl-1-cyclopropyl)-5-acetylfuran (IIIb). A 1.34-g sample of boron trifluoride etherate was added all at once at 0° to a stirred mixture of 12.2 g (0.1 mole) of 2-(2-methyl-1-cyclopropyl)furan and 11.7 g of acetic anhydride. The mixture was warmed to 40-50°, after which it was cooled to room temperature, stirred for 1 h, treated with 22 ml of ice water, and stirred again until its temperature dropped to room temperature. The mixture was extracted with 50 ml of chloroform, and the extract was washed once with 10% sodium carbonate solution and three times with water, and dried with calcined magnesium sulfate. The solvent was removed by distillation, and the residue was vacuum distilled to give 6 g of ketone IIIb with bp 63-64.8° (1 mm), n_D^{20} 1.5291 and d_4^{20} 1.1079. Found,%: C 73.2; H 7.3. $C_{10}H_{12}O_2$. Calculated,%: C 73.2; H 7.3. The 2,4-dinitrophenylhydrazone was obtained as bright orange crystals with mp 165° (from ethyl acetate). Found,%: C 55.9; H 4.8. $C_{16}H_{16}O_5N_4$. Calculated,%: C 55.8; H 4.7. The NMR spectrum of ketone IIIb contains a signal at 0.9-2 ppm (protons of the three-membered ring and the CH$_3$ group bonded to it), a singlet of a ketone methyl group at 2.15 ppm, and an AX system of furan protons at 6.0 and 7.2 ppm. The absorption band of the carbonyl group lies at 1680 cm^{-1} in the IR spectrum.

2-Cyclopropyl-5-acetylfuran (IIIa). This compound was similarly obtained in 30% yield and had bp 57-58° (1 mm), n_D^{20} 1.5152 and d_4^{20} 1.1182. Found,%: C 72.2; H 6.9. $C_9H_{10}O_2$. Calculated,%: C 72.0; H 6.7.

The NMR spectrum of ketone IIIa contains a signal at 0.8-2 ppm (five protons of the cyclopropane ring), the singlet of a CH_3 group at 2.53 ppm, and doublets of the AX system of the protons of the furan ring at 6.16 and 7.13 ppm.

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