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Common and Specific Features of the Michael Condensation in the Series of 3-R-3*H*-Furan-2-ones

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Abstract—The Michael condensation in the series of 5-aryl-3*H*-furan-2-ones with chalcones containing electron-donating substituents was studied. In the case of α,β-unsaturated ketones containing an electron-donating substituent, the reaction does not stop at the stage of formation of 1,5-dicarbonyl compounds but is accompanied by intramolecular cyclodehydration yielding a new series of furo[2,3-*b*]-4*H*-pyrans. A mechanism of formation of these products was suggested. The structure of reaction products was proved by IR and ^{1}H NMR spectroscopy.

The Michael reaction allows preparation of acyclic, semicyclic, and bicyclic 1,5-diketones of symmetric and unsymmetric structure. Of particular interest is the use of heterocyclic compounds as addends. Such transformations were considered in detail with pyrazol-5-ones [1] and pyron-2-ones [2]. In the series of 5-substituted 3*H*-furan-2-ones, the condensations with aromatic aldehydes, the Mannich reaction [3], methylenethioalkylation, and the Vilsmeier–Haack formylation [4] were studied.

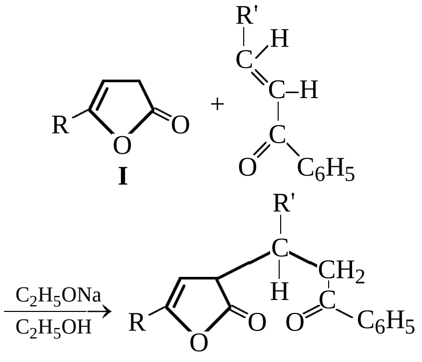
In this work we studied the reaction of 5-substituted 3*H*-furan-2-ones with α,β-unsaturated ketones.

A series of 5-aryl-3*H*-furan-2-ones containing aryl (phenyl, tolyl, xylyl) substituents in the 5-position of the heteroring were prepared in yields of up to 80% starting from 4-oxoalkanoic acids [3]. These compounds were brought in reaction with α,β-unsaturated ketones under the conditions of the Michael condensation.

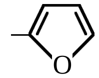
We found that 5-R-3*H*-furan-2-ones **I** can be the methylene components (addends) in the Michael reaction with electron-deficient unsaturated compounds under the conditions of base catalysis. The reaction was carried out in ethanol at 60–80°C for 2–3 h, using sodium ethylate as catalyst. Then the reaction mixture was kept at room temperature for 12 h. The yields and characteristics of the compounds obtained are listed in Table 1.

We found that the product structure depends on the nature of substituents in the phenyl group of the chalcone.

The reactions with benzylidene- and furfurylideneacetophenone, and also with chalcone containing an electron-withdrawing substituent (NO_2 group) give the condensation products in high yields (up to 70%). These products were identified by elemental analysis and IR and ^{1}H NMR spectroscopy as 1,5-dicarbonyl derivatives.



II–VII

R = C_5H_{11}, C_6H_5, $H_3CC_6H_4$, $(H_3C)_2C_6H_3$ (**I**); R = C_5H_{11}, R' = C_6H_5 (**II**); R = C_5H_{11}, R' =  (**III**); R = C_6H_5, R' = C_6H_5 (**IV**); R = $H_3CC_6H_4$, R' = C_6H_5 (**V**); R = $(H_3C)_2C_6H_3$, R' = C_6H_5 (**VI**); R = $(H_3C)_2C_6H_3$, R' = $C_6H_4NO_2$ (**VII**).

The IR spectra of 3-(3-oxo-1-propyl)furan-2-ones **II**–**VII** contain the absorption bands of carbonyl group at 1680–1686 cm^{-1}, and also the bands characteristic of β,γ-unsaturated lactones at 1795–1780 cm^{-1}.

The ^{1}H NMR spectra of 3-(3-oxo-1-propyl)furan-2-ones **II**–**VII** contain the signals of vinyl protons of the furanone moiety at 5.92–5.95 ppm, two signals of

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Table 1. Characteristics of compounds obtained

Comp. no.	Compound name	Yield, %	mp, °C, or bp, °C (*p*, mm)	Found, %		Formula	Calculated, %		*M*
				C	H		C	H	
II[a]	5-Pentyl-3-(3-oxo-1,3-diphenyl-1-propyl)-3*H*-furan-2-one	85	124–125 (4)	79.58	7.30	$C_{24}H_{26}O_3$	79.53	7.23	362.47
III[b]	5-Pentyl-3-(3-oxo-1-furyl-3-phenyl-1-propyl)-3*H*-furan-2-one	80	139–140 (5)	74.85	6.92	$C_{22}H_{24}O_4$	74.98	6.86	352.43
IV	5-Phenyl-3-(3-oxo-1,3-diphenyl-1-propyl)-3*H*-furan-2-one	72	39–40	81.48	5.60	$C_{25}H_{20}O_3$	81.50	5.47	368.44
V	5-(4-Methylphenyl)-3-(3-oxo-1,3-diphenyl-1-propyl)-3*H*-furan-2-one	70	58–59	81.58	5.85	$C_{26}H_{22}O_3$	81.65	5.80	382.46
VI	5-(2,5-Dimethylphenyl)-3-(3-oxo-1,3-diphenyl-1-propyl)-3*H*-furan-2-one	60	90–92	81.68	6.04	$C_{27}H_{20}O_3$	81.79	6.10	392.46
VII[c]	5-(2,5-Dimethylphenyl)-3-[3-oxo-1-(3-nitrophenyl)-3-phenyl-1-propyl]-3*H*-furan-2-one	75	141–142	73.58	5.20	$C_{27}H_{23}NO_5$	73.40	5.25	441.50
VIII	5-Phenylfuro[2,3-*b*]-2-phenyl-4-(2-hydroxyphenyl)-4*H*-pyran	50	131–132	81.72	4.80	$C_{25}H_{18}O_3$	81.95	4.95	366.42
IX	5-Phenylfuro[2,3-*b*]-2-phenyl-4-(2-methoxyphenyl)-4*H*-pyran	58	128–129	81.65	5.04	$C_{26}H_{20}O_3$	82.08	5.30	380.45
X	5-(4-Methylphenyl)furo[2,3-*b*]-2-phenyl-4-(2-hydroxyphenyl)-4*H*-pyran	55	136–138	81.90	5.18	$C_{26}H_{20}O_3$	82.08	5.30	380.45
XI	5-(4-Methylphenyl)furo[2,3-*b*]-2-phenyl-4-(2-methoxyphenyl)-4*H*-pyran	60	144–146	81.96	5.47	$C_{27}H_{22}O_3$	82.21	5.62	394.47
XII	5-(2,5-Dimethylphenyl)furo-[2,3-*b*]-2-phenyl-4-(2-hydroxyphenyl)-4*H*-pyran	45	159–162	82.10	5.44	$C_{27}H_{22}O_3$	82.21	5.62	394.47
XIII	5-(2,5-Dimethylphenyl)furo-[2,3-*b*]-2-phenyl-4-(2-methoxyphenyl)-4*H*-pyran	52	168–170	82.16	5.78	$C_{28}H_{24}O_3$	82.33	5.92	408.50

[a] n_D^{20} 1.5090. [b] n_D^{20} 1.5116. [c] Found N, %: 3.20. Calculated N, %: 3.17.

methine protons at 4.02–4.10 ppm, t (H^3) and 2.80–2.90 ppm, m (H^2). The protons of the methylene group of the side chain give a doublet of doublets at 3.10–3.20 ppm. In the range 7.40–7.85 ppm, a series of signals belonging to the protons of aromatic substituents are observed (Table 2).

We found that introduction of an electron-donating substituent into the phenyl group of the oxopropyl radical affects the pathway and extent of the process.

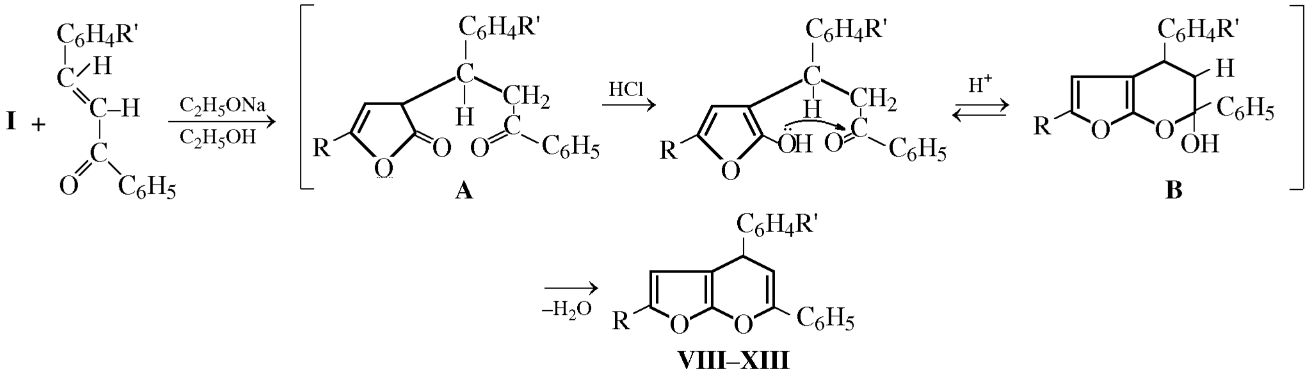
The reaction with 4-hydroxy(methoxy)benzylideneacetophenone was carried out under the conditions similar to those described above. The process was catalyzed with sodium ethylate also.

It was found that the reaction with chalcone containing an electron-donating substituent (OH, CH_3O) is accompanied by intramolecular heterocyclization yielding a new series of furo[2,3-*b*]-4*H*-pyrans **VIII**–**XIII**. These final products are probably formed from intermediate 1,5-dicarbonyl compounds **A**. Their treatment with hydrochloric acid causes enolization of the furanone; this is followed by heterocyclization accompanied by elimination of water from the intermediate **B** and formation of **VIII**–**XIII**.

We suggest the following reaction mechanism:

Table 2. ^{1}H NMR spectra of 5-R-3-(3-oxo-1,3-diaryl-1-propyl)-3*H*-furan-2-ones **II**–**VII** and 5-R-furo[2,3-*b*]-2-phenyl-4-[2-hydroxy(methoxy)phenyl]-4*H*-pyrans **VIII**–**XIII** (solvent $CDCl_3$)

Comp. no.	δ, ppm
II	5.94 d (1H, =CH), 4.05 t (1H, CH<), 2.85 m (1H, CHR'), 3.12 d.d (2H, CH_2), 0.82–1.95 m (11H, C_5H_{11}), 7.40–7.65 m (10H, C_6H_5)
III	5.96 d (1H, =CH), 4.08 t (1H, CH<), 2.85 m (1H, CHR'), 3.15 d.d (2H, CH_2), 0.80–1.95 m (11H, C_5H_{11}), 6.50–7.02 m (3H, C_6H_5)
IV	5.92 d (1H, =CH), 4.02 t (1H, CH<), 2.80 m (1H, CHR'), 3.10 d.d (2H, CH_2), 7.40–7.85 m (15H, C_6H_5)
V	5.94 d (1H, =CH), 4.05 t (1H, CH<), 2.82 m (1H, CHR'), 3.15 d.d (2H, CH_2), 1.25 s (3H, CH_3), 7.45–7.80 m (14H, C_6H_5)
VI	5.94 d (1H, =CH), 4.05 t (1H, CH<), 2.82 m (1H, CHR'), 3.15 d.d (2H, CH_2), 1.25 s (6H, CH_3), 7.45–7.85 m (13H, C_6H_5)
VII	5.95 d (1H, =CH), 4.10 t (1H, CH<), 2.90 m (1H, CHR'), 3.20 d.d (2H, CH_2), 1.25 s (6H, CH_3), 7.45–7.95 m (12H, C_6H_5)
VIII	5.65 s (1H, =CH), 3.72 d (1H, CHR'), 5.06 d (1H, CH=), 7.40–7.78 m (14H, C_6H_5)
IX	5.65 s (1H, =CH), 3.80 d (1H, CHR'), 5.08 d (1H, CH=), 7.40–7.80 m (14H, C_6H_5), 1.30 s (3H, OCH_3)
X	5.67 s (1H, =CH), 3.75 d (1H, CHR'), 5.08 d (1H, CH=), 7.45–7.80 m (13H, C_6H_5), 1.75 s (3H, CH_3)
XI	5.67 s (1H, =CH), 3.75 d (1H, CHR'), 5.10 d (1H, CH=), 7.40–7.80 m (13H, C_6H_5), 1.27 s (3H, CH_3), 1.30 s (3H, OCH_3)
XII	5.67 s (1H, =CH), 3.80 d (1H, CHR'), 5.10 d (1H, CH=), 7.45–7.80 m (12H, C_6H_5), 1.25 s (6H, CH_3)
XIII	5.65 s (1H, =CH), 3.78 d (1H, CHR'), 5.08 d (1H, CH=), 7.40–7.78 m (12H, C_6H_5), 1.27 s (6H, CH_3), 1.32 s (3H, OCH_3)



R = C_6H_5, R' = OH (**VIII**); R = C_6H_5, R' = OCH_3 (**IX**); R = $H_3CC_6H_4$, R' = OH (**X**); R = $H_3CC_6H_4$, R' = OCH_3 (**XI**); R = $(H_3C)_2C_6H_3$, R' = OH (**XII**); R = $(H_3C)_2C_6H_3$, R' = OCH_3 (**XIII**).

The structure of **VIII**–**XIII** was determined by IR and ^{1}H NMR spectroscopy. The IR spectra of **VIII**–**XIII** contain no bands characteristic of the carbonyl group of unsaturated lactones or oxopropyl radical of the side chain. Appearance of the absorption band of the ethylene C=C bond of the 4*H*-pyran ring in the range 1640–1630 cm^{-1} confirms the suggested structure. The ^{1}H NMR spectra of **VII**–**XIII** contain two signals of vinyl protons of the furan and pyran rings at 5.65–5.67 and 5.06–5.10 ppm, respectively (Table 2).

Thus, the reaction of 5-substituted 3*H*-furan-2-ones with α,β-unsaturated ketones under the conditions of the Michael condensation was studied for the first time. The nature of substituents in chalcones affects the structure of the reaction products. For example, with chalcones containing an electron-withdrawing substituent, 1,5-dicarbonyl compounds derived from furan-2-ones are formed. With unsaturated ketones containing electron-donating substituents, furo[2,3-*b*]-4*H*-pyrans, the products of intramolecular cyclodehydration, are obtained.

EXPERIMENTAL

The IR spectra were measured on a Specord M-80 spectrometer. The ^{1}H NMR spectra were obtained on a Varian FT-80A spectrometer (80 MHz) in $CDCl_3$ relative to internal TMS.

5-Aryl-3*H*-furan-2-ones were prepared according to [3]. The starting chalcones were synthesized by the procedure in [1].

5-R-3-(3-Oxo-1,3-diaryl-1-propyl)-3*H*-furan-2-ones II–VII. A solution of sodium ethylate was added dropwise to a mixture of 0.002 mol of 5-aryl-3*H*-furan-2-one **I** and 0.002 mol of appropriate α,β-unsaturated ketone in 10 ml of ethanol. The reaction mixture was heated on a water bath at a temperature no higher than 70°C for 3 h. Then the mixture was poured into 100 ml of water and neutralized; the precipitated crystals were filtered off. Compounds **II** and **III** were isolated by vacuum distillation.

5-R-Furo[2,3-*b*]-2-phenyl-4-[2-hydroxy(methoxy)phenyl]-4*H*-pyrans VIII–XIII. A solution of sodium ethylate (0.1 g of Na in 1.5 ml of C_2H_5OH) was added dropwise to a mixture of 0.002 mol of 5-aryl-3*H*-furan-2-one **I** and 0.002 mol of appropriate *o*-hydroxy(methoxy)benzylideneacetophenone in 10 ml of ethanol. The reaction mixture was heated on a water bath at a temperature no higher than 70°C for 3 h. Then the mixture was poured into 100 ml of water and neutralized; the precipitated crystals were filtered off.

REFERENCES

1. Kharchenko, V.G. and Pchelintseva, N.V., *Sposoby polucheniya 1,5-diketonov* (Procedures for Preparing 1,5-Diketones), Saratov: Saratov. Gos. Univ., 1997.
2. Avetisyan, A.A., Karamanyan, A.A., and Melikyan, G.S., *Arm. Khim. Zh.,* 1989, vol. 42, no. 10, p. 633.
3. Sedavkina, V.A., Morozova, N.A., Egorova, A.Yu., and Ostroumov, I.G., *Khim. Geterotsikl. Soedin.*, 1987, no. 4, p. 451.
4. Sedavkina, V.A., Morozova, N.A., and Egorova, A.Yu., *Khim. Geterotsikl. Soedin.,* 1993, no, 4, p. 456.