ON PHTHALIDES AND INDANDIONES. LII.*

REACTIONS OF THE ANION OF 2-ARYL-1,3-INDANDIONES WITH ETHYL ESTERS OF MONO- AND DIHALOACETIC ACIDS

P.HRNČIAR and M.MELICHERČÍK

Department of Organic Chemistry and Biochemistry,
Komenský University, Bratislava 1

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On reaction with an ethyl monohaloacetate, independently of the halogen and solvent, the anions of 2-phenyl-1,3-indandione(*I*) and 2-(2-naphthyl)-1,3-indandione(*II*) give exclusively corresponding C-derivatives. 2-(1-Naphthyl)-1,3-indandione(*III*) gives the C- and O-derivatives. The validity of Kornblum rule was confirmed; it was found that the ratio of the C- to O-derivative increases with increasing polarity of the solvent. Reactions of ethyl dichloro(dibromo) acetate with anions *I* and *II* give corresponding C-derivatives *VIII*–*XI* and bis-C-derivatives *XII* and *XIII*. Anion *III* reacts predominantly with the oxygen, giving substances *XV* and *XVI*.

In works[1–3] it was reported that anions of 2-aryl-1,3-indandiones react with primary alkyl halides in solvents of varying polarity to give thermodynamically more stable C-alkyl derivatives. O-alkyl derivatives were formed only when the nucleophility of the carbon in position 2 and/or the difference in the stability of the O- and C-alkyl derivatives were decreased due to steric effects. In such cases the C/O ratio of the formed derivatives was found to be dependent on the solvent.

We now report the results obtained in a study of reactions of the anions of 2-phenyl-1,3-indandione (*I*), 2-(2-naphthyl)-1,3-indandione (*II*), and 2-(1-naphthyl)-1,3-indandione (*III*) with ethyl esters of monohaloacetic acids (halogen = Cl, Br, I) and dihaloacetic acids (halogen = Cl, Br). Studies of Kornblum and his coworkers[4,5] show that with ambident anions the relative proportion of the formed alkyl derivatives can be influenced by the character of the leaving (substituted) particle of the substrate.

Reactions of anions *I*–*III* with ethyl esters of monohaloacetic acids were carried out in the following solvents: dimethyl sulfoxide, dimethylformamide, acetonitrile, acetone, ethanol and butanol. For the formation of anions *I*–*III* in the medium of alcohols we used sodium alcoholate, in the other solvents we employed potassium carbonate. All reactions were carried out under identical conditions, *i.e.* at 40°C and with equimolar amounts of reaction components. The only exception was the

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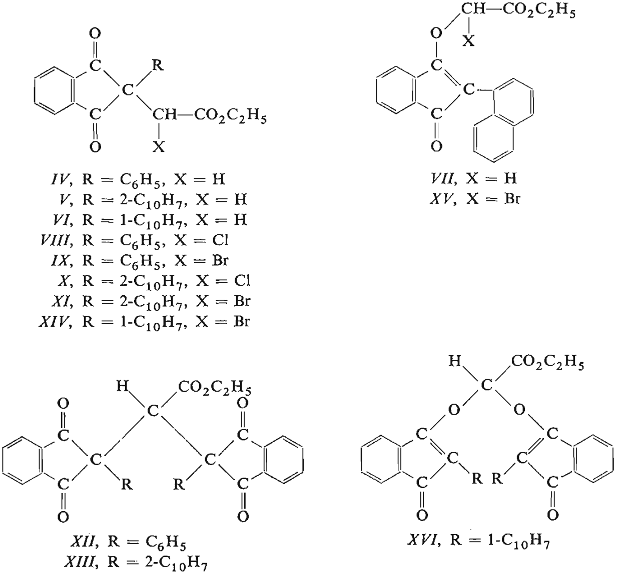
ethyl chloroacetate reaction which was carried out at 56°C, because very poor yields of the products were obtained at the above temperature.

We found that anions *I* and *II* react with ethyl esters of studied monohaloacetic acids to give exclusively C-derivatives *IV* and *V*, *i.e.* the effect of the halogen and of the solvent was unimportant. As it is seen from Table I, the reaction of anion *III* with ethyl esters of monohaloacetic acids yields in all the solvents (except dimethyl sulfoxide) the C-derivative *VI* and the O-derivative *VII*. We found that in either solvent the greatest amount of the O-derivative is always formed with the esters of monochloroacetic acid and the least amount with the ester of monoiodoacetic acid. The reaction of the anion *III* with ethyl esters of monohaloacetic acids proceeds in harmony with Kornblum rule[4,5], *i.e.* the increase of positive charge on the electrophilic centre of the substrate as well as the decrease in polarization of the carbon–halogen bond results in increased yields of the reaction on the more electronegative atom of the ambident anion *III*. When this is expressed in terms of



IV, R = C_6H_5, X = H
V, R = 2-$C_{10}H_7$, X = H
VI, R = 1-$C_{10}H_7$, X = H
VIII, R = C_6H_5, X = Cl
IX, R = C_6H_5, X = Br
X, R = 2-$C_{10}H_7$, X = Cl
XI, R = 2-$C_{10}H_7$, X = Br
XIV, R = 1-$C_{10}H_7$, X = Br

VII, X = H
XV, X = Br

XII, R = C_6H_5
XIII, R = 2-$C_{10}H_7$

XVI, R = 1-$C_{10}H_7$

SCHEME 1

the hard and soft acids and bases (on the basis of which the reactivity of ambident anions is frequently interpreted[6-8]), one can say that the increase in "hardness" of the electrophilic centre in ethyl esters of monohaloacetic acids manifests itself in a greater tendency to react on the harder (*i.e.* more electonegative) atom of the ambident anion *III* (symbiotic effect[6,7]). It is true that with esters of monohaloacetic acids these differences in the softness of the electrophilic centre are not great enough to affect the course of the reactions of anions *I* and *II*, where the difference in the stability of the C- and O-derivatives is greater than with anion *III*. In the latter, repulsive nonbonded interactions induced by the ortho-condensed ring decrease the stability of the C-derivative. Only on reaction with diazomethane, which proceeds as a S_N1 process, or with secondary alkyl halides, the anions *I* and *II* do form the O-derivatives[1,9]. With anion *III*, Kornblum rule is obeyed both in the protic and aprotic solvents of differing dielectric constants, as shown in Table I.

TABLE I

Reactions of Anions of 2-Phenyl-1,3-indandione(*I*), 2-(2-Naphthyl)-1,3-indandione(*II*) and 2-(1-Naphthyl)-1,3-indandione(*III*) with X $CH_2COOC_2H_5$ in Various Solvents

The first value is the overall yield, the second is the C/O ratio. Solvents used: dimethyl sulfoxide (DMS), dimethylformamide (DMF), acetonitrile (ACN), acetone (A), ethanol (E), and n-butanol (B).

X	Anion	DMS	DMF	ACN	A	E	B
Cl	*I*	18·6	69·1	28·3	60·3	9·3	—
		∞	∞	∞	∞	∞	
Br		26·3	71·8	34·6	99·0	16·8	—
		∞	∞	∞	∞	∞	
J		48·5	84·3	72·3	99·5		—
		∞	∞	∞	∞	∞	
Cl	*II*	16·8	64·1	22·4	31·1	86	—
		∞	∞	∞	∞	∞	
Br		93·5	70·2	32·1	76·3	15·8	—
		∞	∞	∞	∞	∞	
J		41·8	69·1	63·2	81·5	48·3	—
		∞	∞	∞	∞	∞	
Cl	*III*	9·3	53·1	51	47·0	4·5	5·0
		∞	0·97	0·98	0·47	0·25	0·26
Br		11·0	56·7	26·6	49·1	9·0	9·0
		∞	1·22	1·28	0·69	0·67	0·53
J		34·7	71·1	79	62·0	44·2	46·4
		∞	15·2	1·70	2·95	10·2	1·04

The results expressing solvent dependence of reactions of anion *III* with esters of monohaloacetic acids are in good agreement with the results obtained for the reactions of the same anion with alkyl halogenides[1-3].

Also on reaction with ethyl esters of dihaloacetic acids, the anion *III* yields different products, compared to the reactions of anions *I* and *II*. Anions *I* and *II* react with ethyl dichloroacetate and ethyl dibromoacetate on the carbon, giving substances *III*, *IX*, *X*, and *XI*, formed by replacement of one halogen, and substances *XII* and *XIII*, arising from replacement of two halogens. The yields of the reaction with ethyl dichloroacetate were very poor and are not therefore recorded in Table II. The anion *II* reacts with ethyl dibromoacetate by the carbon to give compound *XIV*, and by the oxygen to form substances *XV* and *XVI*.

The structure of formed C- and O-derivatives was confirmed by IR spectroscopy. Prepared C- and O-derivatives show in the region of C=O stretching vibrations two absorption bands which correspond to the carbonyl groups of the indandione or the indene skeleton and to the ester carbonyl group. These bands lie at 1710—1730 cm^{-1} (the broader, more intense band) and at 1750—1760 cm^{-1}. The bands of the keto groups overlap with the bands of the ester carbonyl groups so that the identification of the C- and O-derivatives based on these bands, which was possible with C-alkyl and O-alkyl derivatives[1,2], is very difficult. The IR spectra of C-derivatives and O-derivatives differ, however, in the 1624—1631 cm^{-1} region, where O-derivatives show absorption band, corresponding to the stretching vibration of the C=C bond in the five-membered indene ring[1].

The C- and O-derivatives differ in their electronic spectra. The C-derivatives have the indandione ring and the aromatic ring in position 2 oriented out of the plane, whereas the O-derivatives

TABLE II

Reactions of Anions of Compounds *I*—*III* with $Br_2CHCOOC_2H_5$ in Acetone (A), Dimethylformamide (DMF), and Ethanol (E)

Anion	Solvent	Total yield	C-derivative %	Bis-C-derivative %
	A	29·4	76·6	23·4
I	D	53·7	80·6	19·4
	E	15·4	86·9	13·1
	A	33·1	81·6	18·4
II	D	35·0	72·6	27·4
	E	10·4	77·5	22·5
III	A	9·4	34·0[a]	0[a]
	D	10·1	2·9[b]	0[b]

[a] The mixture contained 43·4% O-derivative and 22·6% bis-O-derivative. [b] The mixture contained 0·9% O-derivative and 96·2% bis-O-derivative.

have the indene ring and the aromatic ring in position 2 in in-plane conformation, which reflects in the spectra. Studied compounds all show bands corresponding to the transitions in the regions of 220—270 nm and 350—500 nm, and the bands of presumably n-π transitions in the 270—320 nm region. The O-derivatives show characteristic band at 420 nm, which is connected with the π—π^* transition of the whole conjugated system.

TABLE III

Analytical Data on Prepared Compounds

Compound m.p., °C	Formula m.w.	Calculated/Found			ν(CO), cm^{-1}
		% C	% H	% Br	
IV	$C_{19}H_{16}O_4$	74·08	5·27	—	1 725
106—106·5	308·3	73·98	5·40	—	1 760
V	$C_{23}H_{18}O_4$	77·08	5·06	—	1 728
119—120	358·4	76·36	5·20	—	1 758
VI	$C_{23}H_{18}O_4$	77·08	5·06	—	1 726
149—150	358·4	77·26	5·48	—	1 758
VII	$C_{23}H_{18}O_4$	77·08	5·06	—	1 716[a]
106—107	358·4	76·68	5·12	—	1 760
VIII	$C_{19}H_{15}ClO_4$	66·57	4·41	10·34	1 712
107—108	342·8	66·81	4·30	10·52	1 752
IX	$C_{19}H_{15}BrO_4$	58·93	3·90	20·64	1 712
144—146	378·3	58·76	4·16	20·25	1 750
X	$C_{24}H_{17}ClO_4$	73·35	4·31	9·00	1 712
204—205	394·8	73·45	4·28	9·00	1 750
XI	$C_{24}H_{17}BrO_4$	68·21	3·88	18·21	1 712
221—223	394·8	68·46	3·96	18·06	1 752
XII	$C_{34}H_{24}O_3$	77·26	4·57	—	1 710
214—215	528·6	76·98	4·56	—	1 752
XIII	$C_{42}H_{28}O_6$	80·25	4·49	—	1 710
232—234	628·7	80·20	4·40	—	1 752
XIV	$C_{24}H_{17}BrO_4$	68·21	3·88	18·21	1 712
98—100	439·3	68·05	3·71	18·14	1 754
XV	$C_{24}H_{17}BrO_4$	68·21	3·88	18·21	1 712[b]
140—141	439·3	68·36	3·61	18·36	1 760
XVI	$C_{42}H_{28}O_6$	80·25	4·49	—	1 710[c]
184—186	628·7	80·03	4·40	—	1 760

[a] ν(C=C) = 1 628 cm^{-1}; [b] ν(C=C) = 1 630 cm^{-1}; [c] ν(C=C) = 1 710 cm^{-1}.

EXPERIMENTAL

Infrared spectra of prepared compounds were recorded with a double-beam Zeiss (Jena), Model UR-20, spectrophotometer in the region of 2000—700 cm^{-1} with the use of NaCl optics. The instrument was calibrated with polystyrene film. The samples were measured as nujol mulls (the weight ratio of the compound to the nujol was 4 mg/15 mg). The spectrum of nujol was compensated. The electronic spectra in the 215—170 nm region were measured on a Perkin-Elmer, Model 450, spectrophotometer as 10^{-5}M, 10^{-4}M, and 10^{-3}M solutions of the compounds in methanol in 1.00 cm thick cells.

Reactions of Compounds *I*—*III* with Ethyl Esters of Monohaloacetic Acids

A) *In dimethylformamide, acetonitrile, acetone and dimethyl sulfoxide.* A mixture of 60 ml of the dry solvent, 0·005 mol of *I* (*II*, *III*) and 0·015 mol of anhydrous potassium carbonate was placed into a 250 ml flask and after 5 min 0·005 mol of the corresponding ethyl haloacetate was added and the reaction mixture was heated to 40 ± 1°C for 8 h. After removal of the solvent the dry residue was boiled twice with 120 ml of benzene. The solution was then filtered, evaporated to the total volume of 50 ml and chromatographed on alumina (Brockman II, Reanal, Budapest; the column was 30 cm long and 2 cm across). The eluent was benzene. The colourless C-derivative was eluted first, followed then by the O-derivative (the yellow band in the case of compound *III*). The unreacted compound (*I*—*III*) is not eluted under these conditions, but it can be eluted by ethanol. The eluate containing the C-derivative was evaporated to dryness, the product weighed and recrystallized from light petroleum. The same procedure was used also for the O-derivative (in the case of compound *III*). The yields are given in Table I, the analytical data are recorded in Table III.

B) *In ethanol* (*butanol*). To the alcoholate solution (prepared from 0·2 g of sodium and 30 ml of dry ethanol (butanol)) were added 0·005 mol of *I*(*II*, *III*) and, after 5 min, 0·006 mol of the appropriate ethyl haloacetate. The reaction mixture was then heated to 40 ± 1°C for 8 h (except ethyl chloroacetate when the temperature was always 56°C). Further procedure was the same as in the paragraph *A*.

Reactions of Compounds *I*—*III* with Ethyl Dichloro(dibromo) acetate

The same procedure as in the case of the reactions of ethyl monohaloacetate was employed. The eluate was collected in 50 ml portions, since there was a possibility of the formation of two colourless C-derivatives. The yields are given in Table II, the analytical data are recorded in Table III.

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