REACTIONS OF THE 5,7-DIOXO-6-PHENYL-6,7-DIHYDRO-5H-DIBENZO-[a,c]CYCLOHEPTANE ANION WITH MONOHALOHYDROCARBONS

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Reactions of the 5,7-dioxo-6-phenyl-6,7-dihydro-5H-dibenzo[a,c]cycloheptene (*I*) anion with methyl iodide, ethyl iodide, benzyl chloride, benzyl bromide, and benzyl iodide have been examined in dimethylformamide, dimethyl sulfoxide, acetonitrile, methanol, ethanol, and propanol. Both the C- and O-derivatives are formed in ratios depending on the solvent and, in the case of benzyl halides, on the character of the halo atom. The highest amount of the C-derivative is formed in dimethylformamide and dimethyl sulfoxide. The validity of the Kornblum rule has been confirmed. The spectral characteristics of the C- and O-derivatives are presented.

5,7-Dioxo-6-phenyl-6,7-dihydro-5H-dibenzo[a,c]cycloheptene (*I*) has been for the first time synthesized by Aleksiev and Milošev[1] and shown on the basis of infrared spectra to exist in the enol form (Scheme 1). From infrared spectra taken in chloroform and tetrachloromethane, it has been inferred that compound *I* occurs in these solvents in the keto-enol equilibrium[2]. On the other hand 2-aryl-1,3-indanediones, the anions of which are capable of reactions with electrophilic agents, exist in a diketo form in nonpolar or poorly polar solvents and in the enol anionic form in polar solvents[3]. The reaction of the 2-phenyl-1,3-indanedione anion with primary halohydrocarbons afforded always the thermodynamically more stable C-derivatives regardless the nature of the solvent[4] whereas both the C- and O-alkyl derivatives were formed from 2-phenyl-2,3-dihydro-1,3-phenalenedione[5]. Similarly to compound *I*, 2-phenyl-2,3-dihydro-1,3-phenalenedione exists in the enol form when in the solid
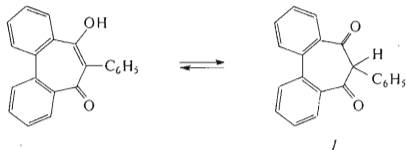

SCHEME 1

state. It was of interest to examine the reaction of halohydrocarbons with the anion I, both nucleophilic centers of which form part of a seven-membered ring, and the enol form of which is more stable than that of 2-phenyl-1,3-indanedione. Further-more, the anion I can not exist in a planar arrangement in contrast to the 2-phenyl--1,3-indanedione anion[6].

Reactions of the anion I with monohalohydrocarbons have been performed at 50°C in dimethylformamide, dimethyl sulfoxide, acetonitrile, acetone, methanol, ethanol, and propanol and in the presence of potassium carbonate. The attempted quantitative separation of the thus-obtained C- and O-derivatives by chromatography on a column of alumina[7-9] failed since the R_F values of the both alkyl derivative types are very similar. The ratio of the O- to C-benzyl derivative as well as of the C- to O-methyl derivative was determined spectrophotometrically in analogy to ref.[10]. In the earlier work[10], the determination of the C/O ratio has been based on the dif-ferent infrared spectra of the C- and O-alkyl derivatives while electron spectra have been used in the present case[5].

In reactions of the anion I with monohalohydrocarbons, a mixture of the C- and O-derivative has been always obtained. As it may be seen from data in Table I, the C/O ratio depends in the benzyl halide reactions both on the solvent nature and on the character of the halo atom to be expelled. From the aprotic solvents, the highest proportion of the C-derivative has been formed in dimethyl sulfoxide, di-methylformamide, and acetonitrile (Table I and II), *i.e.*, in solvents of a higher dielectric constant and of a high solvatation ability while in acetone, the O-derivative predominated. These results are in accordance with those obtained in reactions of 2-(1-naphthyl)-1,3-indanedione, 2-(1-X-2-naphthyl)-1,3-indanedione, 2-(1-X-phe-nyl)-1,3-indanedione, and 2-phenyl-2,3-dihydro-1,3-phenalenedione[7-10]. In spite of the finding that aprotic solvents affect the ratio of C/O derivatives by the ability to solvate cations and not, at least not to a considerable extent, by solvatation of the ambident anion[11,12], it may be assumed that the formation of a higher proportion of the O-derivative in acetone as solvent than in dimethylformamide or dimethyl sulfoxide, is connected with the lower ability of acetone to solvate the ambident
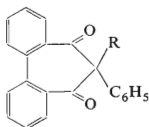
II, R = CH$_3$
IV, R = C$_2$H$_5$
VI, R = C$_6$H$_5$CH$_2$
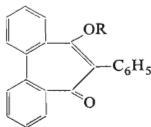
III, R = CH$_3$
V, R = C$_2$H$_5$
VII, R = C$_6$H$_5$CH$_2$

anion such as dimethylformamide or dimethyl sulfoxide. And the solvent solvates to a higher extent the place of a higher electron density. Owing to the rigidity of the cyclic system it may be assumed that in reactions of the anion I, the form W predominates in contrast to anions of acyclic 1,3-dioxo compounds where also the form[13] U must be taken into consideration.

Despite the different dielectric constants of methanol, ethanol, and propanol, the C- and O-derivatives are formed in these solvents in an almost equal ratio. A similar observation has been made by some other authors. Thus, *e.g.*, methylation of 1,3-cyclohexanedione with methyl iodide in alcohols of different dielectric constants affords an approximately equal ratio of the C- and O-methyl derivatives[14].

TABLE I

Reaction of the Anion *I* with Benzyl Halides at 50°C

	$C_6H_5CH_2Cl$			$C_6H_5CH_2Br$			$C_6H_5CH_2I$		
	t min	yield C + O %	C/O^a	t min	yield C + O %	C/O^a	t min	yield C + O %	C/O^a
Dimethyl sulfoxide	300	58	6·9	90	92	17·7	60	97	40·3
Dimethylformamide	180	31	7·0	60	93	10·0	60	98	31·0
Acetonitrile	300	20	13·2	90	95	10·2	60	98	27·0
Acetone	300	15	5·2	90	96	8·9	60	98	24·1
Methanol	—	—	—	80	90	10·0	90	98	15·0
Ethanol	—	—	—	120	89	8·8	90	97	15·4
1-Propanol	—	—	—	120	83	10·4	90	90	17·7

[a] The ratio C-derivative/O-derivative . 10^2.

TABLE II

Reaction of the Anion *I* with Methyl Iodide at 40°C for 2 h

Yield	Dimethyl sulfoxide	Dimethyl-formamide	Acetonitrile	Acetone
C + O, %	90	95	60	85
C/O . 10^2	170 (165[a])	168 (150[a])	162	145

[a] Values obtained on the basis of chromatographic separation.

The C/O ratio is not affected by concentration of reactants in the solvent or by the reaction temperature as it may be seen from Table III; in the alkylation of ethyl acetoacetate enolate however, increase of temperature was found to support formation of the O-derivative[14].

As it also may be inferred from data of Table I, the reaction of the anion *I* with benzyl halides is affected by the nature of the halo atom since the amount of the O-derivative increases in the order

$$C_6H_5CH_2I < C_6H_5CH_2Br < C_6H_5CH_2Cl$$

The rule of Kornblum is thus valid[15,16] also in the present case. As expected, the anion *I* reacts with diazomethane at the oxygen atom.
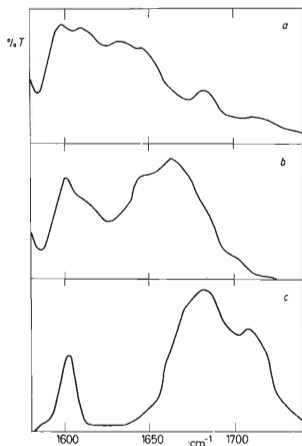

FIG. 1

IR Spectra (in chloroform) in the Region of the Carbonyl Group Stretching Vibrations

a 5,7-Dioxo-6-phenyl-6,7-dihydro-5H-dibenzo[a,c]cycloheptene (*I*); *b* 5-oxo-7-ethoxy--6-phenyl-5H-dibenzo[a,c]cycloheptene (*V*); *c* 5,7-dioxo-6-phenyl-6-ethyl-6,7-dihydro-5H--dibenzo[a,c]cycloheptene (*IV*).
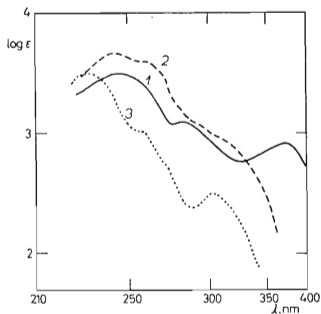

FIG. 2

Electron Spectra in Methanol

1 5,7-Dioxo-6-phenyl-6,7-dihydro-5H-di-benzo[a,c]cycloheptene (*I*); *2* 5-oxo-7-benzyl-oxy-6-phenyl-5H-dibenzo[a,c]cycloheptene (*VII*); *3* 5,7-dioxo-6-phenyl-6-benzyl-6,7-di-hydro-5H-dibenzo[a,c]cycloheptene (*VI*).

The present results thus support the known experience that the ability of the ambdient anion to react at the oxygen atom increases with the increasing stability of the enol form of the 1,3-dioxo compound. The present enol form is more stable than the enol form of 2-phenyl-1,3-indanedione[3]; the anion *I* reacts with halohydrocarbons both at oxygen and carbon atoms while only the carbon atom is involved in reactions of the 2-phenyl-1,3-indanedione anion[4].

Structures of the thus-obtained C-alkyl and O-alkyl derivatives have been confirmed by measurements of infrared and electron spectra. As it may be seen from

TABLE III

Effect of Temperature on the C/O Ratio in Reactions of the Anion *I* with Benzyl Chloride and Ethyl Iodide in Dimethylformamide

Temperature °C	$C_6H_5CH_2Cl$			C_2H_5I		
	t, min	C + O, %	$C/O \cdot 10^2$	t, min	C + O, %	$C/O \cdot 10^2$
80	180	94	7·3	60	98	14
70	180	77	6·6	—	—	—
60	180	56	7·5	—	—	—
50	180	31	7·0	—	—	—
40	180	12	7·3	120	80	13

TABLE IV

Analytical Data of the C- and O-Alkyl Derivatives

Compound Alkyl	M.p., °C (Kofler)	Formula (m.w.)	Calc./Found % C	% H	νCO cm^{-1}	νC=C cm^{-1}
II CH$_3$	110	$C_{22}H_{16}O_2$ (312·35)	84·59 84·59	5·16 5·35	1 684 1 712	—
III CH$_3$	142	$C_{22}H_{16}O_2$ (312·35)	84·59 84·72	5·16 5·29	1 655	1 640
IV C$_2$H$_5$	134—135	$C_{23}H_{18}O_2$ (326·4)	84·64 84·72	5·55 5·94	1 685 1 712	—
V C$_2$H$_5$	123—125	$C_{23}H_{18}O_2$ (326·4)	84·64 84·67	5·55 5·77	1 665	1 647
VI C$_6$H$_5$CH$_2$	223—224	$C_{28}H_{20}O_2$ (388·4)	86·57 86·50	5·19 5·23	1 680 1 710	—
VII C$_6$H$_5$CH$_2$	110—111	$C_{28}H_{20}O_2$ (388·4)	86·57 86·54	5·19 5·23	1 650	1 635

Table IV and Fig. 1, the C-alkyl derivatives exhibit two bands in the C=O region, namely, at $1680-1685$ cm^{-1} (more intensive) and at $1710-1712$ cm^{-1} (less intensive), i.e., in the region of the dioxo form I. Analogously to compound I, the more intensive band of a lower frequency has ben ascribed to the v_{as} asymmetric stretching vibration and the less intensive band of a higher frequency to the v_s symmetric stretching vibration. The position of these vibrations is lower than that of the analogous 2-alkyl-2-phenyl-1,3-indanediones but is somewhat higher than that of 2-alkyl--2-phenyl-2,3-dihydro-1,3-phenalenediones. Thus, e.g., 2-methyl-2-phenyl-1,3-indanedione[2] exhibits v_{as} at 1713 cm^{-1} and v_s at 1751 cm^{-1}, 2-methyl-2-phenyl-2,3-dihydro-1,3-phenalenedione[4] shows v_{as} at 1680 cm^{-1} and v_s at 1705 cm^{-1}, and in the case of 5,7-dioxo-6-methyl-6-phenyl-6,7-dihydro-5H-dibenzo[a,c]cycloheptene, v_{as} lies at 1680 cm^{-1} and v_s at 1705 cm^{-1} (Table IV). The latter values are more closely related to those of 2-methyl-2-phenyl-2,3-dihydro-1,3-phenalenedione than to those of 2-methyl-2-phenyl-1,3-indanedione. The infrared spectra of compounds formed by the O-alkylation differ in the region of C=O vibrations, i.e., only a single band at $1650-1660$ cm^{-1} may be observed. Also in this case the vibration is by $50-55$ cm^{-1} lower than that of 1-alkoxy-2-phenyl-1-inden-3-ones and only by $5-10$ cm^{-1} higher than that of 2-phenyl-3-alkoxy-1-phenalenones.

The different electron spectra of the C- and O-derivatives (Fig. 2) made posible to determine the C/O ratio by spectral means.

EXPERIMENTAL

5,7-Dioxo-6-phenyl-6,7-dihydro-5H-dibenzo[a,c]cycloheptene (I)

Modification of the original procedure[1,17] allowed to raise the yield of compound I by 10%. Thus, a mixture of diphenic anhydride (33·6 g; 0·15 mol), phenylacetic acid (34 g; 0·25 mol), triethylamine (80 ml), and acetic anhydride (210 ml) is refluxed for 6 h, poured into ice (800 g), and diluted with conc. hydrochloric acid (200 ml). The precipitate is collected with suction, washed with water and ethanol, and dried to afford 17·8 g (45%) of the acetate, m.p. 155—156·5°C; reported[17], m.p. 157—158°C. The acetate of compound I is dissolved in methanolic sodium methoxide (from 1·6 g of sodium and 150 ml of methanol), the solution refluxed for 1 h, cooled down, and acidified with 10% aqueous hydrochloric acid. The crude product is recrystallised from ethanol to afford 13·2 g (85%) of compound I, m.p. 182—184°C; reported[1], m.p. 181—183°C.

Reactions of the Anion I

A mixture of compound I (0·37 g; 1·5 mmol), freshly calcinated potassium carbonate (0·34 g; 2·5 mmol), and the corresponding solvent (20 ml) was kept at 50 ± 1°C for 15 min and then treated with the appropriate halohydrocarbon (5 mmol). The reaction was checked by chromatography. The reaction time was changed according to the reactivity of the halohydrocarbon (Table I and II). After elapse of the reaction time, there was added 1·3 ml of aqueous silver nitrate (0·64 g in 1 ml), the mixture stirred for 15 min, the precipitate filtered off, and washed with benzene. The filtrate and washings were combined and evaporated under diminished pressure. The residue

was dissolved in benzene (30 ml) and chromatographed on a 15 cm column (3 cm in diameter) of alumina (Brockmann activity II; Reanal Budapest) in 3 : 1 benzene–light petroleum as eluant. In this solvent system, the unreacted starting compound *I* remained at the top. The first 100 ml of the eluate did not contain any products. The further 250 ml of the eluate contained both the C- and O-derivatives (detection with iodine vapours). The solvents were evaporated and the remaining mixture of products dried at 100°C/25 Torr for 1 h. The C/O ratio was determined by spectral means (Table I and II). The analytical data are in Table IV. The effect of temperature was examined analogously (Table III).

5-Oxo-6-phenyl-7-methoxy-5*H*-dibenzo[*a,c*]cyclopentene (*III*)

A mixture of compound *I* (1·49 g; 5 mmol) in ether (40 ml) and ethereal diazomethane (10 mmol) was kept at room temperature for 5 h, evaporated, and the residue crystallised from the solvent mixture benzene–light petroleum (1 : 20) to afford 85% of compound *III*, m.p. 142°C.

Determination of C-Alkyl and O-Alkyl Derivatives in Mixtures

The C/O ratio was determined by an analytical method using a system of equations based on wavenumbers and calibration mixtures[10,18]. The absorbancy of mixtures was recorded at twenty wavelengths in the 230—280 nm region (Fig. 2). Spectra of solutions of calibration mixtures and the sample in methanol were measured. The concentration of solutions was $5 . 10^{-5}$M; 1 cm wide cells were used. The methanolic solution of the corresponding O-alkyl derivative was used as the standard filter.

The spectra were taken on a prismatic Perkin-Elmer Model 450 spectrophotometer. The spectral data were processed on the Gier digital computer (Regnezentralen, Denmark, program Algol, modification Gieralgol IV). The C/O ratios are given in Table I and II as an arithmetic mean of three measurements; maximum deviation in concentrations of components, $\pm 2\%$ (benzyl derivatives) and $\pm 3\%$ (methyl derivatives).

Infrared spectra were taken on a double-beam Zeiss UR-20 spectrophotometer (polystyrene foil calibration).

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