

REACTIONS OF 6,7-DIHYDRO-5H-DIBENZO[*a,c*]CYCLOHEPTEN-5,7-DIONE WITH AROMATIC ALDEHYDES

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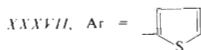
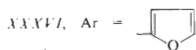
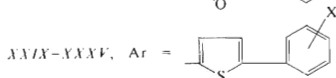
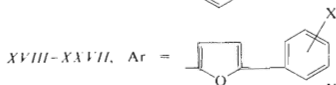
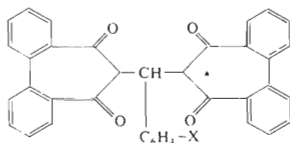
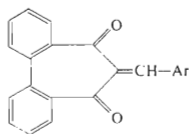
The reactions of 6,7-dihydro-5H-dibenzo[*a,c*]cyclohepten-5,7-dione (A) with X-substituted benzaldehydes, 5-(X-phenyl)-2-furaldehydes, 5-(X-phenyl)-2-thiophenecarboxaldehydes, furaldehyde, thiophenecarboxaldehyde, and ferrocenecarboxaldehyde were investigated in benzene and in 96% ethanol. It was found that A reacts with the aldehydes B in the ratios 1 : 1 and 2 : 1, giving the products AB and ABA. The effect of the substituent X on the equilibrium $AB \rightleftharpoons ABA$ in the reactions of A with X-substituted benzaldehydes is discussed. With other aldehydes, only AB were isolated, since ABA were unstable.

It is known that cyclic β -diketones react with aromatic aldehydes in the 1 : 1 or 2 : 1 ratio, the structure of reaction products being dependent on the β -diketone. Thus, for example, dimedon reacts in ethanol with aldehydes quantitatively in the 2 : 1 ratio to form alkylmethylene- or arylmethylene-bis-dimedon¹. The reaction of 1,3-indandione with X-substituted benzaldehydes catalysed by piperidine gives 2-benzylidene-1,3-indandiones^{2,4}. However, under suitable reaction conditions also 2-benzylidene-bis(1,3-indandione) is obtained in addition to 2-benzylidene-1,3-indandione⁵. The bisderivatives are formed when the reaction components are used in the 2 : 1 ratio with respect to the indandione. The formation of the bisderivatives is, of course, dependent also on the substituent attached to the phenyl group. These compounds have not been obtained with the derivatives substituted with 2-OH, 4-CH₃O—, or 4-(CH₃)₂N— group⁵. It was also observed that the indandione undergoes autoaldolisation under the conditions under which it reacts with aldehydes⁶.

We have carried out the reactions of 6,7-dihydro-5H-dibenzo[*a,c*]cyclohepten-5,7-dione (A) using the conditions reported for the reactions of aromatic aldehydes with 1,3-indandione. The dione A was synthesised according to Ried and Conte⁷, except that cyclisation of methyl ester of 2'-acetylphenyl-2-carboxylic acid was effected with potassium tert-butoxide in benzene in place of sodium ethoxide in ethanol. By this way, a high yield of the product was obtained (up to 95%).

The reactions of the dione A with X-substituted benzaldehydes were carried out

in benzene and 96% ethanol (the reactions of the indandione with aldehydes were performed in ethanol²⁻⁵) in the presence of a catalytic amount of piperidine. The reaction components were used in the 1 : 1 and 2 : 1 ratios with respect to the dione A. The course of the reaction was followed by chromatography. It was found that the reaction of A with the aldehydes B yields the products of two types: 6-(X-phenylmethylene)-6,7-dihydro-5H-dibenzo[*a,c*]cyclohepten-5,7-diones I–XVI, *i.e.* the AB products which are formed by 1 : 1 reaction of A with aldehydes, and 6-(X-phenylmethylene)-bis-(6,7-dihydro-5H-dibenzo[*a,c*]cyclohepten-5,7-dione) XXXIX–XLIV, *i.e.* the ABA products which were formed by the reaction of A with aldehydes in the 2 : 1 ratio (Scheme 1). The relative amounts of these products vary with the substituent and also with the solvent. Thus, for example, in the reaction of A with 4-dimethylaminobenzaldehyde the greater amount of AB is formed in ethanol than in benzene. With other aldehydes, the greater amount of AB is formed in benzene (Table I). Comparison of the AB to ABA ratios obtained in benzene in dependence on substituents reveals that the $AB \rightleftharpoons ABA$ equilibrium is shifted most to the AB product for the 2-hydroxy derivative and to the ABA product for the 4-dimethylamino deriva-



XXXIX, X = 4-OCH₃

XI, X = 4-N(CH₃)₂

XLI, X = H

XLII, X = 4-Cl

XLIII, X = 4-CH₃

XLIV, X = 4-NHCOCH₃

TABLE I
6-Arylmethylene-5*H*-dibenzo[*a,c*]cyclohepten-5,7-diones

Compound	M.p., °C	Formula (m.w.)	Calculated/Found			Time, h ^a (yield, %)	ν(CO) cm ⁻¹
			% C	% H	% X		
6- <i>X</i> -Benzylidene-5 <i>H</i> -dibenzo[<i>a,c</i>]cyclohepten-5,7-diones							
<i>I</i>	137	C ₂₂ H ₁₄ O ₂	85.14	4.55	—	2 (1)	1663
H		(310.4)	85.36	4.55	—	62 (2)	1698
<i>II</i>	126	C ₂₂ H ₁₃ ClO ₂	76.64	3.80	10.28	3	1664
2-Cl		(344.8)	76.69	3.63	10.60	64	1698
<i>III</i>	139	C ₂₂ H ₁₃ ClO ₂	76.64	3.80	10.28	4	1664
3-Cl		(344.8)	76.60	4.07	10.12	61	1699
<i>IV</i>	139—141	C ₂₂ H ₁₃ ClO ₂	76.64	3.80	10.28	3	1664
4-Cl		(344.8)	76.80	3.83	10.18	85	1699
<i>V</i>	98—100	C ₂₂ H ₁₃ BrO ₂	67.80	3.37	20.53	3.5	1663
3-Br		(389.3)	67.93	3.40	20.65	67	1698
<i>VI</i>	194—196	C ₂₂ H ₁₄ O ₃	80.97	4.32	—	2	1666
2-OH		(326.4)	81.30	4.48	—	99	1675
<i>VII</i>	211—212	C ₂₂ H ₁₄ O ₃	80.97	4.32	—	2 (1)	1650
4-OH		(326.4)	81.04	4.35	—	95 (56)	1695
<i>VIII</i>	158	C ₂₂ H ₁₅ O ₄	77.73	4.25	—	4	1656
3,4-O ₂ CH ₂		(355.35)	77.50	4.20	—	49	1693
<i>IX</i>	— ^b	C ₂₃ H ₁₆ O ₃	81.16	4.74	—	3	1663
3-OCH ₃		(340.4)	80.84	4.73	—	55	1699
<i>X</i>	157—158	C ₂₃ H ₁₆ O ₃	81.16	4.74	—	2.5 (1)	1652
4-OCH ₃		(340.4)	81.39	4.85	—	85 (9)	1652
<i>XI</i>	82 (112)	C ₂₃ H ₁₆ O ₂	85.16	4.97	—	2.5	1658
4-CH ₃		(324.4)	85.20	5.25	—	70	1696
<i>XII</i>	200—202	C ₂₂ H ₁₃ NO ₄	74.36	3.69	3.94	3	1655
3-NO ₂		(355.3)	74.48	3.66	4.12	62	1699
<i>XIII</i>	229—231	C ₂₂ H ₁₃ NO ₄	74.36	3.69	3.94	3	1666
4-NO ₂		(355.3)	74.60	3.67	3.94	70	1699
<i>XIV</i>	228—230	C ₂₃ H ₁₃ NO ₄	82.37	3.91	4.18	4	1966
4-CN		(335.4)	82.53	4.00	4.18	52	1698
<i>XV</i>	238	C ₂₄ H ₁₉ NO ₂	81.56	5.42	3.96	4 (1)	1639
4-N(CH ₃) ₂		(353.4)	81.79	5.38	3.20	35 (80)	1683
<i>XVI</i>	240—242	C ₂₄ H ₁₇ NO ₃	78.46	4.66	3.81	4.5	1658
4-NHCOCH ₃		(364.4)	78.48	4.74	3.83	71	1700

TABLE I
(Continued)

Compound	M.p., °C	Formula (m.w.)	Calculated/Found			Time, h ^a (yield, %)
			% C	% H	% X	
6-(5- <i>X</i> -Phenyl)-2-furfurylidene-5 <i>H</i> -dibenzo[<i>a,c</i>]cyclohepten-5,7-diones						
<i>XVII</i> H	169–171	C ₂₆ H ₁₆ O ₃ (376.4)	82.96 82.73	4.28 4.31	—	2 70
<i>XVIII</i> 3-F	177	C ₂₆ H ₁₅ FO ₃ (394.4)	79.18 79.32	3.83 3.83	4.81 4.65	1.5 85
<i>XIX</i> 2-Cl	216–217	C ₂₆ H ₁₅ ClO ₃ (410.9)	76.01 76.43	3.68 4.00	8.63 8.42	1.5 99
<i>XX</i> 3-Cl	182	C ₂₆ H ₁₅ ClO ₃ (410.9)	76.01 75.71	3.68 3.79	8.63 8.42	2 87
<i>XXI</i> 4-Cl	142–144	C ₂₆ H ₁₅ ClO ₃ (410.9)	76.01 75.50	3.68 4.08	8.63 8.30	1.5 (1) 99 (30)
<i>XXII</i> 3-Br	188–189	C ₂₆ H ₁₅ BrO ₃ (455.3)	68.59 68.46	3.32 3.43	17.55 17.91	2 80
<i>XXIII</i> 4-Br	169–170	C ₂₆ H ₁₅ BrO ₃ (455.3)	68.59 69.00	3.32 3.52	17.55 17.90	1.5 99
<i>XXIV</i> 2-NO ₂	155–156	C ₂₆ H ₁₅ NO ₅ (421.4)	74.11 75.00	3.59 3.63	3.32 3.20	1.5 95
<i>XXV</i> 3-NO ₂	248–250	C ₂₆ H ₁₅ NO ₅ (421.4)	74.11 74.03	3.59 3.61	3.32 3.48	2 82
<i>XXVI</i> 4-NO ₂	160–162	C ₂₆ H ₁₅ NO ₅ (421.4)	74.11 74.23	3.59 3.83	3.32 3.62	1.5 87
<i>XXVII</i> 4-CH ₃	174–175	C ₂₇ H ₁₈ O ₃ (378.4)	82.52 82.46	4.79 4.83	— —	1.5 91
<i>XXVIII</i> 4-CH ₃ O	195–196	C ₂₇ H ₁₈ O ₄ (406.4)	79.79 79.65	4.46 4.21	— —	1.5 95
6-(5- <i>X</i> -Phenyl)-2-thenylidene-5 <i>H</i> -dibenzo[<i>a,c</i>]cyclohepten-5,7-dione						
<i>XXIX</i> H	147–146	C ₂₆ H ₁₆ O ₂ S (392.5)	79.57 80.01	4.11 4.21	8.17 8.25	3 65
<i>XXX</i> 3-Cl	161–163	C ₂₆ H ₁₅ ClO ₂ S (426.9)	73.15 72.93	3.54 3.46	7.51 7.32	3 60
<i>XXXI</i> 4-Cl	151–153	C ₂₆ H ₁₅ ClO ₂ S (426.9)	73.15 73.24	3.54 3.55	7.51 7.43	3 70

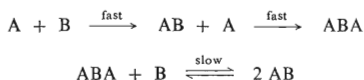
TABLE I
 (Continued)

Compound	M.p., °C	Formula (m.w.)	Calculated/Found			Time, h ^a (yield, %)
			% C	% H	% X	
XXXII 4-Br	150—152	C ₂₆ H ₁₅ BrO ₂ S (471.4)	66.25	3.21	6.80	2
			66.32	3.52	6.59	70
XXXIII 4-CH ₃ O	133—134	C ₂₇ H ₁₈ O ₃ S (422.5)	76.76	4.29	7.59	2.5
			76.81	4.61	7.32	77
XXXIV 3-CH ₃	154—155	C ₂₇ H ₁₈ O ₂ S (406.5)	79.78	4.46	7.19	3
			79.92	4.31	8.21	65
XXXV 4-CH ₃	134—135	C ₂₇ H ₁₈ O ₂ S (406.5)	79.78	4.46	7.89	3
			79.61	4.61	7.36	69
6-Arylmethylene-5H-dibenzo[a,c]cyclohepten-5,7-dione						
XXXVI furfurylidene	159—161	C ₂₀ H ₁₂ O ₃ (300.3)	79.99	4.03	—	66
			79.50	4.05	—	66
XXXVII thenylidene	144	C ₂₀ H ₁₂ O ₂ S (316.4)	75.93	3.82	10.11	3
			75.85	3.46	9.67	64
XXXVIII ferrocenyldiene	150—152 ^c	C ₂₆ H ₁₉ FeO ₂ (418.3)	74.48	4.57	13.32	3
			74.50	4.50	13.00	60

^a Data for the reactions in ethanol are given in parenthesis; ^b An oily product; ^c decomposition.

tive (Table I). This equilibrium is further strongly temperature-dependent. The formation of the AB product increases with increasing temperature.

As it was found by chromatographic analysis of the reaction course, the ABA product is rapidly formed in the initial phase of the reaction (the exception was only the reaction of A with salicylaldehyde), *i.e.* Knoevenagel condensation followed by the Michael addition proceed as fast, kinetically controlled reactions. Later, the ABA formed reacts with the aldehyde to give AB until the equilibrium between these two products is established (thermodynamically controlled phase of the reaction). The reaction of ABA with B determined the rate of the AB formation. The formation of AB from A and B can be depicted by the following scheme.



SCHEME 1

The fact that the bisderivative ABA reacts with another molecule of B to give two molecules of AB was also confirmed by allowing the compound XXXIX to react with 4-chlorobenzaldehyde in benzene in the presence of piperidine. The reaction gave compounds X, IV, XXXIX, and XLII. After 8 h-refluxing, the X/IV ratio was constant and equaled to 1.4 and the ratio of the bisderivatives XXXIX/XLI = 0.2. A similar situation was observed also with the reactions of XLII with 4-methoxybenzaldehyde and of XXXIX with 4-dimethylaminobenzaldehyde, the X/XV ratio being here 0.7.

TABLE II

Substituted Phenylmethylene-bis(6,7-dihydro-5*H*-dibenzo[*a,c*]cyclohepten-5,7-dione) XXXIX to XLIV

Compound	X	M.p., °C	Formula (m.w.)	Calculated/Found		
				% C	% H	% X
XXXIX	4-OCH ₃	212–214	C ₃₈ H ₂₂ O ₅ (562.6)	80.71	4.76	—
				81.10	4.80	—
XL	4-N(CH ₃) ₂	140–145	C ₃₉ H ₃₀ NO ₄ (576.4)	81.27	5.23	2.43
				81.40	4.93	2.82
XLI	H	190–193	C ₃₇ H ₂₄ O ₄ (332.6)	83.44	4.54	—
				83.62	4.45	—
XLII	4-Cl	212–214	C ₃₇ H ₂₃ ClO ₄ (567.0)	78.36	4.08	—
				78.52	4.00	—
XLIII	4-CH ₃	208–210	C ₃₈ H ₂₆ O ₄ (546.6)	83.49	4.49	—
				83.40	4.50	—
XLIV	4-NHOCCH ₃	172–174	C ₃₉ H ₂₇ NO ₅ (589.6)	79.44	4.61	2.37
				79.20	4.67	2.42

The suggested course of the reaction is further supported by the following experiments. The reaction of the 4-methoxy derivative X with 4-chlorobenzaldehyde gives the 4-chloro derivative and the bisderivatives XXXIX (4-methoxy) and XLII (4-chloro). On the contrary, the reaction of the 4-chloro derivative with 4-methoxybenzaldehyde affords the 4-methoxy derivative and the same bisderivatives XXXIX and XLII. The ratio of the monoderivatives IV : X equaled to 1. It is worth mentioning that some monoderivatives do not undergo the above mentioned reaction with aldehydes. Thus, for example, the 4-dimethylamino derivative XV does not react with *p*-nitrobenzaldehyde.

We have further found that A reacts under similar conditions also with 5-(X-phenyl)-2-furaldehydes, 5-(X-phenyl)-2-thiophenecarboxaldehydes, furaldehyde, 2-thiophenecarboxaldehyde, and 2-ferrocenecarboxaldehyde. With these aldehydes only the monoderivatives *XVII*–*XXXVIII* could be isolated. The bisderivatives were found to be less stable than the bisderivatives formed in the reactions of A with X-substituted benzaldehydes. It is noteworthy that the bisderivatives *XXXIX*–*XLIV* quantitatively decompose to the monoderivatives and the dione A on heating to the temperature 5–10°C higher than their melting point (Table II). The bisderivatives ABA are unstable in solutions and decompose to the monoderivatives. For that reason they must be isolated immediately after the equilibrium is established. Because of their instability, we were unable to determine physical constants for some of the compounds prepared.

The compounds *I*–*XXXVIII* show the two bands, the more intense band at 1650 to 1666 cm^{-1} and the less intense one at 1675–1699 cm^{-1} , in the region of the C=O stretching vibration. Reasoning by analogy to 1,3-indandione, the lower frequency band can be ascribed to the asymmetric vibration and the higher frequency band to the symmetric coupling of the C=O vibrations.

EXPERIMENTAL

Infrared spectra were recorded with a double-beam prism Zeiss UR-20 spectrophotometer. The instrument was calibrated with a polystyrene film.

6,7-Dihydro-5*H*-dibenzo[*a,c*]cyclohepten-5,7-dione (A)

To 300 ml of benzene, 7.8 g (0.2 mol) of potassium and 40 ml of tert-butanol were added, and the reaction mixture was stirred with cooling until the potassium reacted. Then, a solution of 24.4 g (0.1 mol) of methyl ester of 2'-acetylphenyl-2-carboxylic acid in 120 ml of benzene was added such that the temperature did not raise above 30 to 35°C, the mixture was allowed to stir at room temperature for another 1/2 h, 400 ml of water were added and the layers were separated. The aqueous layer was extracted with 150 ml of benzene. The dione A was obtained from the aqueous layer by acidification with 5% H_2SO_4 (pH 1–2). After recrystallisation of the crude product from methanol, 20 g of the dione was obtained (93%) yield. M.p. 169°C, ref.⁷ records 171°C.

6-Arylmethylene-6,7-dihydro-5*H*-dibenzo[*a,c*]cyclohepten-5,7-dione (*I*–*XXXVIII*)

A mixture of 0.44 g (2 mmol) of the dione A, 30 ml of benzene (10 ml of 96% ethanol), 2 mmol of an aldehyde, and several drops of piperidine (0.3 mmol) was refluxed for the time given in Table I. The products were isolated by chromatography on a column filled with silica gel (L 40/100) by elution with chloroform. On eluting the compounds *VI*, *XV*, and *XVI*, 5% ethyl acetate was added, and in the case of *VII*, the coeluent was 8% ethyl acetate. The monoderivatives of substances *I*–*XXXVIII* were eluted first and had the yellowish to redish colouration. The solvent was distilled off and the crude products were recrystallised from benzene or a benzene–light petroleum mixture, except for the compound *XV* which was recrystallised from chloroform–methanol. Analytical data are presented in Table I.

6-Arylmethylene-bis(6,7-dihydro-5*H*-dibenzo[*a,c*]cyclohepten-5,7-dione) (XXXIX—XLIV)

A solution of 0.44 g (2 mmol) of the dione A, 1 mmol of a benzaldehyde and 1 drop of piperidine (triethylamine) in 10 ml of methanol was refluxed for 30 min, cooled to room temperature and then 2–3 drops of 50% acetic acid were added. After standing the reaction mixture for one day, the precipitate was recrystallised from methanol. Analytical data are given in Table II.

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