72054-85-4; **69**, 2441-46-5; **70**, 67271-97-0; **71**, 74097-25-9; **72**, 64648-87-9; **73**, 74097-26-0; **74**, 64648-88-0; **75**, 74097-27-1; **76**, 74097-20-4; **77**, 74097-28-2; **79**, 74097-29-3; **80**, 74097-30-6; **84**, 64791-61-3; **85**, 74097-31-7; *cis*-**86**, 74097-32-8; *trans*-**86**, 74097-33-9; dimethyl disulfide, 624-92-0; 2-methyl-1,4-dimethoxybenzene, 24599-58-4; 2-(trimethylsilyl)-1,4-dimethoxybenzene, 72054-75-2; 2-(1-methoxyethyl)-1,4-dimethoxybenzene, 72054-77-4; 1,2,4-trimethoxybenzene, 135-77-3; piperidine, 110-89-4; 3-bromo-4-methoxyphenol, 17332-12-6; 4-methoxy-1-naphthol, 84-85-5; allyl bromide, 106-95-6; methyl bromide, 74-83-9.

Supplementary Material Available: Experimental details of reactions utilized in establishing the structures of the monoketals and spectroscopic data of compounds formed in these reactions (15 pages). Ordering information is given on any current masthead page.

Thallium in Organic Synthesis. 57. Reaction of Chalcones and Chalcone Ketals with Thallium(III) Trinitrate[1]

Edward C. Taylor,* Richard A. Conley, and David K. Johnson

Department of Chemistry, Princeton University, Princeton, New Jersey 08540

Alexander McKillop and Michael E. Ford

School of Chemical Sciences, University of East Anglia, Norwich NR4 7TJ, Norfolk, England

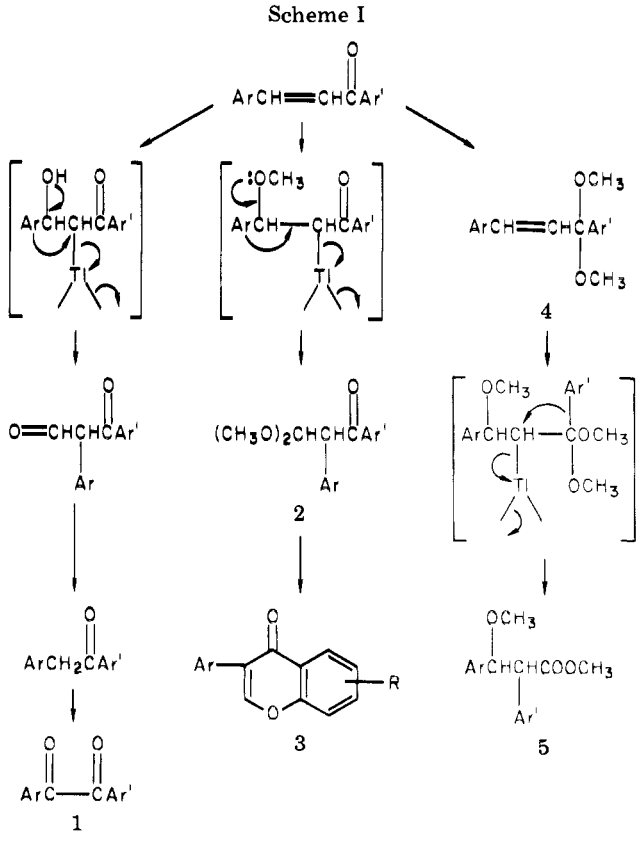
Received February 29, 1980

Treatment of chalcones (ArCH=CHCOAr') with thallium(III) trinitrate (TTN) in acidic methanol or in trimethyl orthoformate (TMOF) gives 3,3-dimethoxy-1,2-diarylpropan-1-ones (oxythallation, Ar rearrangement) and/or methyl 2,3-diaryl-3-methoxypropanoates (in situ ketal formation, oxythallation, Ar' rearrangement). The effect of substituents on Ar and Ar' on the ratio of the above rearrangement products has been examined.

Thallium(III) trinitrate (TTN) is now firmly established as a useful and extremely versatile reagent in organic synthesis.[2] Among the readily accessible substrates which have been shown to undergo novel oxidative rearrangement reactions with TTN are chalcones. Thus, oxidation of chalcones in aqueous acidic glyme constitutes a convenient synthesis of benzils (**1**).[3] In addition, the TTN-mediated oxidative rearrangement of chalcones in acidic methanol provides a route to 3,3-dimethoxy-1,2-diarylpropan-1-ones (**2**), key intermediates in the synthesis of isoflavones (**3**) when the Ar' ring possesses an *o*-hydroxyl group, and this reaction has now been extensively exploited.[4] Furthermore, transformation of chalcones into their ketals (**4**) followed by reaction with TTN in trimethyl orthoformate (TMOF) as solvent has recently been shown to give methyl 2,3-diaryl-3-methoxypropanoates (**5**; see Scheme I).[5]

This latter transformation of chalcone ketals to **5** was discovered during an intensive study of TTN oxidations in TMOF as solvent. Thus, although treatment of chalcone itself (Ar = Ar' = C_6H_5) with TTN in acidic methanol yields 3,3-dimethoxy-1,2-diphenylpropan-1-one (**2**, Ar = Ar' = C_6H_5), we found that reaction in TMOF as solvent gave a 50:50 mixture of the latter compound and methyl 2,3-diphenyl-3-methoxypropanoate (**5**, Ar = Ar' = C_6H_5). The keto acetal **2** was obviously formed by the usual Ar ring migration, but the ester **5** must have resulted from the migration of the Ar' group, an unprecedented oxidative rearrangement of chalcones. Formation of the ester **5** may

Scheme I



(1) For the previous paper in this series, see E. C. Taylor, G. E. Jagdmann, Jr., and A. McKillop, *J. Org. Chem.*, **45**, in press.

(2) See A. McKillop and E. C. Taylor, *Endeavour*, **35**, 88 (1976). See also the previous papers in this series.

(3) A. McKillop, B. P. Swann, M. E. Ford, and E. C. Taylor, *J. Am. Chem. Soc.*, **95**, 3641 (1973).

(4) (a) L. Farkas, A. Gottsegen, M. Nogradi, and S. Antus, *J. Chem. Soc., Perkin Trans 1*, 305 (1974); (b) S. Antus, L. Farkas, M. Nogradi, and P. Sohar, *J. Chem. Soc., Chem. Commun.*, 799 (1974); (c) L. Farkas, S. Antus, and M. Nogradi, *Acta Chim. Acad. Sci. Hung.*, **82**, 225 (1974); (d) A. Levai and L. Balogh, *Pharmazie*, **30**, 747 (1975); (e) S. Antus, L. Farkas, Z. Kardos-Balogh, and M. Nogradi, *Chem. Ber.*, **108**, 3883 (1975); (f) S. Antus, L. Farkas, A. Gottsegen, Z. Kardos-Balogh, and M. Nogradi, *ibid.*, **109**, 3811 (1976); (g) M. A. Leon and M. C. Cabaleiro, *An. Asoc. Quim. Argent.*, **64**, 331 (1976); (h) T. G. Fourie, D. Ferreira, and D. G. Roux, *J. Chem. Soc., Perkin Trans. 1*, 125 (1977); (i) M. E. Oberholzer, G. J. H. Rall, and D. G. Roux, *ibid.*, 423 (1977); (j) Z. Kardos-Balogh, L. Farkas, and A. Wolfner, *Acta Chim. Acad. Sci. Hung.*, **94**, 75 (1977); (k) S. Antus, F. Boross, L. Farkas, and M. Nogradi in "Flavonoids and Bioflavonoids: Proceedings of the 5th Hungarian Bioflavonoid Symposium", 1977, pp 171–180; (l) F. R. van Heerden, E. V. Brandt, and D. G. Roux, *J. Chem. Soc., Perkin Trans. 1*, 137 (1978); (m) S. Antus and M. Nogradi, *Chem. Ber.*, **112**, 480 (1979).

(5) E. C. Taylor, R. A. Conley, D. K. Johnson, and A. McKillop, *J. Org. Chem.*, **42**, 4167 (1977).

0022-3263/80/1945-3433$01.00/0

be rationalized as follows. Since the oxythallation reaction (which precedes oxidative rearrangement) of chalcone with TTN is slow due to deactivation of the olefinic double bond by the carbonyl group, ketalization of the latter by TMOF, catalyzed either by TTN itself as a Lewis acid or by acid, becomes a competing reaction. Once the ketal is formed, however, oxythallation is rapid (the substrate ketal is now a simple substituted styrene), and the intermediate oxythallation compound then undergoes Ar′ group migration rather than Ar migration because of stabilization of the intermediate carbenium ion by the geminal methoxy groups.[6] This interpretation was readily tested by the independent preparation of chalcone dimethyl ketal and its subsequent reaction with TTN in TMOF; the reaction was rapid and gave exclusively the ester **5** (Ar = Ar′ = C_6H_5).

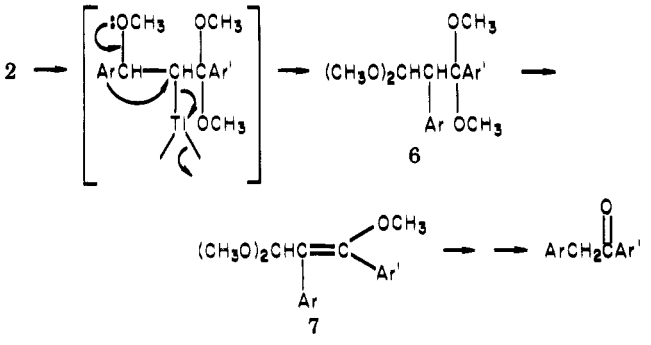
These preliminary results have led us to compare the reaction of TTN with substituted chalcones, both in TMOF and in acidic methanol, with the reaction of the corresponding chalcone dimethyl ketals in TMOF. The results of this study are reported in the present paper.

Reaction of TTN with Chalcones. The reaction of TTN either in TMOF or in acidic methanol with chalcones in which the Ar group is activated leads exclusively and quantitatively to the keto acetals **2**. We were unable to detect (NMR) the formation of esters **5** which would have resulted from in situ ketal formation and subsequent Ar′ migration from the resulting oxythallation intermediates. Thus, oxythallation of the chalcone and subsequent rearrangement of the Ar group successfully compete with ketalization. The activated Ar group probably promotes this reaction pathway in two ways: (1) the double bond is activated toward oxythallation; (2) the enhanced migratory aptitude of the Ar ring leads to rapid oxidative rearrangement. Both factors thus favor the observed transformation and consequently inhibit the competing sequence of reactions (ketal formation, oxythallation, and subsequent Ar′ group migration). It is therefore reasonable that reactions with the above substrates were equally effective in methanol or in TMOF. Only in the oxidative rearrangement of the chalcone where Ar = 4-$CH_3OC_6H_4$ and Ar′ = 2-thienyl was TMOF superior to acidic methanol, and this is probably due to the sensitivity of the thienyl group to acid.

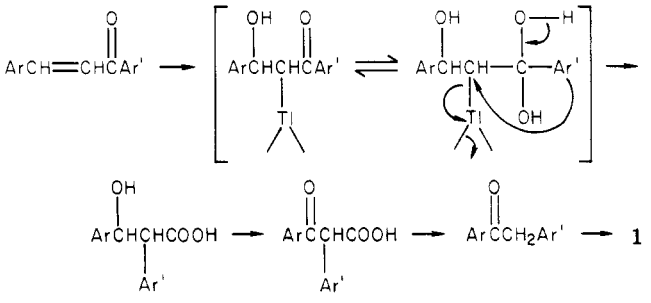
In chalcones in which the Ar ring is only moderately activated and thus possesses average migratory aptitude, reaction with TTN either in TMOF or in acidic methanol is slow, and mixtures of the ketal acetals **2** and the esters **5** are obtained. More ester (20–30%) is formed in TMOF than in methanol, but this is reasonable, since under these latter conditions, ketalization would be expected to compete with "normal" oxidative rearrangement to give the keto acetals **2**. TMOF is thus less desirable as a solvent than acidic methanol for the oxidative rearrangement of chalcones possessing only moderately activated Ar rings (but see below for the deliberate conversion of such chalcones to **5** via their preformed ketals).

With chalcones possessing a deactivated Ar ring (for example, *p*-nitro), "normal" oxidative rearrangement to **2** is now inhibited by the deactivated double bond so that the only viable reaction pathway is in situ ketalization and subsequent oxidative rearrangement of the Ar′ grouping; the ester **5** is the only product. Synthetically, however, oxidative rearrangement of such chalcones to methyl 2,3-diaryl-3-methoxypropanoates (**5**) is best carried out by prior in situ formation of the corresponding chalcone dimethyl ketals with TMOF in the presence of an ion-exchange resin, followed by filtration and subsequent addition of TTN (see below).

Scheme II



Scheme III

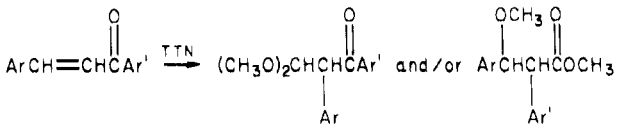


Reation of TTN with Preformed Chalcone Ketals. In chalcone ketals possessing a moderately activated or a deactivated Ar ring and an Ar′ group either moderately activated or strongly activated, the esters **5** are the only products of oxidative rearrangement, and they are formed in excellent yield. This is entirely reasonable, as a combination of favorable migratory aptitude of the Ar′ group and stabilization of the intermediate carbenium ion by the geminal methoxy groups should favor this reaction pathway. However, complex reaction mixtures are obtained with chalcone ketals in which the Ar ring is activated and the Ar′ group is not. Some of the esters **5** can be detected in the NMR spectra of the crude reaction mixtures, but many other products are present as well, and the reaction has no synthetic utility. Since acid hydrolysis of the crude reaction mixtures gives low yields of deoxybenzoins, it seems probable that acetals **6**, enol ethers **7**, or related products resulting from competitive Ar ring migration are also present (Scheme II).

Formation of Benzils from Chalcones. As mentioned above, benzils can be conveniently prepared from a wide variety of chalcones with TTN in acidic aqueous glyme.[3] In view of the presumed reaction pathway (see Scheme I) which involves oxythallation of the carbon–carbon double bond, oxidative rearrangement of the Ar group, reverse Claisen condensation to give a deoxybenzoin, and subsequent oxidation, it had been assumed that the preparation of unsymmetrical benzils in which one of the Ar rings was deactivated required a starting chalcone in which the deactivating substituent was present in the Ar′ ring. In view of our present results which indicate that, under reaction conditions which allow ketal formation to compete with "normal" oxidative rearrangement, Ar′ group migration can be observed, we have reexamined the above premise. Two chalcones with deactivated Ar rings (4-nitrochalcone and 4-nitro-4′-methoxychalcone) were treated with TTN in aqueous glyme; the corresponding benzils were obtained in moderate yields. The results suggest that Ar′ migration is indeed possible in aqueous

(6) C. H. V. Dusseau, S. E. Schaafsma, H. Steinberg, and T. J. deBoer, *Tetrahedron Lett.*, 467 (1969).

Table I. Reaction of Chalcones and Chalcone Ketals with TTN



Ar	Ar'	reaction solvent	ratio of K/E[a]	yield, % crude	yield, % recryst[b]	mp, °C keto acetal	mp, °C ester
4-$CH_3OC_6H_4$	4-$CH_3OC_6H_4$	CH_3OH	100/0	100	66[c]	74-75	
		TMOF	100/0	100	77		
		ketal	*d*	20	14		104.5-106.0
4-$CH_3OC_6H_4$	C_6H_5	CH_3OH	100/0	97	74	84-86	
		TMOF	100/0	100	80		
		ketal	*e*				
4-$CH_3OC_6H_4$	4-ClC_6H_4	TMOF	100/0	96	*f*		
4-$CH_3OC_6H_4$	3-$O_2NC_6H_4$	TMOF[g]	100/0	100	88[h]	134-135	
4-$CH_3OC_6H_4$	4-$O_2NC_6H_4$	TMOF	100/0	84	46	71-72	
4-$CH_3OC_6H_4$	2-C_4H_3S	CH_3OH	100/0	56	25	98-100	
		TMOF	100/0	100	83		
4-$CH_3C_6H_4$	4-$CH_3C_6H_4$	CH_3OH	92/8	75	36	88-91.5	
		TMOF	70/30	93	42		
4-$CH_3C_6H_4$	C_6H_5	CH_3OH	100/0	100	37[i]	59.5-61.5	
		TMOF	75/25	19	7		
C_6H_5	C_6H_5	CH_3OH	100/0	47[j]	43	94.5-96.5	
		TMOF	50/50				
		ketal	0/100	100	31		93.5-95.5
C_6H_5	4-$CH_3OC_6H_4$	CH_3OH	58/42	100	33	120-121	
		TMOF	35/65	100			
		ketal	0/100	97	37		80.5-82
C_6H_5	4-$CH_3C_6H_4$	CH_3OH	65/35	100	38	113-115	
		TMOF	43/57	99			
		ketal	0/100	99	59		97-98.5
C_6H_5	4-BrC_6H_4	CH_3OH	100/0	97	46	84-86	
4-ClC_6H_4	C_6H_5	CH_3OH	86/14	85	46[k]	93.0-93.5	
		TMOF	40/60	89			
		ketal	0/100		81		81.5-84
4-ClC_6H_4	4-$CH_3OC_6H_4$	CH_3OH	43/57	88	*l*		
		TMOF	33/67	100	*l*		
		ketal	0/100	97	61		91.5-93
2-ClC_6H_4	C_6H_5	CH_3OH	31/69	99	45		*o*
		TMOF	12/88	96	66		72-73
		ketal	0/100	86	45		
4-$O_2NC_6H_4$	C_6H_5	ketal	0/100	100	62		91-93
4-$O_2NC_6H_4$	4-$CH_3OC_6H_4$	ketal	0/100	100	32		97.5-99.5
3-$O_2NC_6H_4$	4-$CH_3OC_6H_4$	TMOF	0/100	100	57		88-90[m]
		ketal	0/100	100	64		84.5-86[n]

[a] Ratio determined by NMR by integration of methinyl proton signals. [b] Recrystallization (from methanol except where otherwise noted) was usually accompanied by significant material loss. Satisfactory microanalytical data (C, H, and, where appropriate, N) were obtained for all new compounds. [c] Recrystallized from heptane. [d] The reaction mixture was extremely complex. The ester was recovered by trituration of the crude reaction mixture with methanol. [e] The only product isolated from the complex reaction mixture was methyl 3-(4-methoxyphenyl)-2-phenylpropenoate: 21%; mp 153-156 °C. [f] Although the crude product appeared to be pure (NMR, IR), distillation resulted in extensive decomposition with the formation of considerable amounts of enol ether. [g] Refluxed 3.5 h. Since the product was insoluble in ether, the workup was carried out by using chloroform. [h] Recrystallized from 95% ethanol. [i] Recrystallized from heptane. [j] Yield of crude product which precipitated from the reaction mixture upon trituration with methanol; mp 91.5-94 °C. [k] Recrystallized from petroleum ether (bp 40-60 °C). [l] Isolation of pure product(s) by fractional crystallization was unsuccessful. [m] Product analyzed for $C_{18}H_{19}NO_6 \cdot {}^1/_3CH_3OH$. [n] Recrystallized from acetone. [o] The boiling point is 178-180 °C (0.7 mm).

glyme, and a plausible alternative reaction pathway to benzils is outlined in Scheme III.

Experimental Section

Reaction of Chalcones with TTN in Methanol. General Procedure. A solution of the chalcone (0.01 mol) in 25 mL of methanol was added to a solution of 5.0 g of $TTN \cdot 3H_2O$ (0.011 mol) in 50 mL of methanol containing 5 mL of 70% perchloric acid, and the reaction mixture was stirred at room temperature for 4–25 h. A small amount of sodium bisulfite was then added to ensure complete reduction of Tl(III), and the mixture was cooled and filtered through a sintered-glass filter to remove $TlNO_3$. The filtrate was diluted with 100 mL of water and extracted with three 50-mL portions of chloroform. The combined extracts were washed with 50 mL of saturated sodium bicarbonate and 50 mL of water and dried (Na_2SO_4). Evaporation under reduced pressure then gave the crude product which was examined by NMR. In chalcones where the migratory aptitude (MA) of the Ar ring is high, 3,3-dimethoxy-1,2-diarylpropan-1-ones (keto acetals) are the only products, and they may be recovered in good yield by recrystallization from the solvents specified in Table I. In chalcones where the MA of the Ar ring is only moderate or poor, however, the crude reaction products are a mixture of the keto acetal and methyl 2,3-diaryl-3-methoxypropanoates (esters); the former could often be obtained pure from the mixture in moderate yield by recrystallization, usually from methanol.

Reaction of Chalcones with TTN in Trimethyl Orthoformate (TMOF). General Procedure. A solution of 5.5 g (0.011 mol) of $TTN \cdot 3H_2O$ in 25 mL of TMOF was added to a solution or slurry of the chalcone (0.01 mol) in 35 mL of TMOF, and the mixture was stirred at room temperature for 4–25 h (until the disappearance of Tl(III), as monitored by starch–iodide paper) and then worked up as described above except that ether rather

than chloroform was used in the extraction.

Reaction of Chalcone Ketals with TTN in TMOF. General Procedure. Chalcone ketals were prepared in situ by stirring the chalcone (0.01 mol) with 2–6 g of Dowex 50W-X4 cation-exchange resin in 35 mL of TMOF at room temperature. After ketal formation was complete (15–24 h, as determined by TLC monitoring using chloroform and silica gel plates), the reaction mixture was filtered into a solution of 5.0 g (0.011 mol) of $TTN{\cdot}3H_2O$ in 20 mL of TMOF. After the oxidative rearrangement was complete [6–24 h, as determined by the disappearance of Tl(III)], a small amount of sodium bisulfite was added, followed by 200–300 mL of ether, and the reaction mixture was chilled and filtered to remove $TlNO_3$. It was then worked up as described above. The methyl 2,3-diaryl-3-methoxypropanoates, which were obtained crude (90–98% purity by NMR) in almost quantitative yield, were recrystallized from methanol for analysis.

4-Nitrobenzil. To a slurry of 5.06 g (0.02 mol) of 4-nitrochalcone in 40 mL of 1,2-dimethoxyethane, 20 mL of water, and 10 mL of 70% perchloric acid was added 39.08 g (0.088 mol) of $TTN{\cdot}3H_2O$. The reaction mixture was heated under reflux for 1 h and cooled, 50 mL of chloroform was added, and the reaction mixture was filtered to remove $TlNO_3$. The filtrate was diluted with saturated sodium chloride solution and extracted with two 50-mL portions of chloroform. The combined extracts were washed with 5% sodium bicarbonate solution and water, dried ($MgSO_4$), and evaporated under reduced pressure to give 3.20 g of crude product which was recrystallized from aqueous ethanol: yield 1.64 g (32%) of 4-nitrobenzil; mp 139.5–140.5 °C (lit.[3] mp 140–141 °C).

Anal. Calcd for $C_{14}H_9NO_4$: C, 65.88; H, 3.56; N, 5.49. Found: C, 66.03; H, 3.51; N, 5.64.

4-Nitro-4′-methoxybenzil was prepared as described above in 52% yield from 4-nitro-4′-methoxychalcone and TTN; mp 154 °C (lit.[7] mp 156 °C).

(7) S. Kanno and S. Suzuki, *Yakugaku Zasshi*, 71, 1247 (1951).

Anal. Calcd for $C_{15}H_{11}NO_5$: C, 63.15; H, 3.89; N, 4.91. Found: C, 62.94; H, 3.81; N, 5.08.

Acknowledgment. We are indebted to the National Science Foundation (Grant CHE76 16506) for support of this work.

Registry No. 4,4′-Dimethoxychalcone, 2373-89-9; 4-methoxychalcone, 26522-20-3; 4-methoxy-4′-chlorochalcone, 6552-63-2; 4-methoxy-3′-nitrochalcone, 73911-01-0; 4-methoxy-4′-nitrochalcone, 6552-62-1; 3-(4-methoxyphenyl)-1-(2-thienyl)-2-propen-1-one, 6028-93-9; 4,4′-dimethylchalcone, 21551-47-3; 4-methylchalcone, 4224-87-7; chalcone, 94-41-7; 4′-methoxychalcone, 959-23-9; 4′-methylchalcone, 4224-96-8; 4′-bromochalcone, 2403-27-2; 4-chlorochalcone, 956-04-7; 4-chloro-4′-methoxychalcone, 6552-68-7; 2-chlorochalcone, 3300-67-2; 4-nitrochalcone, 1222-98-6; 4-nitro-4′-methoxychalcone, 6552-67-6; 3-nitro-4′-methoxychalcone, 68063-55-8; K (Ar, Ar′ = $4\text{-}CH_3OC_6H_4$), 74007-46-8; K (Ar = $4\text{-}CH_3OC_6H_4$, Ar′ = C_6H_5), 22755-95-9; K (Ar = $4\text{-}CH_3OC_6H_4$, Ar′ = $4\text{-}ClC_6H_4$), 74007-47-9; K (Ar = $4\text{-}CH_3OC_6H_4$, Ar′ = $3\text{-}O_2NC_6H_4$), 74007-48-0; K (Ar = $4\text{-}CH_3OC_6H_4$, Ar′ = $4\text{-}O_2NC_6H_4$), 74007-49-1; K (Ar = $4\text{-}CH_3OC_6H_4$, Ar′ = $2\text{-}C_4H_3S$), 74007-50-4; K (Ar, Ar′ = $4\text{-}CH_3C_6H_4$), 74007-51-5; K (Ar = $4\text{-}CH_3C_6H_4$, Ar′ = C_6H_5), 74007-52-6; K (Ar, Ar′ = C_6H_5), 41841-06-9; K (Ar = C_6H_5, Ar′ = $4\text{-}CH_3OC_6H_4$), 74007-53-7; K (Ar = C_6H_5, Ar′ = $4\text{-}CH_3C_6H_4$), 74007-54-8; K (Ar = C_6H_5, Ar′ = $4\text{-}BrC_6H_4$), 74007-55-9; K (Ar = $4\text{-}ClC_6H_4$, Ar′ = C_6H_5), 74007-56-0; K (Ar = $4\text{-}ClC_6H_4$, Ar′ = $4\text{-}CH_3OC_6H_4$), 74007-57-1; K (Ar = $2\text{-}ClC_6H_4$, Ar′ = C_6H_5), 74007-58-2; E (Ar, Ar′ = $4\text{-}CH_3OC_6H_4$), 74007-59-3; E (Ar, Ar′ = $4\text{-}CH_3C_6H_4$), 74007-60-6; E (Ar = $4\text{-}CH_3C_6H_4$, Ar′ = C_6H_5), 74007-61-7; E (Ar, Ar′ = C_6H_5), 64686-04-0; E (Ar = C_6H_5, Ar′ = $4\text{-}CH_3OC_6H_4$), 64686-06-2; E (Ar = C_6H_5, Ar′ = $4\text{-}CH_3C_6H_4$), 64686-05-1; E (Ar = $4\text{-}ClC_6H_4$, Ar′ = C_6H_5), 74007-62-8; E (Ar = $4\text{-}ClC_6H_4$, Ar′ = $4\text{-}CH_3OC_6H_4$), 64686-07-3; E (Ar = $2\text{-}ClC_6H_4$, Ar′ = C_6H_5), 74007-63-9; E (Ar = $4\text{-}O_2NC_6H_4$, Ar′ = C_6H_5), 64686-08-4; E (Ar = $4\text{-}O_2NC_6H_4$, Ar′ = $4\text{-}CH_3OC_6H_4$), 64686-09-5; E (Ar = $3\text{-}O_2NC_6H_4$, Ar′ = $4\text{-}CH_3OC_6H_4$), 74007-64-0; TTN, 10102-45-1; 4-nitrobenzil, 22711-24-6; 4-nitro-4′-methoxybenzil, 2387-74-8.

Phase-Transfer Catalyzed Reactions. 5.[1] Dramatic Effect of the Concentration of Base on the Dimerization of Crotonaldehyde

John M. McIntosh,* Hamdy Khalil,[2] and David W. Pillon

Department of Chemistry, University of Windsor, Windsor, Ontario, Canada N9B 3P4

Received October 30, 1979

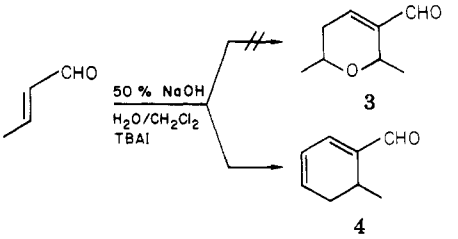
Self-condensation of crotonaldehyde under base-catalyzed phase-transfer conditions leads to aldehydes **3** or **4**, depending only on the concentration of aqueous hydroxide used. Quaternary ammonium fluorides in anhydrous THF is shown to be a useful system for conjugate additions involving base-sensitive aldehydes.

In recent years, we have been exploring the application of phase-transfer catalysis to a variety of reactions. Our interest was triggered initially by the serendipitous observation[3] that conjugated carbonyl compounds [e.g., crotonaldehyde (**1**)] would react with thiolacetic acid and sodium hydroxide in a conjugate addition–aldol condensation sequence to afford thiacyclohexenecarboxaldehydes **2** (eq 1). We now wish to document the amazing plethora

1 2 (1)

of results obtained when changes, some of which are apparently minor, are made in the reagents and reaction conditions.

Although it was known that oxygen anions are both harder and poorer nucleophiles than the analogous sulfur anions,[4] we considered the use of acetic acid as a possible route to dihydropyrans **3**. In the event, this reaction afforded none of **3**, but rather a 49% yield of **4**[5] was obtained.



(1) For part 4, see J. M. McIntosh, *Tetrahedron Lett.*, 403 (1979).
(2) NSERC predoctoral fellow, 1974–1977; taken in part from the Ph.D. thesis of H.K., University of Windsor, 1977.
(3) J. M. McIntosh and H. Khalil, *J. Org. Chem.*, **42**, 2123 (1977).
(4) J. O. Edwards and R. G. Pearson, *J. Am. Chem. Soc.*, **84**, 16 (1962).

0022-3263/80/1945-3436$01.00/0