

## Acetylenic Ketones. I. Reaction of Aroylphenylacetylenes with Compounds Containing An Active Methylene Group

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Aroylphenylacetylenes reacted with ethyl phenylacetate and benzyl cyanide in the presence of sodium ethoxide to give 6-aryl-3,4-diphenyl-2*H*-pyran-2-ones (**2**) and 4-aryol-2,3-*cis*-diphenylcrotonitriles (**11**), respectively. The structure and configuration of the products are based on chemical and spectroscopic evidence.

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The reactions of benzoyl phenylacetylene with ethyl phenylacetate (**2**), ethyl *p*-toluylacetate (**3**) and benzyl cyanide (**4**) have been reported. The present work was intended to extend the study of the reactions of some aroylphenylacetylenes with ethyl phenylacetate, benzyl cyanide, and establish the structure and configuration of the products, as well as the mechanisms of the reactions.

### a) Reaction with Ethyl Phenylacetate.

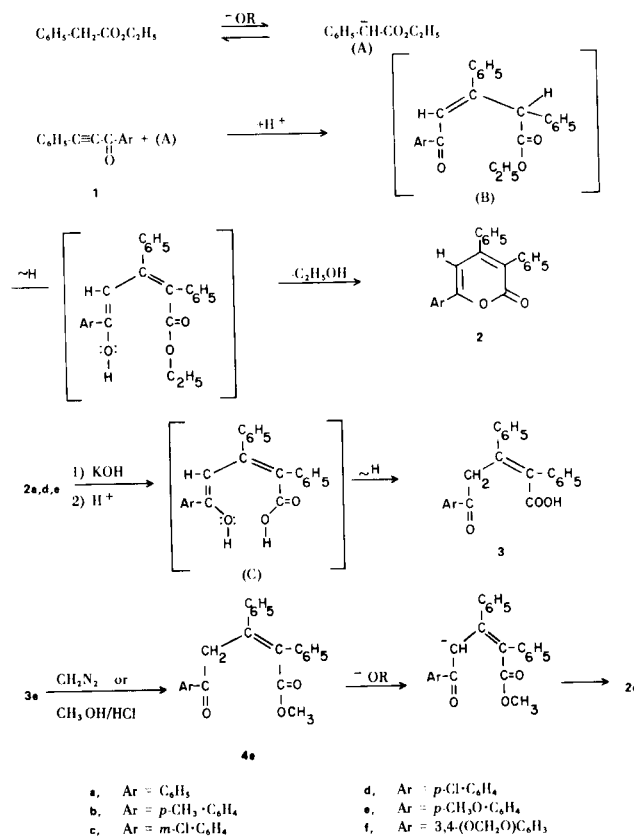
When benzoyl- **1a**, *p*-toluyl- **1b**, *m*-chlorobenzoyl- **1c**, *p*-chlorobenzoyl- **1d**, *p*-methoxybenzoyl- **1e** and 3,4-methylenedioxybenzoyl- **1f** phenylacetylenes were allowed to react with ethyl phenylacetate in the presence of a suspension of sodium ethoxide in ether, they gave rise to the corresponding 6-aryl-3,4-diphenyl-2*H*-pyran-2-ones, **2a-f**. The product **2d** was also obtained in 80% yield when sodium hydride (in benzene) was used instead of sodium ethoxide. In all cases the reaction seems to proceed by Michael addition of the carbanion (A) to the aroylphenylacetylene followed by cyclization of the intermediate (B). This mechanism is similar to that proposed for the reaction of malonic esters with acetylenic ketones (5-7).

The structure of the pyrones **2a-f** was established by both chemical and spectroscopic evidence.

### (1) Chemical Evidence.

When the pyrones **2a,d** and **e** were subjected to alkaline cleavage, 4-aryol-*cis*-2,3-diphenyl-but-2-enoic acids **3a,d** and **e** were produced. The structure assigned to the keto-acid **3a** was established by ozonolysis to give dibenzoylmethane. Adequate evidence for the structure of the keto-acids **3a,d** and **e** is forthcoming from their spectral data. Thus, their nmr spectra show chemical shifts which can be assigned to the different protons of these compounds (Table I). Their ir spectra (Table I) show stretching

bands which can be correlated to the  $\nu$  C=O of the aroyl (**8,9a**) and carboxyl (**8,9b,c**) groups. The electronic spectra of these acids show an absorption maximum between 273-244 nm (Table I) attributed to the K-band. This absorption can be ascribed to the acetophenone moiety and its corresponding *p*-substituted derivatives (**10-12**) rather than to stilbene (**13**) or cinnamic acid (**14**) moieties, since it is affected by the type of substituent in the aroyl group. The  $n-\pi^*$  and  $^1I_b$  bands which appear



in the spectra of acetophenone, do not appear in the spectra of these acids, being obscured by the strong  $\pi$ - $\pi^*$  transition band. However, the high absorption intensity of these acids may be due to the fact that this absorption is a composite of the absorption by the aryl methylene (Ar-CO-CH<sub>2</sub>-) and *cis*-stilbene chromophores. The deviation of the absorption intensity from additivity may be attributed to steric inhibition of resonance in the 2-phenylcinnamic acid residue by the bulky substituents attached to the ethylenic double bond.

Methylation of **3e** gave the corresponding ester **4e**, which upon treatment with sodium ethoxide in ether (room temperature), was converted to the corresponding pyrone **2e**. The structure of the above ester was established from its spectral data (Table I).

The *cis*-configuration of the acids **3a,d,e** and **4e** was inferred from the following facts:

(i) The formation of the acids from the pyrones by alkaline cleavage, and the conversion of the ester **4e** to the pyrone **2e** by sodium ethoxide.

(ii) The nmr spectra of the acids **3a,d** and **e** show two signals in the ranges  $\delta$  7.37-7.39 (s, 5, C<sub>6</sub>H<sub>5</sub>) and  $\delta$  7.23-7.34 (s, 5, C<sub>6</sub>H<sub>5</sub>) (Table I), indicating the *cis*-relationship of the two phenyl groups. The appearance of a singlet signal for the phenyl groups was considered by Buggle, *et al.*, (8) to be an evidence for the *cis*-(C<sub>6</sub>H<sub>5</sub>/C<sub>6</sub>H<sub>5</sub>)-configuration.

The structure of the pyrones **2a-f** was further supported by their reaction with hydrazine hydrate to give the

corresponding 1-amino-2-pyridone **5a-f**. Supporting evidence for the structure of compound **5a**, was obtained from its conversion to the pyridone **6a**, by the action of nitrous acid. The latter was found to be identical with the product obtained by the condensation of benzoylphenylacetylene and phenylacetamide. When the aminopyridone **5c** was treated with acetic anhydride, it gave the *N*-diacetyl derivative **7c**. The structure of the latter product was substantiated by its ir, uv and nmr spectra (Table II). Further information on the structure of compounds **5a-f** is forthcoming from their spectral data. Thus, their ir spectra (*cf.* Table II) show two sharp bands in the 3 $\mu$  region which are correlated to  $\nu$  NH<sub>2</sub> (9d,16,17) in addition to a sharp band in the 6 $\mu$  region that can be ascribed to the  $\nu$  C=O of the pyridone ring (16,17,18). The nmr spectra show a broad signal which stands for the two protons of the amino group (19), since when the solution of **5e** in deuteriochloroform was shaken with deuterium oxide, the broad band at  $\delta$  4.67 (2H) was replaced by a sharp band at  $\delta$  4.65 due to deuterium hydroxide. The electronic spectra of these compounds are very similar to those of 1-amino-4,5,6-trisubstituted-2-pyridones (16,18).

(2) Spectroscopic Evidence for the Structure of 2*H*-Pyran-2-ones (**2a-f**).

The infrared spectra of these compounds (Table III) were devoid of absorption characteristic of the acetylenic linkage (9e), whereas absorption in the 1724-1720 cm<sup>-1</sup>

Table I

## Spectrophotometric Data

Compound	Nmr (deuteriochloroform)		Ir (potassium bromide)		Uv (ethanol)	
	$\delta$	Assignment (a)	cm <sup>-1</sup>	$\nu$	$\lambda$ max (nm)	log $\epsilon$
<b>3a</b> (b)	7.49-7.90	(m, 5, COC <sub>6</sub> H <sub>5</sub> )	1690	C=O	244	4.24
	7.39	(s, 5, Ar-H)	1600	C=C		
	7.27	(s, 5, Ar-H)				
	4.08	(s, 2, CO-CH <sub>2</sub> -)				
<b>3d</b> (b)	6.9-8.0	(m, 4, <i>p</i> -Cl·C <sub>6</sub> H <sub>4</sub> )	1715	C=O (ArCO)	253	4.39
	7.37	(s, 5, Ar-H)	1690	C=O (CO <sub>2</sub> H)		
	7.34	(s, 5, Ar-H)	1594	C=C		
	3.9	(s, 2, CO-CH <sub>2</sub> -)				
<b>3e</b> (b)	6.9-7.8	(m, 4, <i>p</i> -CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub> )	1695	C=O (CO <sub>2</sub> H)	273	4.24
	7.38	(s, 5, Ar-H)	1683	C=O (ArCO) (c)		
	7.23	(s, 5, Ar-H)	1610	C=C		
	4.0	(s, 2, CO-CH <sub>2</sub> -)				
	3.34	(s, 3, OCH <sub>3</sub> )				
<b>4e</b>	6.73-7.8	(m, 14, ArH)	1729	C=O (COOCH <sub>3</sub> )	273	4.33
	4.07	(s, 2, CO-CH <sub>2</sub> -)	1675	C=O (ArCO)		
	3.83	(s, 3, OCH <sub>3</sub> )	1609	C=C		
	3.43	(s, 3, CO <sub>2</sub> CH <sub>3</sub> )				

(a) Abbreviations: s = singlet; m = multiplet. (b) COOH proton was not shown at lower field as in the nmr spectrum of *p*-methoxybenzoic acid (15). (c) Carbonyl stretching frequency for *p*-methoxyacetophenone (10) = 1681 cm<sup>-1</sup>.

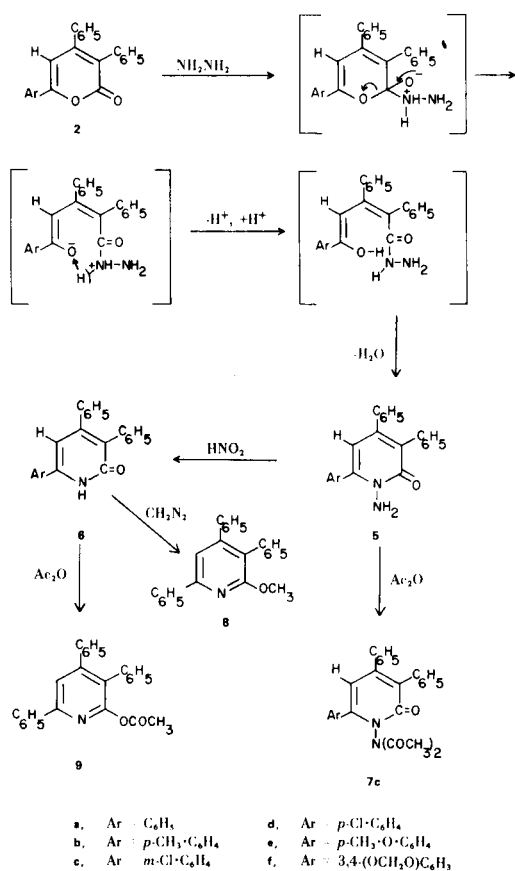
Table II

Compound	Spectrophotometric Data			Nmr (deuteriochloroform)		
	Uv (ethanol) $\lambda$ max (nm)	log $\epsilon$	Ir (potassium bromide) $\text{cm}^{-1}$ (a)	$\nu$	$\delta$ Assignment (b)	
<b>5a</b>	340	4.09	3300 (m)	NH <sub>2</sub>	7.1-7.63	(m, 15, Ar-H)
	288	3.81	3200 (b)		6.33	(s, 1, -C=CH)
	248-255 (sh)	4.23	1635 (s)	C=O	5.0	(b, 2, NH <sub>2</sub> )
	225-235 (sh)	4.38	1600 (s)	C=O		
			1590 (m)			
<b>5b</b>	341	4.09	3300 (m)	NH <sub>2</sub>	7.03-7.57	(m, 14, Ar-H)
	289	3.79	3210 (m)		6.25	(s, 1, -C=C-)
	250-258 (sh)	4.24	1635 (s)	C=O	5.01	(b, 2, NH <sub>2</sub> )
	234-239 (sh)	4.34	1612 (s)	C=C	2.4	(s, 3, Ar-CH <sub>3</sub> )
			1590 (m)			
<b>5c</b>	340	4.12	3300 (m)	NH <sub>2</sub>	7.0-7.77	(m, 14, Ar-H)
	288	3.85	3210 (m)		6.35	(s, 1, -C=CH-)
	256-259 (sh)	4.20	1638 (s)	C=O	4.70	(b, 2, NH <sub>2</sub> )
	235-240 (sh)	4.30	1600 (s)	C=C		
			1573 (m)			
<b>5d</b>	340	4.09	3328 (m)	NH <sub>2</sub>	7.13-7.6	(m, 14, Ar-H)
	290	3.80	3260 (m)		6.35	(s, 1, -C-CH-)
	255-266 (sh)	4.22	1637 (s)	C=O	4.92	(b, 2, NH <sub>2</sub> )
	235-240 (sh)	4.35	1605 (s)	C=C		
			1570 (s)			
<b>5e</b>	343	4.23	3295 (m)	NH <sub>2</sub>	6.92-7.67	(m, 14, Ar-H)
	250-255 (sh)	4.33	3200 (m)		6.63	(s, 1, -C=CH-)
	220-226 (sh)	4.51	1633 (s)	C=O	4.67	(b, 2, NH <sub>2</sub> )
			1606 (s)	C=C	3.85	(s, 3, OCH <sub>3</sub> )
			1588 (m)			
<b>5f</b>	342	4.19	3300 (m)	NH <sub>2</sub>	6.83-7.33	(m, 13, Ar-H)
	280-283 (sh)	3.96	3210 (m)		6.33	(s, 1, -C=CH-)
	220-229 (sh)	4.47	1635 (s)	C=O	6.07	(s, 2, O-CH <sub>2</sub> -O)
			1612 (s)	C=C	5.03	(b, 2, NH <sub>2</sub> )
			1589 (m)			
<b>6c</b>	333	4.21	1750 (s)	C=O of	7.33	(m, 14, Ar-H)
	294-298 (sh)	4.04	1728 (s)	acetate	6.43	(s, 1, -C=CH-)
	244	4.39	1656 (s)	C=O of	2.33	(s, 6, N-COCH <sub>3</sub> )
			1615 (m)	pyridone		
			1584 (m)		C=C	

(a) Abbreviation: s = strong; m = medium; b = broad. (b) Abbreviation: s = singlet; m = multiplet; b = broad.

region are attributable to the carbonyl stretching frequency of the 2-pyrone (2,18,20,21). The two bands which lie in the range 1632-1615  $\text{cm}^{-1}$  and at 1535  $\text{cm}^{-1}$  are due to the stretching frequency of C<sub>5</sub>-C<sub>6</sub> and C<sub>3</sub>-C<sub>4</sub> double bond, respectively. This is characteristic of the 2-pyrone structure (18,19). The assignment of the 1535  $\text{cm}^{-1}$  band to the C<sub>3</sub>-C<sub>4</sub> double bond is based on its non-sensitivity to substituents in the aryl group. The electronic spectra of the compounds **2** (Table III) give a further support for the proposed structure and show good resemblance to the spectra of substituted 2-pyrones (2,18,21). The nmr spectra of the pyrones **2a-f** and the assignment of the signals, are reported in Table III.

The structure of the authentic specimen **6a**, was established by both spectral and chemical tools. The spectral data of **6a** indicated that it exists as the 2-pyridone, whereas chemical reactions reflect its existence as 2-hydroxypyridine derivative. Thus, its ir spectrum (Table IV) shows a strong absorption band characteristic of the pyridone carbonyl stretching frequency (18,22,23). The spectrum also shows two bands in the 6-7  $\mu$  region which are attributed to carbon-carbon double bond in the pyridone ring (18,22), and a broad band in the 3  $\mu$  region which is ascribed to the intermolecularly hydrogen bonded NH group (18,22,23). The nmr spectrum (DMSO) shows signals at  $\delta$  6.53 (s, 1, olefinic) and  $\delta$  7.65 (m, 16,



aromatic and NH). Its electronic spectrum is very similar to that of the corresponding 2-pyridone **2a**, and the 2-pyridones previously reported (18). The fact that **6a** absorbs at a longer wavelength than the corresponding 2-methoxypyridine derivative **8** (cf. Table IV) can be considered as a support for its existence as a 2-pyridone derivative rather than as a 2-hydroxypyridine derivative (24).

Chemical reactions, however, point out to its existence as a 2-hydroxypyridine derivative. Thus, methylation of **6a** with diazomethane gave the 2-methoxypyridine derivative **8** (25), which does not show carbonyl absorption in its ir spectrum (Table IV). The structure of **8** was established by its nmr spectrum which shows signals at  $\delta$  4.07 (s, 3,  $\text{OCH}_3$ ) and  $\delta$  7.73 (m, 16, Ar-H and olefinic). Acetylation of **6a** with acetic anhydride gave the 2-acetoxy-pyridine **9**, which exhibits strong bands in its ir spectrum, characteristic of arylacetates (9f). The nmr spectrum of **9** shows signals at  $\delta$  2.03 (s, 3,  $\text{O-COCH}_3$ ) and  $\delta$  7.65 (m, 16, ArH and olefinic). The electronic spectra of compounds **8** and **9** give a further support for the postulated structures (24,26) (cf. Table IV).

b) Reaction with Benzyl Cyanide.

The reaction of benzoyl- **1a** and *p*-toluyl- **1b** phenylacetylenes with benzyl cyanide, in the presence of a suspension of powdered sodium ethoxide in dry ether, produced the corresponding 4-aryl-2,3-*cis*-diphenylcroto-

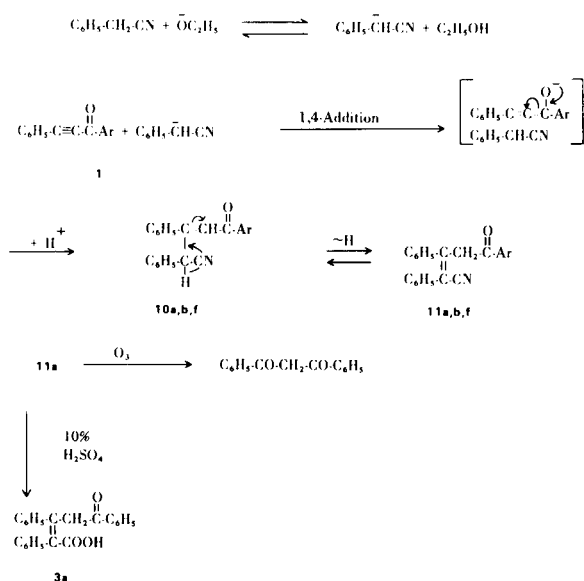
Table III

## Spectrophotometric Data

Compound	Uv (ethanol)		Ir (potassium bromide)		Nmr (deuteriochloroform)	
	$\lambda$ max (nm)	log $\epsilon$	$\text{cm}^{-1}$	$\nu$	$\delta$	Assignments
<b>2a</b>	356	4.21	1710 (s)	C=O	7.1-8.07	(m, 15, Ar-H)
	255	4.29	1628 (s)	C=C	6.83	(s, 1, =CH-)
	240-245 (sh)	4.16	1535 (s)	C=C		
<b>2b</b>	360	4.25	1712 (s)	C=O	7.1-7.93	(m, 14, Ar-H)
	260	4.34	1628 (s)	C=C	6.83	(s, 1, =CH-)
	243-246 (sh)	4.18	1535 (s)	C=C	2.43	(s, 3, Ar- $\text{CH}_3$ )
<b>2c</b>	354	4.12	1716 (s)	C=O	7.1-8.0	(m, 14, Ar-H)
	255	4.17	1629 (m)	C=C	6.83	(s, 1, =CH-)
	245-249 (sh)	4.15	1535 (s)	C=C		
<b>2d</b>	358	4.23	1715 (s)	C=O	7.13-8.0	(m, 14, Ar-H)
	260	4.39	1632 (s)	C=C	6.83	(s, 1, =CH-)
	235-240 (sh)	4.23	1535 (s)	C=C		
<b>2e</b>	372	4.35	1724 (s)	C=O	6.86-7.93	(m, 14, Ar-H)
	268	4.34	1625 (s)	C=C	6.7	(s, 1, =CH-)
	244	4.22	1535 (s)	C=C	3.83	(s, 3, $\text{OCH}_3$ )
<b>2f</b>	375	4.41	1710 (s)	C=O	6.73-7.6	(m, 13, Ar-H)
	265	4.29	1615 (s)	C=C	6.67	(s, 1, =CH-)
	236	4.38	1535 (s)	C=C	6.00	(s, 2, $\text{O-CH}_2\text{-O}$ )

Table IV

Compound	Spectrophotometric Data			
	Uv (ethanol) $\lambda$ max (nm)	$\log \epsilon$	Ir (potassium bromide) $\text{cm}^{-1}$	$\nu$
<b>6a</b>	345	4.28	3200-2500 (b)	NH (bonded)
	252	4.38	3400 (s) in chloroform	NH (free)
			1634 (s)	C=O
			1605 (m)	
			1587 (w)	C=C
<b>8</b>	313	4.32	1594 (s)	
	253	4.41	1577 (m)	C=C
<b>9</b>	295	4.06	1770 (s)	C=O
	253	4.37	1595 (m)	C=C
			1200 (s)	C-O (acetate)
<b>11a</b>			2220 (m)	$\text{C}\equiv\text{N}$
			1690 (s)	C=O
			1600 (m)	C=C
<b>11b</b>			2220 (m)	$\text{C}\equiv\text{N}$
			1680 (s)	C=O
			1600 (m)	C=C
<b>11f</b>			2220 (m)	$\text{C}\equiv\text{N}$
			1680 (s)	C=O
			1605 (m)	C=C



nitriles **11a,b** rather than the 3-cyano-2,3-diphenyl-1-propenyl aryl ketones **10a,b** as reported by Kohler and Barrett (4). Tlc, however, showed that the products contain traces of the isomers **10a** and **10b**, respectively. 3,4-Methylenedioxybenzoylphenylacetylene (**1f**) gave upon the same treatment a product which was proved by tlc to be a mixture of **10f** and **11f**, in which the former is predominant (see spectroscopic evidence). These reactions appear to proceed by Michael addition of the benzyl

cyanide carbanion to the triple bond of the acetylenic ketone (4) (1,4-addition).

Strong chemical and spectral evidence have been adduced in favour of the structure of the products **11a,b,f**. Thus, the ozonolysis of the product from benzoylphenylacetylene gave dibenzoylmethane, indicating that it is the crotonitrile derivative **11a**. Although, Kohler and Barrett (4) failed to hydrolyse the cyanide group of **11a**; it was possible to effect this hydrolysis with 10% sulphuric acid to give 4-benzoyl-2,3-cis-diphenyl-but-2-enoic acid (**3a**); a product which was also obtained by alkaline hydrolysis of the 2-pyrone **2a**. The *cis*-(C<sub>6</sub>H<sub>5</sub>/C<sub>6</sub>H<sub>5</sub>)-configuration of the nitriles **11a,b,f** is inferred from the hydrolysis of **11a** to the *cis*-acid **3a**.

The infrared spectra (Table IV) of compounds **11a,b,f** show absorption bands in the 4-5  $\mu$  and 6  $\mu$  region which are ascribed to the stretching frequency of the cyano (9g) and carbonyl groups (9a), respectively, (*cf.* Table I). The nmr spectra of **11a** and **b** (deuteriochloroform) show a singlet at  $\delta$  4.50 (2H) and  $\delta$  4.67 (2H), respectively. This is attributed to the  $=\text{C}-\text{CH}_2-\text{CO}$  protons (8). They also show a multiplet centered at  $\delta$  7.6 (15 ArH) and  $\delta$  7.63 (14 ArH), respectively; whereas that of **11b** shows an extra singlet at  $\delta$  2.47 (3H) correlated to the (CH<sub>3</sub>) protons of the *p*-tolyl group. The isomers **10a** and **10b** which were found by tlc to be present in traces did not show in the nmr spectra of these compounds. The product from 3,4-methylenedioxybenzoylphenylacetylene,

however, proved to be a mixture of two isomers **10f** and **11f** by its nmr spectrum (deuteriochloroform) which shows two singlets at  $\delta$  6.07 and  $\delta$  6.02, attributable to the methylenedioxy protons of **10f** and **11f**, respectively. The integration of the two signals indicated that isomer **10f** is present in a greater proportion than isomer **11f**. The spectrum also shows a singlet at  $\delta$  4.57 for the methine proton (-CH-) in **10f** and a singlet at  $\delta$  4.2 for the (-CH<sub>2</sub>-C=O) in **11f**.

#### EXPERIMENTAL

Microanalyses were performed by Dr. A. Bernhardt, Mikroanalytisches Laboratorium, B.R.D. The infrared spectra were measured on Unicam SP-1000 and the electronic spectra were taken on Unicam SP-8000 spectrophotometers, respectively. The nmr spectra were recorded for solutions in deuteriochloroform with TMS as external standard on Varian T60A spectrometer. Melting points are uncorrected.

Preparation of 1,3-Diaryl-2-propyn-1-ols.

1,3-Diaryl-2-propyn-1-ols were prepared from the corresponding aldehydes according to the method outlined by Parker, *et al.*, (27).

a) 3-Phenyl-1-*p*-tolyl-2-propyn-1-ol.

This compound had b.p. 196-198°/6 mm;  $n_{20} = 1.6073$ , yield = 89%.

*Anal.* Calcd. for C<sub>16</sub>H<sub>14</sub>O: C, 86.45; H, 6.35. Found: C, 86.11; H, 6.02.

b) 1-*m*-Chlorophenyl-3-phenyl-2-propyn-1-ol.

This compound had b.p. 190-192°/4 mm,  $n_{20} = 1.6195$ , yield = 80%.

*Anal.* Calcd. for C<sub>15</sub>H<sub>11</sub>ClO: C, 74.23; H, 4.57; Cl, 14.61. Found: C, 74.02; H, 4.32; Cl, 15.05.

c) 1-(3,4-Methylenedioxyphenyl)-3-phenyl-2-propyn-1-ol.

This compound had b.p. 214-217°/2 mm,  $n_{20} = 1.6238$ , yield = 75%.

*Anal.* Calcd. for C<sub>16</sub>H<sub>12</sub>O<sub>3</sub>: C, 76.18; H, 4.79. Found: C, 76.55; H, 4.91.

Preparation of Arylphenylacetylenes.

Arylphenylacetylenes **1a-f** were prepared by the oxidation of the corresponding 1-aryl-3-phenyl-2-propyn-1-ols according to the method outlined by Parker, *et al.*, (27).

a) *p*-Toluyphenylacetylene (**1b**).

This compound had m.p. 71-72° (Reported m.p. 72°) (28), yield = 86%.

b) *m*-Chlorobenzoylphenylacetylene (**1c**).

This compound had m.p. 90-91°, yield = 80%.

*Anal.* Calcd. for C<sub>15</sub>H<sub>9</sub>ClO: C, 74.85; H, 3.77; Cl, 14.73. Found: C, 74.69; H, 3.70; Cl, 14.53.

c) 3,4-Methylenedioxybenzoylphenylacetylene (**1f**).

This compound had m.p. 102-103°, yield 94%.

*Anal.* Calcd. for C<sub>16</sub>H<sub>10</sub>O<sub>3</sub>: C, 76.79; H, 4.03. Found: C, 76.73; H, 3.90.

Preparation of 6-Aryl-3,4-diphenyl-2H-pyran-2-ones **2** Method A. General procedure.

Ethyl phenylacetate (0.015 mole) and the arylphenylacetylene (**1**) (0.015 mole) were added successively to a suspension of sodium ethoxide (0.015 mole) in dry ether (50 ml. per 1.0 g. of ketone). The reaction mixture, which gradually acquired a deep orange color, was kept at room temperature for 2 days with occasional stirring, then poured into cold water and extracted with ether. The ethereal layer was dried (sodium sulfate), evaporated and the residue crystallized from a suitable solvent to give 6-aryl-3,4-diphenyl-2H-pyran-2-ones **2** as yellow crystals. The results are reported in Table V.

The alkaline aqueous layer was acidified with dilute sulfuric acid and extracted with ether. Evaporation of the ether gave phenylacetic acid, m.p. and mixed m.p. 76-77°.

Method B.

*p*-Chlorobenzoylphenylacetylene (**1d**) (0.015 mole) in benzene was added to the stirred solution of ethyl phenylacetate (0.015 mole) and sodium hydride (0.02 mole) in benzene, and the stirring continued for 10 hours. The reaction mixture was poured into water (200 ml.), and the benzene layer was separated, dried (sodium sulfate) and evaporated. The yellow solid was crystallized from ethyl alcohol to give 6-*p*-chlorophenyl-3,4-diphenyl-2H-pyran-2-one (**2d**) as yellow needles, m.p. and mixed m.p. 184-185°, yield = 80%.

The alkaline aqueous layer was worked up as in method A to give phenylacetic acid.

4-Aryl-2,3-diphenylbut-2-enoic Acids **3**. General procedure.

The pyrone **2** (0.5 g.) was refluxed on a boiling water-bath with 3% methanolic potassium hydroxide (30 ml.) for 30 minutes. The solution was diluted with water and extracted with ether to remove the neutral fraction. The aqueous alkaline solution was acidified and extracted with ether. Evaporation of the dried ether gave a yellow oil, which solidified upon trituration with light petroleum (b.p. 60-80°). Crystallization from light petroleum gave **3**. The results are reported in Table VI.

The structure and configuration of these acids were established by ozonolysis, and by esterification followed by cyclization.

a) Ozonolysis of 4-Benzoyl-2,3-diphenylbut-2-enoic Acid (**3a**).

The solution of the acid **3a** (0.5 g.) in chloroform (30 ml.) was subjected to ozonolysis (2 hours), and the ozonide was decomposed with zinc/dilute acetic acid mixture. The chloroform solution was washed with sodium hydrogen carbonate solution and distilled to give a colorless solid (0.25 g.), which proved to be dibenzoylmethane, m.p. and mixed m.p. 79-80°.

b) Esterification of 4-*p*-Methoxyphenyl-2,3-*cis*-diphenylbut-2-enoic Acid (**3e**).

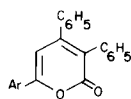
This was accomplished either by refluxing the acid **3e** (0.8 g.) with methyl alcohol (3 ml.) and few drops of concentrated sulfuric acid for one hour, or by the action of an ethereal solution of diazomethane. The product was crystallized from light petroleum (b.p. 60-80°) to give methyl 4-*p*-methoxyphenyl-2,3-*cis*-diphenylbut-2-enoate (**4e**) as colorless leaflets, m.p. 100-101°, yield = 93%.

*Anal.* Calcd. for C<sub>25</sub>H<sub>22</sub>O<sub>4</sub>: C, 77.70; H, 5.74; OCH<sub>3</sub>, 16.06. Found: C, 77.75; H, 5.80; OCH<sub>3</sub>, 15.81.

c) Conversion of Methyl 4-*p*-methoxyphenyl-2,3-*cis*-diphenylbut-2-enoate (**4e**) to the Corresponding Pyrone **2e**.

The solution of the ester **4e** (0.5 g.) in dry ether (35 ml.) was stirred with a suspension of sodium ethoxide (0.1 g.) for a period

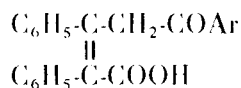
Table V

6-Aryl-3,4-diphenyl-2H-pyran-2-ones **2**

Compound	Ar	Yield %	M.p. °C	Formula	Calcd. %				Found %			
					C	H	Cl	OCH <sub>3</sub>	C	H	Cl	OCH <sub>3</sub>
<b>2a</b> (2)	C <sub>6</sub> H <sub>5</sub>	83	185-186 (a)	C <sub>23</sub> H <sub>16</sub> O <sub>2</sub>	85.16	4.97			85.57	5.37		
<b>2b</b> (29)	<i>p</i> -CH <sub>3</sub> -C <sub>6</sub> H <sub>4</sub>	89	187-188 (a)	C <sub>24</sub> H <sub>18</sub> O <sub>2</sub>	85.18	5.37			85.25	5.43		
<b>2c</b>	<i>m</i> -Cl-C <sub>6</sub> H <sub>4</sub>	85	171-172 (a)	C <sub>23</sub> H <sub>15</sub> ClO <sub>2</sub>	76.99	4.21	9.88		77.07	4.02	9.91	
<b>2d</b>	<i>p</i> -Cl-C <sub>6</sub> H <sub>4</sub>	86	184-185 (b)	C <sub>23</sub> H <sub>15</sub> ClO <sub>2</sub>	76.99	4.21	9.88		77.04	4.21	10.21	
<b>2e</b>	<i>p</i> -CH <sub>3</sub> O-C <sub>6</sub> H <sub>4</sub>	84	180-181 (a)	C <sub>24</sub> H <sub>18</sub> O <sub>3</sub>	81.34	5.12		8.76	81.79	4.97		8.27
<b>2f</b>	3,4-(OCH <sub>2</sub> O)-C <sub>6</sub> H <sub>3</sub>	85	199-200 (b)	C <sub>24</sub> H <sub>16</sub> O <sub>4</sub>	78.25	4.38			78.20	4.55		

(a) Crystallized from methyl alcohol. (b) Crystallized from ethyl alcohol.

Table VI

4-Aroyl-2,3-*cis*-diphenylbut-2-enoic Acids **3**

Compound	Ar	Yield %	M.p. °C	Formula	Calcd. %				Found %			
					C	H	Cl	OCH <sub>3</sub>	C	H	Cl	OCH <sub>3</sub>
<b>3a</b>	C <sub>6</sub> H <sub>5</sub>	63	180-181	C <sub>23</sub> H <sub>18</sub> O <sub>3</sub>	80.68	5.59			81.00	5.26		
<b>3d</b>	<i>p</i> -Cl-C <sub>6</sub> H <sub>4</sub>	78	144-145	C <sub>23</sub> H <sub>17</sub> ClO <sub>3</sub>	73.31	4.55	9.41		73.41	4.71	9.23	
<b>3e</b>	<i>p</i> -CH <sub>3</sub> O-C <sub>6</sub> H <sub>4</sub>	90	151-152	C <sub>24</sub> H <sub>20</sub> O <sub>4</sub>	77.40	5.41		8.33	77.61	5.51		7.92

of 12 hours at room temperature. The reaction mixture was poured into cold water and the ethereal layer was evaporated. The residue was crystallized from ethyl alcohol to give **2e** (0.3 g.). The alkaline aqueous layer was acidified with dilute sulfuric acid and extracted with ether. Evaporation of the ether gave 4-*p*-methoxyphenyl-2,3-*cis*-diphenylbut-2-enoic acid (**3e**) (0.1 g.), m.p. mixed m.p. 151-152°.

1-Amino-6-aryl-3,4-diphenyl-2-pyridones **5**. General procedure.

A solution of the pyrone **2** (2.0 g.) in ethyl alcohol (20 ml.) was refluxed with hydrazine hydrate (99% w/w, 3 ml.) on a boiling water-bath for a period of 5 hours. The reaction mixture was diluted with water, and the precipitated solid was crystallized from a suitable solvent to give the corresponding 1-aminopyridones **5** as colorless leaflets. The results are reported in Table VII.

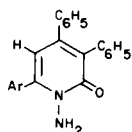
The structure of these compounds was established by a) acetylation and b) reaction with nitrous acid.

## a) Acetylation.

A mixture of acetic anhydride (3 ml.) and 1-amino-6-*m*-chlorophenyl-3,4-diphenyl-2-pyridone (**5c**) (1.0 g.) was heated on a boiling water-bath for one hour. The reaction mixture was treated with 50% ethyl alcohol (15 ml.) and the precipitated solid was crystallized from methyl alcohol to give 1,1-diacetyl-1-amino-6-*m*-chlorophenyl-3,4-diphenyl-2-pyridone (**7c**) as colorless needles, m.p. 171-172°, yield = 81%.

*Anal.* Calcd. for C<sub>27</sub>H<sub>21</sub>ClN<sub>2</sub>O<sub>3</sub>: C, 70.97; H, 4.63; N, 6.13; Cl, 7.76; COCH<sub>3</sub>, 13.34. Found: C, 70.69; H, 4.71; N, 6.44; Cl, 7.81; COCH<sub>3</sub>, 12.78.

Table VII

1-Amino-6-aryl-3,4-diphenyl-2-pyridones **5**

Compound	Ar	Yield %	M.p. °C	Formula	Calcd. %				Found %			
					C	H	N	Cl	C	H	N	Cl
<b>5a</b>	C <sub>6</sub> H <sub>5</sub>	67	131-132 (a)	C <sub>23</sub> H <sub>18</sub> N <sub>2</sub> O	81.63	5.37	8.28		81.18	5.39	8.08	
<b>5b</b>	<i>p</i> -CH <sub>3</sub> -C <sub>6</sub> H <sub>4</sub>	82	224-225 (b)	C <sub>24</sub> H <sub>20</sub> N <sub>2</sub> O	81.79	5.72	7.95		81.72	5.52	8.46	
<b>5c</b>	<i>m</i> -Cl-C <sub>6</sub> H <sub>4</sub>	87	138-139 (b)	C <sub>23</sub> H <sub>17</sub> ClN <sub>2</sub> O	74.09	4.60	7.51	9.51	73.77	4.77	7.34	9.35
<b>5d</b>	<i>p</i> -Cl-C <sub>6</sub> H <sub>4</sub>	77	188-189 (b)	C <sub>23</sub> H <sub>17</sub> ClN <sub>2</sub> O	74.09	4.60	7.51	9.51	74.08	4.51	7.67	9.35
<b>5e</b>	<i>p</i> -CH <sub>3</sub> O-C <sub>6</sub> H <sub>4</sub> (c)	82	209-210 (b)	C <sub>24</sub> H <sub>20</sub> N <sub>2</sub> O <sub>2</sub>	78.24	5.47	7.66		77.92	5.31	8.04	
<b>5f</b>	3,4-(OCH <sub>2</sub> O)-C <sub>6</sub> H <sub>3</sub>	67	224-225 (b)	C <sub>24</sub> H <sub>18</sub> N <sub>2</sub> O <sub>3</sub>	75.58	4.75	7.32		75.41	4.84	7.67	

(a) Crystallized from cyclohexane. (b) Crystallized from methyl alcohol. (c) OCH<sub>3</sub> %: Found: 8.86; Calcd.: 8.42.

## b) Action of Nitrous Acid.

A solution of sodium nitrite (1.5 g.) in water (12 ml.) was added dropwise to a solution of 1-amino-3,4,6-triphenyl-2-pyridone (**5a**) (0.7 g.) in glacial acetic acid (15 ml.). The mixture was heated to boiling, diluted and the precipitated solid was identified to be 3,4,6-triphenyl-2-pyridone, m.p. and mixed m.p. 305-306° (next experiment).

3,4,6-Triphenyl-2-pyridone (**6a**).

Phenylacetamide (1.96 g.) in dry benzene (50 ml.) was heated under reflux with powdered sodium (0.33 g.) for 20 hours. Benzoylphenylacetylene **1a** (3 g.) in benzene (15 ml.) was then added and the mixture was refluxed for 4 hours. The reaction product was poured into water (200 ml.) and the benzene layer was washed with water, dried (sodium sulfate) and evaporated to give 3,4,6-triphenyl-2-pyridone (**6a**) as colorless cubic crystals, m.p. 305-306° [Reported m.p. 300-301° (30)], yield = 62%.

*Anal.* Calcd. for C<sub>23</sub>H<sub>17</sub>NO: C, 85.41; H, 5.31; N, 4.34. Found: C, 85.81; H, 5.40; N, 4.18.

The aqueous alkaline layer was acidified and the precipitated acid extracted with ether. Evaporation of the ether gave benzoic acid, m.p. and mixed m.p. 121-122°, yield = 12.5%.

2-Methoxy-3,4,6-triphenylpyridine (**8**).

The pyridone **6a** (0.5 g.) in methyl alcohol (10 ml.) was treated with an ethereal solution of the diazomethane [from nitrosomethylurea (1.0 g.)]. The reaction product (0.45 g.) was crystallized from ethyl alcohol to give **8** as colorless crystals, m.p. 133-134°, yield = 86%.

*Anal.* Calcd. for C<sub>24</sub>H<sub>19</sub>NO: C, 85.43; H, 5.68; N, 4.15; OCH<sub>3</sub>, 9.20. Found: C, 84.94; H, 5.92; N, 4.25; OCH<sub>3</sub>, 9.17.

2-Acetoxy-3,4,6-triphenylpyridine (**9**).

The pyridone **6a** (0.5 g.) in acetic anhydride (2 ml.) was heated on a boiling water-bath for 20 minutes. The reaction

mixture was cooled and diluted with 50% ethyl alcohol (25 ml.). The solidified product (0.5 g.) was crystallized from methyl alcohol to give **9** as colorless needles, m.p. 142-143°, yield = 88%.

*Anal.* Calcd. for C<sub>25</sub>H<sub>19</sub>NO<sub>2</sub>: C, 82.16; H, 5.25; N, 3.84; COCH<sub>3</sub>, 11.79. Found: C, 82.01; H, 5.35; N, 4.09; COCH<sub>3</sub>, 11.71.

4-Aroyl-2,3-*cis*-diphenylcrotonitrile (**11**). General procedure.

Benzyl cyanide (0.015 mole) and the aroylphenylacetylene **1** (0.015 mole) were added successively to a suspension of sodium ethoxide (0.015 mole) in dry ether (50 ml. per 1.0 g. of ketone). The reaction mixture, which gradually acquired deep red color, was stirred at room temperature for 2 days. It was then poured into ice-cold water and extracted with ether. The ethereal layer was dried (sodium sulfate), evaporated and the residue was crystallized from a suitable solvent to give **11** as colorless needles (*cf.* Table VIII).

The alkaline aqueous layer was acidified with dilute sulfuric acid and extracted with ether. The ethereal solution was extracted with sodium hydrogen carbonate solution and evaporated to give a further amount of **11**. The sodium hydrogen carbonate washings gave on acidification phenylacetic acid, m.p. and mixed m.p. 76-77°.

The structure and configuration of these nitriles **11** were established by a) ozonolysis, and b) hydrolysis.

a) Ozonolysis of 4-Benzoyl-2,3-*cis*-diphenylcrotonitrile (**11a**).

The solution of the nitrile **11a** (0.5 g.) in chloroform (30 ml.) was subjected to ozonolysis (2 hours), and the ozonide was worked up to give dibenzoylmethane, m.p. and mixed m.p. 79-80°.

b) Hydrolysis of 4-Benzoyl-2,3-*cis*-diphenylcrotonitrile (**11a**).

A mixture of the nitrile **11a** (0.5 g.) and 10% sulfuric acid (15 ml.) was heated under reflux for 10 hours. The reaction mixture was then poured into water (30 ml.), and extracted with sodium hydrogen carbonate solution. Evaporation of the dried



Table VIII

4-Aroyl-2,3-diphenylcrotonitriles **11**

$$\begin{array}{c} \text{C}_6\text{H}_5\text{-C-CH}_2\text{-CO-Ar} \\ \parallel \\ \text{C}_6\text{H}_5\text{-C-CN} \end{array}$$

Compound	Ar	Yield %	M.p. °C	Formula	Calcd. %			Found %		
					C	H	N	C	H	N
<b>11a</b>	C <sub>6</sub> H <sub>5</sub>	53	138-139 (a)	C <sub>23</sub> H <sub>17</sub> NO	85.41	5.31	4.33	85.02	5.24	4.53
<b>11b</b>	<i>p</i> -CH <sub>3</sub> -C <sub>6</sub> H <sub>4</sub>	55	137-138 (a)	C <sub>24</sub> H <sub>19</sub> NO	85.41	5.67	4.17	85.29	5.70	4.37
<b>11f</b>	3,4-(OCH <sub>2</sub> O)-C <sub>6</sub> H <sub>3</sub>	56	144-145 (b)	C <sub>24</sub> H <sub>17</sub> NO <sub>3</sub>	78.46	4.67	3.82	78.07	4.88	3.86

(a) Crystallized from cyclohexane. (b) Crystallized from methyl alcohol.

ether left an oily product, which solidified on trituration with cyclohexane to give the unchanged nitrile **11a**, identified by m.p. and mixed m.p., yield = 0.3 g.

The sodium hydrogen carbonate extract was acidified and the precipitated acid extracted with ether. Evaporation of the solvent gave a solid (0.2 g.), which was crystallized from benzene light-petroleum (b.p. 60-80°) to give **3a**, m.p. and mixed m.p. 181-182°.

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