with, and an olefin of higher purity could be obtained, since on concentration the product in the ethereal extract spontaneously crystallized; yield 594 mg. (84%). One crystallization from ethanol gave 504 mg. of VI whose m.p. was 67–69° (lit.[7] 68–89°), assay, 2.370 mc. carbon-14 per mole.

2. **By the Method of Lane and Walters.**[5]—The carbinol (VI) could also be dehydrated by simple crystallization from glacial acetic acid.[5] One sample prepared in this way melted at 71–72°.

Rearrangement of 2-Bromo-1,1,2-triphenylethanol-1-C¹⁴ (VII).—The bromohydrin (VII), prepared from VI by the method of Lane and Walters, was converted to phenyl benzhydryl ketone-C¹⁴ (VIII) as reported by these same authors, by allowing 714 mg. of VII and 326 mg. of mercuric nitrate in 85 cc. of 70% aqueous dioxane to stand at room temperature for six days. The yield of once-crystallized ketone was 273 mg.; m.p. 136–137.5° (lit.[5] 137–139°).

Isomerization of IIIa with Phosphorus Pentoxide. Experiment No. 1.—The olefin (IIIa, 500 mg.) was allowed to react with approximately 0.5 g. of phosphorus pentoxide in boiling xylene for 30 minutes. The mixture was cooled and 100 cc. of water was added, followed by 100 cc. of hexane. The layers were separated, and the hexane layer was washed with water until the washings were neutral to litmus paper. The concentrated, dried olefin (IIIab) was not further purified, but was immediately subjected to a permanganate oxidation as indicated in Table I. **Experiment No. 2.**—The olefin (IIIa, 743 mg.) was heated under reflux for 30 minutes with 0.3–0.4 g. of phosphorus pentoxide in 17 cc. of xylene. The mixture was cooled, and treated as in experiment No. 1 above. From the concentrated hexane mixture there was isolated 362 mg. of IIIab; m.p. 67–69°. This was subjected to permanganate oxidation as indicated in Table I.

Permanganate Oxidations of Various 1,1,2-Triphenylethyl Derivatives.—In a typical oxidation experiment, 500 mg. of olefin (III) and 800 mg. of potassium permanganate were allowed to react at room temperature in 25 cc. of acetone and 10 cc. of water containing 1 cc. of glacial acetic acid. The reaction was complete within an hour. The excess of permanganate was decomposed with bisulfite, and the mixture was filtered. The concentrated filtrate was made alkaline and continuously extracted with ether. The concentrated ether extract was dissolved in 5 cc. of alcohol and to it was added a solution of 400 mg. of 2,4-dinitrophenylhydrazine in 2 cc. of H₂SO₄ and 1 cc. of water. The solution was warmed on the steam-bath. The 2,4-dinitrophenylhydrazone (217 mg., 31%) crystallized almost immediately. After one crystallization from dioxane it melted at 238–239°. The aqueous layer from the ether extraction was acidified and re-extracted with ether, yielding 108 mg. (45%) of benzoic acid. After one crystallization from water the benzoic acid had a m.p. of 121–122°.

The oxidations of the ketone (VIII) were parallel to the above described experiment with the exception that (a) appropriately more permanganate was employed and (b) the oxidations required four days for completion. The data for all of these oxidative degradations are summarized in Table I.[8]

TABLE I[8]

SUMMARY OF DATA FOR PERMANGANATE OXIDATIONS OF IIIa, IIIab AND VIII

| Compound oxidized | Radioactivity assay of fraction isolated, mc. per mole | |
	Benzophenone 2,4-DNPH	Benzoic acid
IIIa[a]	...	0.0322
IIIa[b]	2.432	0.0564
IIIab[c]	1.238, 1.238	1.203
IIIab[d]	...	0.645, 0.628
VIII[e]	0.026	2.392
VIII[f]	0.022	2.485[g]

[a] Prepared by the method of Adkins and Zartman (ref. 7). [b] Prepared by the method of Lane and Walters (ref. 5). [c] From the phosphorus pentoxide isomerization of IIIa, experiment No. 1. [d] From the phosphorus pentoxide isomerization of IIIa, experiment No. 2. [e] From rearrangement of the bromohydrin VII. [f] From direct synthesis (ref. 2). [g] This molar radioactivity is not consistent with the molar radioactivities of the other compounds described in this paper because of the different origin (ref. 2) of the sample of VIII oxidized.

(8) It is apparent from Table I that the benzoic acid fractions isolated upon permanganate oxidation of the olefin IIIa contain approximately 1–2% of the total molar radioactivity of the original olefin. Since this same order of radioactivity is also present in the benzophenone fractions obtained upon permanganate oxidation of compound VIII and its derivatives, we have concluded that an approximate 1% phenyl migration must occur during the oxidation reaction. The benzoic acid fraction isolated upon permanganate oxidation of phenyl benzhydryl ketone-C¹⁴ (VIII, last reaction in Table I) has a molar radioactivity lower by several per cent. than the base level of radioactivity (2.688 mc. per mole; see ref. 2). This has been shown (ref. 2) to be in all probability the consequence of dilution with non-radioactive benzoic acid arising by slight oxidation of the non-radioactive benzophenone fraction. This explanation seems inapplicable, however, to the low level of radioactivity found in the benzoic acid fraction arising on oxidation of IIIa, since these olefin oxidations appear essentially complete within less than an hour, hardly enough time (ref. 2) to allow appreciable oxidation of benzophenone to benzoic acid.

OAK RIDGE, TENN.

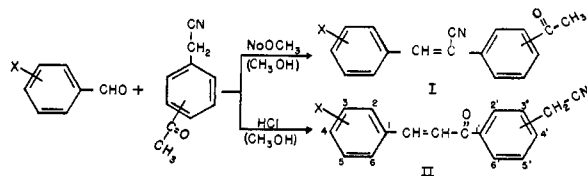# Condensations of Substituted Benzaldehydes with m- or p-Acetylphenylacetonitrile[1]

BY KURT RORIG

Sodium methoxide in methanol catalyzes the reaction of various benzaldehydes with m- or p-acetylphenylacetonitrile to give substituted α-acetylphenylcinnamonitriles (I). Methanolic hydrogen chloride, however, catalyzes the formation of substituted 4'-cyanomethylchalcones (II) from p-acetylphenylacetonitrile and substituted benzaldehydes.

In the presence of alkaline catalysts aromatic aldehydes react with phenylacetonitrile to give α-phenylcinnamonitriles, whereas they react with acetophenone to give chalcones. Thus it was of interest to determine which of these two types of compound, I or II (or both), would be formed from substituted benzaldehydes and m- or p-acetylphenylacetonitrile in alkaline media.

(1) Presented before the Division of Organic Chemistry at the 123rd Meeting of the American Chemical Society, Los Angeles, California, March, 1953.

The use of sodium methoxide catalyst in methanol yielded as the principal products the substituted α-acetylphenylcinnamonitriles (I). The

amount of isomeric chalcone (II) found in the crude alkali-catalyzed reaction product was very little as judged by infrared analysis and was readily removed on recrystallization.

The structure of one alkaline condensation product was proved by degradation to a known compound and by comparison of its ultraviolet spectrum with those of similar compounds. This product, α - (4' - acetylphenyl) - 4 - methoxycinnamonitrile yielded α-(4'-carboxyphenyl)-4-methoxycinnamonitrile upon treatment with sodium hypoiodite. Esterification with diazomethane then yielded the known α-(4'-carbomethoxyphenyl)-4-methoxycinnamonitrile.[2]

The ultraviolet absorption spectrum of α-(4'-acetylphenyl)-4-methoxycinnamonitrile shows two maxima: one at 240 mμ (ε 13,300), the other at 352 mμ (ε 28,100). The acid and methyl ester derived from this α-(4'-acetylphenyl)-4-methoxycinnamonitrile have very similar ultraviolet absorption spectra. Recently Codington and Mosettig[3] have shown that for a variety of substituted stilbenes, including α-phenylcinnamonitriles, the ultraviolet absorption spectra show two maxima between 200 and 400 mμ. Further, when the aromatic rings were *trans* to one another the extinction coefficient (ε) of the first maximum (that at the lower wave length) was less than the extinction coefficient of the second maximum. For the aromatic rings *cis* to one another the reverse relationship obtained; the first maximum had the larger extinction coefficient. Thus it is probable that our α-(4'-acetylphenyl)-4-methoxycinnamonitrile had its aromatic rings in the *trans* relation.

Each of the major products of the base-catalyzed reaction was assigned the *p*-acetylphenylcinnamonitrile structure on the basis of close similarity of its infrared absorption spectrum to that of α-(4'-acetylphenyl)-4-methoxycinnamonitrile and to the spectrum of the known α-phenyl-4-methoxycinnamonitrile.[4]

In marked contrast to the action of the methoxide catalyst, the use of methanolic hydrogen chloride caused the formation of substituted 4'-cyanomethylchalcones (II) from the substituted benzaldehydes and *p*-acetylphenylacetonitrile. These chalcone structures were assigned on the basis of elementary analyses, non-identity with the isomeric base-catalyzed product, and the striking similarity of their infrared spectra to those of undoubted chalcones such as the known 4-chlorochalcone[5] and the new 4'-cyano-4-methoxychalcone, prepared for comparison.

Three points on the infrared spectra served to differentiate the chalcones (II) from the cinnamonitriles (I). First, the absorption of the conjugated cyano group of the cinnamonitriles is at a longer wave length (at approximately 4.5 μ) and of greater intensity than the —C≡N absorption (at approximately 4.4 μ) of the unconjugated nitrile group

of the chalcones (II). Secondly, the doubly conjugated carbonyl group of the chalcones (II) absorbs at about 6.04 μ rather than in the 5.95 μ region characteristic of *p*-acetylphenylcinnamonitriles (I) whose carbonyl group is conjugated with only one aromatic ring. Thirdly, the benzene –C=C– absorption at 6.26μ is more intense in the chalcones (II) than in the cinnamonitriles (I).

The formation of chalcones (II) by acidic catalysts and cinnamonitriles (I) by basic catalysts accords with the expectations of modern theory.[6] Thus basic catalysts would be expected to facilitate attack at the carbon bearing the most acidic hydrogen, that is, the methylene carbon flanked by two activating groups. The protonic catalyst, however, would be expected to induce condensation at the carbon having the most readily enolizable hydrogen, that is, the methyl carbon adjacent to a carbonyl group.

It is of interest that the rate of the base-catalyzed condensation was little affected by the nature of the substituent in the benzaldehyde whereas the rate of the acid-catalyzed chalcone formation was markedly inhibited by electron-withdrawing groups on the benzaldehyde. *o*-Bromobenzaldehyde and *p*-cyanobenzaldehyde may be cited as examples of complete reaction inhibition. They gave no chalcones with *p*-acetylphenylacetonitrile even when double the normal reaction time was used. This inhibitory effect of electron-withdrawing substituents has been noted in a related acid-catalyzed condensation.[7]

Experimental[8]

m- and *p*-Acetylphenylacetonitriles.—A mixture of these two isomers was obtained in 62% yield from 320 g. of phenylacetonitrile, 500 g. of acetyl chloride and 840 g. of AlCl₃ in 1.0 l. carbon disulfide by refluxing and stirring for 22 hours.[9] The mixed isomers (267 g.), b.p. 120–145° at 0.5 mm., were refrigerated overnight and filtered on a chilled, sintered glass funnel to obtain 110 g. of the crystalline *p*-acetylphenylacetonitrile. This was recrystallized from benzene–petroleum ether to give 85 g. of massive colorless crystals, m.p. 84.5–86.0°; λmax 4.41 μ (CN), 5.94 μ (CO). The oily filtrate was redistilled to yield 117 g. of yellow oil, b.p. 118–123° at 0.2 mm., rich in the *m*-acetylphenylacetonitrile.

α-(4'-Acetylphenyl)-4-methoxycinnamonitrile.—To a warm (50°) solution of 1.59 g. of *p*-acetylphenylacetonitrile and 1.36 g. of anisaldehyde in 20 ml. of methanol was added 0.2 g. of solid sodium methoxide. Within thirty seconds abundant canary yellow crystals appeared. After 0.75 hour standing at room temperature the product was removed by filtration and dried to give 2.20 g. of α-(4'-acetylphenyl)-4-methoxycinnamonitrile, m.p. 146–149°. Two crystallizations from dioxane and one from ethanol raised the melting point to 150.5–152.0°; ultraviolet λmax 240 mμ (ε 13,300), 352 mμ (ε 28,100); infrared λmax 4.48 μ (CN), 5.95 μ (CO).

The other substituted α-acetylphenylcinnamonitriles described in Table I were prepared in analogous fashion.

4'-Cyanomethyl-4-methoxychalcone.—To a solution of 4.77 g. of *p*-acetylphenylacetonitrile and 4.08 g. of anisaldehyde in 56 ml. of absolute methanol was added 4.0 ml. of isopropanolic hydrogen chloride (containing 0.22 g. of HCl per

(2) P. Pfeiffer, H. Behr, H. Kubler and H. Ruping, *J. prakt. Chem.*, **121**, 93 (1929). This work suggests, though it does not conclusively prove, that α-(4'-carbomethoxyphenyl)-4-methoxycinnamonitrile has its aromatic rings in the *trans* relation.

(3) J. Codington and E. Mosettig, *J. Org. Chem.*, **17**, 1027, 1035 (1952).

(4) K. Brand and O. Loehr, *J. prakt. Chem.*, **109**, 364 (1925).

(5) R. Walther and W. Raetze, *ibid.*, **65**, 280 (1902).

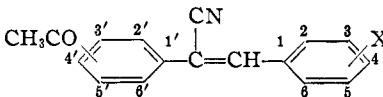(6) G. W. Wheland, "Advanced Organic Chemistry," 2nd ed., John Wiley and Sons, Inc., New York, N. Y., 1949, p. 255.

(7) S. M. McElvain and R. E. McMahon, THIS JOURNAL, **71**, 902 (1949).

(8) The melting points and boiling points are uncorrected. The ultraviolet absorption spectra were determined in methanol on a Beckman model DU spectrophotometer. The infrared absorption spectra were determined in 2% solutions of the compound in chloroform or carbon disulfide on a Beckman model IR-2T recording spectrophotometer.

(9) F. Kunckell, *Ber.*, **39**, 3145 (1906).

TABLE I

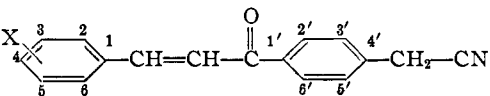SUBSTITUTED α-ACETYLPHENYLCINNAMONITRILES (I)

Substituents CH₃-CO	X	Formula	Yield,[a] %	M.p. (uncor.), °C.	Color	Carbon Calcd.	Carbon Found	Hydrogen Calcd.	Hydrogen Found	Nitrogen Calcd.	Nitrogen Found	Halogen Calcd.	Halogen Found
4′	4-H	C₁₇H₁₃NO	95	134–139[b]	White	82.57	82.62	5.30	5.25	5.67	5.53		
4′	4-CH₃O–	C₁₈H₁₅NO₂	79	150.5–152[b]	Yellow	77.95	78.19	5.45	5.55				
3′	4-CH₃O–	C₁₈H₁₅NO₂	c	102.5–103.5[b]	Yellow	77.95	77.98	5.45	5.49	5.05	5.06		
4′	3-CH₃O–	C₁₈H₁₅NO₂	38	124–126[b]	Ivory	77.95	77.56	5.45	5.39	5.05	5.02		
4′	4-(CH₃)₂N–	C₁₉H₁₈N₂O	79	200–201[d]	Golden	78.59	78.60	6.25	6.46	9.65	9.40		
4′	2-Br–	C₁₇H₁₂BrNO	74	146–147[b]	White	62.59	62.44	3.71	3.77			24.50	24.62
4′	4-CN–	C₁₈H₁₂N₂O	68	238–239[d]	Ivory	79.39	79.27	4.44	4.36	10.29	10.34		
4′	4-Cl–	C₁₇H₁₂ClNO	96	145–146.5[b]	Ivory	72.47	72.73	4.29	4.27				

[a] Yield of unrecrystallized product.   [b] Recrystallized from abs. ethanol.   [c] A meaningful yield cannot be computed since the starting *m*-acetylphenylacetonitrile contained an undetermined amount of the para isomer.   [d] Recrystallized from dioxane.

TABLE II

SUBSTITUTED 4′-CYANOMETHYLCHALCONES (II)

X	Formula	Reacn. time,[a] days	Yield,[b] %	M.p.,[c,d] °C.	Color	Carbon Calcd.	Carbon Found	Hydrogen Calcd.	Hydrogen Found	Nitrogen Calcd.	Nitrogen Found
4-CH₃O–	C₁₈H₁₅NO₂	14	58	122.5–123.5	Yellow	77.95	77.85	5.45	5.47	5.05	5.08
3-CH₃O–	C₁₈H₁₅NO₂	14	30	107–108.5	Ivory	77.95	78.00	5.45	5.38		
-H–	C₁₇H₁₃NO	12	25	107–108	Yellow	82.57	82.73	5.30	5.16		
4-Cl–	C₁₇H₁₂ClNO	14	11	169–171	Ivory	72.47	72.69	4.29	4.15	4.97	5.01

[a] All reactions run at room temperature (≅ 25°).   [b] Yield of unrecrystallized product.   [c] All melting points are uncorrected.   [d] All products were recrystallized from absolute ethanol.

ml.). After standing for 3 days at room temperature, a first crop weighing 3.80 g., m.p. 119–121.5°, was obtained. After 14 days the mother liquor yielded a second crop weighing 1.05 g., m.p. 117–120°. The first crop was twice crystallized from absolute ethanol to give 3.12 g. of pale yellow needles 4′-cyanomethyl-4-methoxychalcone, m.p. 122.5–123.5°, λₘₐₓ 4.41 μ(CN), 6.04 μ(CO).

The other 4′-cyanomethylchalcones described in Table II were made in the manner described above.

4′-Cyano-4-methoxychalcone.—This was made for spectral comparison by adding 0.4 g. of sodium methoxide powder to a warm solution of 2.72 g. anisaldehyde and 2.90 g. of *p*-cyanoacetophenone[10] in 20 ml. absolute methanol. After one hour's standing at room temperature, 3.0 g. of product melting 140.5–142° was obtained. This was crystallized twice from ethanol to give thin yellow plates of 4′-cyano-4-methoxychalcone, m.p. 146–147.5°; λₘₐₓ 4.47 μ(CN), 6.03 μ(CO).

Anal. Calcd. for C₁₇H₁₃NO₂: C, 77.55; H, 4.98; N, 5.32. Found: C, 76.99; H, 4.88; N, 5.25.

α-Phenyl-4-methoxycinnamonitrile,[4] m.p. 94–95°, had λₘₐₓ 4.48 μ(CN).

α-(4′-Carboxyphenyl)-4-methoxycinnamonitrile.—One gram of α-(4′-acetylphenyl)-4-methoxycinnamonitrile was dissolved in 50 ml. of dioxane and heated to 50°. To this

was added 10 ml. of a 10% aq. NaOH solution and a solution of 2.5 g. of KI and 1.2 g. of iodine in 10 ml. of water. The mixture was then heated to 60–65° for 1.24 hours and diluted with 250 ml. of water. There was obtained by filtration 0.52 g. of neutral material, m.p. 136–143°, which was predominantly starting material. The basic filtrate was acidified to give 0.40 g. of powder, m.p. 267–272°. This was recrystallized from glacial acetic acid to give 0.20 g. of yellow, powdery α-(4′-**carboxyphenyl**)-4-methoxycinnamonitrile, m.p. 288–290° with dec.; λₘₐₓ 240 mμ (ε 14,200), 344 mμ (ε 30,500).

Anal. Calcd. for C₁₇H₁₃NO₃: C, 73.11; H, 4.69; N, 5.02. Found: C, 72.78; H, 4.65; N, 5.00.

The methyl ester of this acid was made with diazomethane. The yellow, crystalline α-(4′-carbomethoxyphenyl)-4-methoxycinnamonitrile[2] melted at 155.5–157° after two crystallizations from methanol, λₘₐₓ 241 mμ (ε 12,950), 345 mμ (ε 24,700). This melting point agrees with the literature value of 158°.[2]

(10) F. Ahrens, *Ber.*, **20**, 2955 (1887).