Table II. Unsaturated Nitriles

Nitrile[a]	Registry no.	% yield	NMR, ppm CH$_3$	NMR, ppm Vinylic H(s)
1b	63089-63-4	97	1.85 (s) 0.85 (s)	
2b	63089-64-5	98	1.45 (s) 0.88 (s)	5.8–6.0
2c	63089-65-6	98	1.26 (d, J = 6 Hz) 0.88 (s)	5.6–5.9
6	63089-66-7	82	1.90 (s)	5.26 (s) 5.00 (m)
8a		98	1.49 (s) 1.62 (s) 1.70 (s)	4.9 5.23 5.05–5.35

[a] Satisfactory analytical data (C, H, N) for all compounds were submitted for review.

Table III. Olefins

Olefin(s)[c]	Registry no.	% yield	NMR CH$_3$	NMR Vinylic H
4c	15822-49-8	92	0.88 (s) 0.90 (t, J = 8 Hz)	5.3–5.6
3a	5749-72-4	91	1.68 (s)	
4b[a]	63089-67-8	93	0.90 (s) 1.0 (d, J = 14 Hz)	5.3–5.5
9a	63089-68-9	94	1.62 (s)	5.0–5.3
9b	63089-69-0	78[b]	1.65 (s)	4.9–5.3
9c	63089-70-3	88[b]	1.61 (s)	4.9–5.3

[a] Obtained from acid treatment of **3b**, **4b** mixture. [b] Overall yield from conjugated nitrile **7**. [c] Satisfactory analytical data for all compounds except **4c** and **3a** were submitted for review.

stirred suspension of 0.83 g (20 mmol) of sodium hydride in 15 mL of 1,2-dimethoxyethane (DME) was added 3.5 mL (20 mmol) of 2-(diethylphosphono)propanenitrile in 5 mL of DME.[10] The mixture was stirred at reflux until cessation of hydrogen evolution, whereupon 1.25 g (9.9 mmol) of 4-*tert*-butylcyclohexanone in 10 mL of DME was added and reflux was continued for 20 h. The cooled mixture was poured into water and the product was isolated by ether extraction and chromatographed on alumina to give 1.58 g (97%) of nitrile **1b**, mp 66–67 °C (Table II).

General Alkylation Procedure. To a solution of lithium diisopropylamide (prepared from 1.25 mL of diisopropylamine in 150 mL of tetrahydrofuran, 3.6 mL of 2.2 M *n*-butyllithium, and 1.8 mL of hexamethylphosphoramide) at −78 °C was added 3.4 mmol of conjugated nitrile in 20 mL of tetrahydrofuran.[1,11] After 15 min, 8 mmol of methyl iodide or 4 mmol of α,ω-dibromide was added and the stirred mixture was allowed to reach room temperature over a 2-h period. Water was added and the alkylated unsaturated nitriles (**2b**, **6**, and **8a**) were isolated by ether extraction and purified by short-path distillation. These results are shown in Table II. Nitriles **8b** and **8c** were reduced directly without purification.

2-(4-*tert*-Butyl-1-cyclohexenyl)propanenitrile (2c). To a solution of lithium diisopropylamide (prepared from 0.8 mL of diisopropylamine in 10 mL of tetrahydrofuran, 2.3 mL of 2.2 M *n*-butyllithium, and 1.0 mL of hexamethylphosphoric triamide) at −78 °C was added 0.64 g of nitrile **1c**. After 15 min, 0.6 mL of glacial acetic acid was added.[11] The solution was allowed to reach room temperature, water was added, and the product was isolated by ether extraction to give 0.63 g (98%) of deconjugated nitrile **2c**, bp 70°C at 0.05 Torr (Table II).

General Reduction Procedures. To a stirred solution of 10 mg-atoms of sodium in 25 mL of refluxing ammonia contained in a three-neck flask equipped with a cold finger condenser charged with dry ice–acetone slurry was added a solution of 1 mmol of nitrile in 2–3 mL of tetrahydrofuran. After sitrring for 1 h, the mixture was treated with solid ammonium chloride to discharge the blue color. The ammonia was allowed to evaporate, 25 mL of water was added, and the olefin products (**4c**, **3a**, **9a**, **9b**, and **9c**) were isolated by hexane extraction and purified by short-path distillation. The results are shown in Table III.

Equilibration of Olefins 3b and 4b.[12] A solution of 0.18 g of a 55:45 mixture of olefins **3b** and **4b** in 10 mL of 5% sulfuric acid in acetic acid was stirred at room temperature for 1 h. The acid was neutralized with 10% sodium hydroxide and the product was isolated by hexane extraction, affording 0.17 g (93%) of a 95:5 mixture of **4b** and **3b**, bp 70 °C (bath temperature) at 15 mm.

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Registry No.—**3b**, 14033-75-1; **8a** isomer I, 63089-71-4; **8a** isomer II, 63089-72-5; **8b** isomer I, 63122-45-2; **8b** isomer II, 63089-73-6; **8c** isomer I, 63089-74-7; **8c** isomer II, 63089-75-8; 2-(diethylphosphono)propanenitrile, 29668-61-9; 4-*tert*-butylcyclohexanone, 98-53-3.

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(9) The apparatus described by W. S. Johnson and W. P. Schneider ["Organic Syntheses", Collect. Vol. IV, Wiley, New York, N.Y., 1963, p 132] was used to maintain an argon atmosphere. The isolation procedure consisted of thorough extractions with the specified solvent, washing the combined extracts with water, saturated brine solution, and drying the extracts over anhydrous sodium sulfate. The solvent was removed from the filtered extracts under reduced pressure on a rotary evaporator. Microanalyses were performed by Micro-Tech Laboratories, Inc., Skokie, Ill. Nuclear magnetic resonance spectra were recorded with Varian T-60 or Perkin Elmer R20B spectrometers. Signals are reported as the chemical shift downfield from tetramethylsilane (Me$_4$Si) in parts per million (ppm) of the applied field. Coupling constants are reported in hertz (Hz).

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Coordinative Role of Alkali Cations in Organic Synthesis. 2. The Chalcone–Flavanone System

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Coordination of alkali cations (M) with neutral organic nucleophiles is now well known,[1–3] and the effect of such interactions on the methylation of kojic acid with dimethyl sulfate has been reported.[4] Significantly, the mechanism of organic reactions involving caustic alkalies and alkali salts is always discussed by considering only the anionic part of the inorganic species.[5] It is demonstrated in this paper that a full mechanism of such reactions cannot be written until the interactive behavior of the cationic counterpart is also discussed, for there is no reason why a cation should be inert when negatively charged or polarized species are involved in the reaction. To illustrate this point, we describe the condensation of 2-hydroxyacetophenone (HAP) with benzaldehyde (BLD) to produce chalcone and cyclization of the latter to produce flavanone as a function of the nature and concentration of the caustic alkalies. In the following, notations such as E, E$_4$, and

Table I. Yield of Chalcone with Different Alkalies under Different Conditions

Medium of synthesis	Reaction mixture (MOH:BLD:HAP)	% yield KOH	% yield NaOH	% yield LiOH
E	3:1:1	5	10	16
E_4	3:1:1	40	52	91
	5:1:1	66	85	93[a]
	9:1:1	85	90	92[a]
E_{25}	3:1:1	35	48	70
E_{50}	3:1:1	15	20	30
E_{75}	3:1:1	SR[b]	SR	SR

[a] Undissolved portion of the alkali decanted before acidification of the reaction mixture. [b] SR, slight reaction.

E_{25} used for the reaction media denote ethanol, ethanol–water (96:4) and ethanol–water (75:25), respectively.

Experimental Section

Synthesis of Chalcone. HAP (2.5 mL) and BLD (2.55 mL) were added to 30 mL of the reaction medium (Table I) in a conical flask. Weighed solid caustic alkali was added. The reaction mixture was shaken constantly until alkali dissolved (20–30 min) and the orange-red solution produced crystals of metal chalconate. When LiOH in E or E_4 was used, slight warming of the reaction mixture was necessary to produce the orange-red solution; Li^+-chalconate does not crystallize. The reaction mixture was set aside for 4 h and neutralized with 1 N HCl. The crude chalcone was collected, washed three times with 10–20-mL lots of water, dried at room temperature, and weighed. The yield of the crude chalcone (mp 85–7 °C) obtained under different conditions is shown in Table I. The crude product was recrystallized from E_4 (mp 90 °C) before further work.

Synthesis of Chalcone in the Absence of M. KOH (2 mmol, 0.11 g) in 2 mL of E_4 was treated with dicyclohexyl-18-crown-6 (4 mmol, 1.48 g) to obtain the naked hydroxide.[6] HAP (0.7 mmol, 0.092 g) in 1 mL of E_4 was then added and the reaction mixture was swirled for 5–10 min. BLD (0.7 mmol, 0.72 g) dissolved in 1 mL of E_4 was added and the reaction mixture was set aside for 4 h. On acidification with 1 N HCl, the solution produced only the reactants, although in the absence of the crown ether such a reaction mixture produced the chalcone in about 40% yield (Table I).

Cyclization of Chalcone. Cyclization experiments were carried out by two methods.

(a) **Weight Technique.** Chalcone (0.224 g) was added to 10 mL of alkali solution in E_{75} and set aside at room temperature (20–22 °C) for the desired time period as indicated in Table II. The colorless flavanone was collected, dried, and weighed. Although ethanol present in the medium solubilizes a fraction of the product, nonetheless it had to be used to prevent cocrystallization of chalcone from the hydrolysis of M^+-chalconate in the equilibrium:

$$\text{chalcone} \rightleftharpoons M^+\text{-chalconate} \rightleftharpoons \text{flavanone}$$

The relative results with different alkalies are shown in Table II.

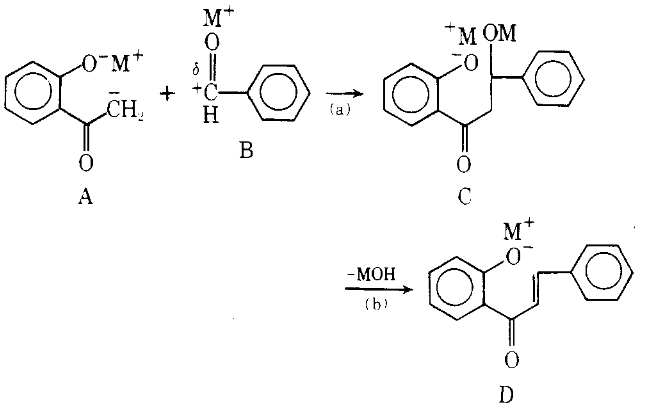
(b) **pH-Metric Technique.** Four 10-mL lots of E_{50} were adjusted at pH 11 using LiOH, NaOH, KOH, and Bu_4NOH. The yellow ethanolic solution of the chalcone (0.1 mL of 1%) was added to each. The time required for the decolorization of the color was taken as an indication of the efficiency of the different cations toward cyclization of the chalcone at a given OH ion concentration.

Results and Discussion

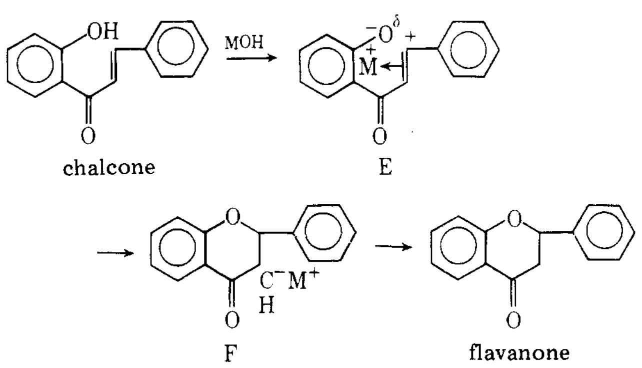
Synthesis of Chalcone. The results shown in Table I show that the yield of the chalcone is the highest in E_4, with the yield enhanced in the order of KOH, NaOH, and LiOH and as the concentration of alkali was increased. This indicates that synthesis is favored as charge density and concentration of M increase, which in turn means that M coordinates with the carbonyl of BLD as shown for B in the Scheme I; the degree of the carbonium character in B and hence of its condensation with A is expected to be in accordance with the strength of the BLD→M^+ bond and hence the charge density of M. Coordination of M with aromatic aldehydes in known[7-9] and for Li with BLD is confirmed by the fact that solubility of LiOH in E_4 (under N_2) is significantly enhanced with BLD.

Scheme I

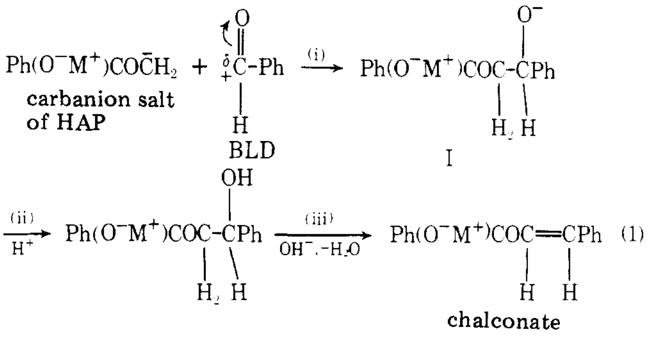
Synthesis of chalcone



Cyclization of chalcone



The basic role of M during synthesis is confirmed by the observation that condensation fails to take place when the K of the alkali is concealed from the reaction mixture using the crown ether. When the reaction medium is dehydrated, condensation does not take place. Some water in the medium is therefore necessary, for ionic reactions are involved. Also, the yield of chalcone decreases as water in the medium exceeds 4% (Table I), indicating that water weakens the BLD→M^+ bond, diminishes the carbonium character of B, and hinders its condensation with A.



$$\underset{\text{carbanion salt of HAP}}{\mathrm{Ph(O^-M^+)CO\bar{C}H_2}} + \underset{\text{BLD}}{\underset{\displaystyle \mathrm{H}}{\overset{\displaystyle \mathrm{O}}{\overset{\delta}{\underset{+}{\mathrm{C}}}}}\mathrm{{-}Ph}} \xrightarrow{(i)} \underset{\text{I}}{\mathrm{Ph(O^-M^+)CO\underset{H_2}{C}{-}\underset{H}{\overset{O^-}{C}}Ph}}$$

$$\xrightarrow[H^+]{(ii)} \mathrm{Ph(O^-M^+)CO\underset{H_2}{C}{-}\underset{H}{\overset{OH}{C}}Ph} \xrightarrow[OH^-,\,-H_2O]{(iii)} \underset{\text{chalconate}}{\mathrm{Ph(O^-M^+)CO\underset{H}{C}{=}\underset{H}{C}Ph}} \quad (1)$$

Mechanism of Condensation. The condensation mechanism is usually[10] written as shown in eq 1. With an increase in concentration of alkali, protonation of I and hence yield of the chalconate should decrease. However, we note that the yield of the latter (e.g., in E_4, Table I) increases with the amount of alkali used. This indicates that the route of synthesis is not via steps i to iii but via a and b shown in Scheme I. The latter mechanism explains how excess alkali favors the yield of the chalconate by enhancing the carbonium character of B, by favoring "acid-catalyzed" elimination of MOH from C, and by stabilizing the product of the latter, D, against cyclization through strengthening the M^+-phenoxide ion pair; the term "acid catalyzed" has been used for elimination of

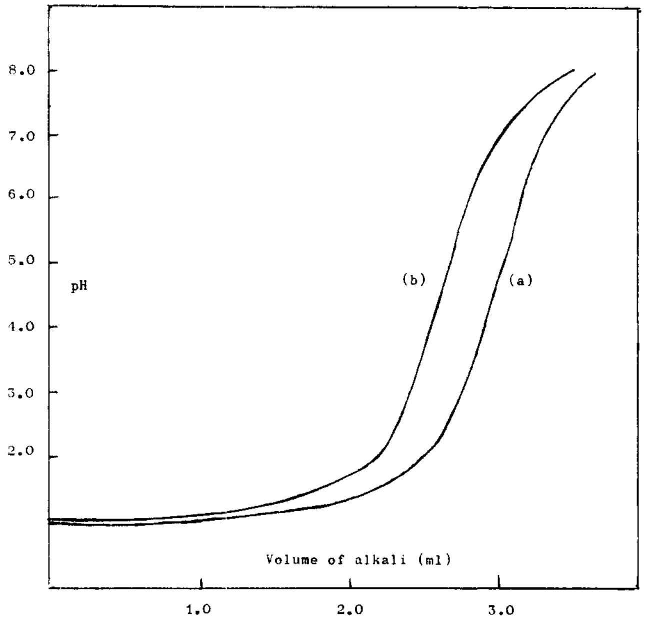


Figure 1. pH metric curves of $HClO_4$–Bu_4NOH systems in alcoholic medium when ionic strength (0.06 M) was maintained with $Bu_4N^+I^-$: (a) in the absence of chalcone, and (b) in the presence of chalcone (0.005 M).

Table II. Efficiency of Different Alkalies toward Cyclization of Chalcone (Medium of Work, E_{75}; Alkali:Chalcone, 1:1)

Molar concn of each reactant, M	Time of contact, h	% cyclization KOH	NaOH	LiOH
0.1	2	72[a]	68[a]	Nil[b]
	5	82	80	Nil
	20	86	86	Nil
0.03	2	75	71	Li^+–$Chal^-$ + flavanone[c]
	5	87	88	92[d]
	20	90	90	Flavanone + Li^+–$Chal^-$
0.01	2	78	76	Flavanone Li^+–$Chal^-$
	5	88	88	94
	20	92	93	94[d,e]

[a] In the earlier stages of the reaction NaOH and KOH are even less efficient; for a contact period of 30 min, % cyclization with KOH (70) and NaOH (61) is as shown in parentheses. [b] Li^+–chalconate only was recovered. [c] Products are shown in the order of relative yield. [d] A few crystals of Li^+–chalconate were present. [e] Contamination by Li^+–chalconate shows that decyclization of the product also starts taking place due to an extended period of contact of the latter with LiOH.

MOH because the proton eliminated as MOH is polarized indirectly by M^+ which is a Lewis acid.

Cyclization of Chalcone. Very dilute (4×10^{-4} M) solutions of chalcone at pH 11 are cyclized by LiOH, NaOH, KOH, and Bu_4NOH in 54, 38, 23, and 18 min, respectively. This indicates that the anion of M^+–chalconate cyclizes rapidly as the charge density of M decreases and the strength of the M^+–phenoxide ion pair loosens. The results in Table II also indicate that at high concentration (0.1 M) cyclization is favored in the order LiOH, NaOH, and KOH and as the alkali/chalcone ratio is decreased. However, at intermediate concentrations (e.g., 0.03 M) efficiency of the alkalies is in the order KOH, NaOH, and LiOH. This can be attributed to M^+–π interaction as shown for E in Scheme I, an interaction which fails to contribute toward the stability of the M^+–chalconate at high dilution (4×10^{-4} M) and goes undetected at high concentrations (0.1 M) due to a dominating contribution of the M^+–phenoxide ion pair. The following observation confirms the activity of unsaturation of the aliphatic part in E.

When $HClO_4$ is titrated in the pH range 2 to 8 (where the chalcone does not ionize) in the presence and absence of chalcone employing NaOH and Bu_4NOH as alkalies, chalcone is found to decrease the concentration of $HClO_4$ but only in the case of Bu_4NOH (see Figure 1). This shows that a neutral molecule of chalcone deprotonates $HClO_4$ to become itself protonated in the cavity through M^+–π bonds as with M^+ in E. The "encapsulated" proton can be replaced by the small-sized Na^+ during titration but not by the bulky Bu_4N^+ which competes unfavorably on steric as well as charge-density grounds. If protonation should have taken place outside the cavity, say at the carbonyl group, then both the alkalies could deprotonate the H^+–chalcone complex successfully.

Mechanism of Cyclization. The mechanism of the cyclization is also described in Scheme I. The M^+–π interaction in E enhances the carbonium character at the β carbon and also loosens the $-O^-M^+$ ion pair. The phenoxy anion so destabilized attacks the β carbon to produce the closed-ring labile carbanion salt (F). The latter hydrolyzes easily to produce the flavanone.

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Registry No.—HAP, 582-24-1; BLD, 100-52-7; chalcone, 94-41-7; flavanone, 487-26-3.

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Photochemical Reactions of Aromatic Compounds. 27.[1] Stereospecific Photocycloaddition of *cis*- and *trans*-1-Methoxypropenes to 2-Naphthonitrile

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The photocycloadditions of olefinic compounds and furan to aromatic nitriles usually occur in a stereoselective manner[2-4] and have been discussed in terms of exciplexes. In a previous paper,[2a] we reported that irradiation of 2-naphthonitrile (1) and alkyl vinyl ethers at 313 nm exclusively gives endo [2 + 2] cycloadduct **5a**, whereas that at >280 nm for a longer time results in formation of a cyclobutene compound **3** as a main product. In this note, we report the stereospecific photocycloadditions of *cis*- and *trans*-1-methoxypropenes (**4c** and **4t**) to 2-naphthonitrile (1).