Anal. Calcd for $C_7H_{14}O_4 \cdot 0.5H_2O$: C, 48.56; H, 8.74. Found: C, 48.20; H, 8.60.

Hexadecylmethylmalonyl Chloride. A solution of diethyl hexadecylmalonate (5.0 g, 16.6 mmol) and MeI (14.2 g, 97 mmol) in 25 mL of CH_2Cl_2 was stirred with tetra-*n*-butylammonium chloride (11.3 g, 50 mmol) and NaOH (4.0 g, 100 mmol) in 75 mL of H_2O for 1 h at room temperature. The CH_2Cl_2 layer was separated and evaporated in vacuo. After addition of Et_2O (100 mL), filtration, drying ($MgSO_4$), and evaporation in vacuo, the residue was chromatographed on silica gel with CH_2Cl_2 as eluent to provide 4.5 g (86%) of diethyl hexadecylmethylmalonate as a colorless oil: IR 1747 (C=O); ^{1}H NMR δ 0.75–2.15 (m, 42 H), 4.0–4.5 (q, 4 H); MS, m/e 398.6 (M^+). Anal. Calcd for $C_{24}H_{46}O_4$: C, 72.31; H, 11.63. Found: C, 72.27; H, 11.62.

Diethyl hexadecylmethylmalonate (4.0 g, 10 mmol) was added to 50% aqueous NaOH (50 mL) and the reaction mixture was refluxed for 12 h, acidified to pH 1 with 6 N HCl, and extracted with EtOAc (50 mL). The EtOAc layer was washed with H_2O (50 mL), dried ($MgSO_4$), and evaporated in vacuo to give a quantitative yield of hexadecylmethylmalonic acid as a white solid with mp 60–61 °C: IR 3600–2400 (O–H), 1745 (C–O); ^{1}H NMR δ 0.75–2.15 (m). Anal. Calcd for $C_{20}H_{38}O_4$: C, 70.13; H, 11.18. Found: C, 70.15; H, 10.95.

Hexadecylmethylmalonic acid (3.0 g, 8.8 mmol) was stirred with 5 mL of oxalyl chloride in 20 mL of dry benzene at room temperature for 12 h under nitrogen. The solvent was evaporated in vacuo and 50 mL of 30–60 °C petroleum ether was added to the residue. Filtration and evaporation of the solvent gave a quantitative yield of hexadecylmethylmalonyl chloride as a colorless oil: IR 1763 (C=O); ^{1}H NMR δ 0.75–2.15 (m).

General Procedure for Preparation of Bis(crown ether) Esters 3–5. A solution of the appropriate hydroxymethyl crown ether (40 mmol) in 25 mL of dry C_6H_6 was added to a solution of hexadecylmethylmalonyl chloride (20 mmol) in dry C_6H_6 (50 mL) and pyridine (30 mL). The solution was refluxed for 24 h under nitrogen and evaporated in vacuo to give an oil that was dissolved in EtOAc (100 mL). The EtOAc solution was washed with 5% aqueous AcOH, dried ($MgSO_4$), and evaporated in vacuo to give a crude product, which was chromatographed on silica gel with CH_2Cl_2 and CH_2Cl_2–MeOH (20:1) as eluents to afford the product as a yellow oil.

Bis(crown ether) 3 was obtained in 63% yield: IR 1745 (C=O), 1103 (C—O); ^{1}H NMR δ 0.8–2.0 (m, 36 H), 3.4–4.45 (m, 26 H). Anal. Calcd for $C_{34}H_{62}O_{10}$: C, 64.73; H, 9.91. Found: C, 64.52; H, 10.22.

Bis(crown ether) 4 was produced in 62% yield: IR 1732 (C=O), 1132 (C—O); ^{1}H NMR δ 0.8–1.9 (m, 36 H), 3.4–4.35 (m, 34 H). Anal. Calcd for $C_{38}H_{70}O_{12}$: C, 63.48; H, 9.81. Found: C, 63.36; H, 9.82.

Bis(crown ether) 5 was formed in 68% yield: IR 1745 (C=O), 1130 (C—O); ^{1}H NMR δ 0.6–1.6 (m, 36 H), 1.7–2.4 (m, 6 H), 3.45–4.15 (m, 36 H). Anal. Calcd for $C_{42}H_{78}O_{12} \cdot 0.5H_2O$: C, 64.34; H, 10.14. Found: C, 64.43; H, 10.16.

Picrate Extractions into Deuteriochloroform. Bis(crown ether) solutions (15 mM) were prepared in ethanol-free deuteriochloroform. With use of the reported procedure,[13,14] extractions were conducted by adding 0.50 mL of the 15 mM bis(crown ether) solution in deuteriochloroform to 0.50 mL of a 15 mM alkali metal picrate solution in a centrifuge tube, and the mixture was vigorously agitated with a vortex mixer for 1 min. Five identical samples were run concurrently. The mixtures were centrifuged for 10 min and allowed to stand overnight to assure complete layer separation. Precisely measured aliquots were removed from each layer with microsyringes and diluted in THF. Visible spectra of these solutions were measured in the region of 340–550 nm. In all cases, the picrate absorption maxima were in the region of 343–351 nm, which is characteristic of a tight ion pair.[16] From the alkali metal picrate concentrations in each phase, the K_{ex} (extraction constant) value was calculated[13,14] and converted into the K_a (association constant in deuteriochloroform) value by the reported method. In the calculations, exclusive formation of complexes of one alkali metal cation with one bis(crown ether) was assumed.

Acknowledgment. Portions of this research were supported by the Ames Division of Miles Laboratories and by the Robert A. Welch Foundation (Grant D-775).

Registry No. 3, 108269-91-6; 4, 87377-17-1; 5, 108269-92-7; 6, 108269-93-8; 7, 75507-26-5; 8, 92818-21-8; $(ClCO)_2C(CH_3)(CH_2)_{15}CH_3$, 108269-94-9.

---

(16) Wong, K. H.; Bourgoin, M.; Smid, J. *J. Chem. Soc., Chem. Commun.* **1974**, 715.

The Reaction of Various Methoxy-Substituted Haloarenes with Amines and Nitriles under Aryne-Forming Conditions

Aziz Razzuk and Edward R. Biehl*

Department of Chemistry, Southern Methodist University, Dallas, Texas 75205

Received December 2, 1986

We[1-4] have shown recently that good yields of a single product are obtained via the aryne of disubstituted haloaromatic compounds if the aryne intermediate is either symmetric or is unsymmetric but possesses strongly electron-attracting groups such as methoxy. The aryne reaction of polymethoxyhaloarenes is particularly interesting since methoxy substituents are commonly found in many biologically active compounds. Thus, 2-bromo-1,4-dimethoxybenzene, in the presence of sodamide and various primary and secondary amines, yields *N*-alkyl- and *N*,*N*-dialkyl-2,5-dimethoxyanilines, respectively, via the symmetrical aryne intermediate, 3,6-dimethoxybenzyne.[1] This bromoarene also reacts with nitrile anions in liquid ammonia under aryne-forming conditions, affording mainly 2-(cyanoalkyl)-1,4-dimethoxybenzenes and small amounts of 2,5-dimethoxyaniline.[1]. The isomeric intermediate, 3,4-dimethoxybenzyne, generated from 4-bromo-1,2-dimethoxybenzene is unsymmetric; however, it is aminated in the presence of primary and secondary amines regioselectively at 1-position yielding cine substitution products, *N*-alkyl- and *N*,*N*-dialkyl-3,4-dimethoxyanilines, respectively.[2] In presence of nitrile anions and liquid ammonia, that unsymmetric aryne reacts regioselectively and solely with the less reactive but more abundant ammonia solvent affording 3,4-dimethoxyaniline.[2] The meta-directing effect of the methoxy group is well-known.[5] It has been also shown to increase the reactvity of benzyne by inductively polarizing the "triple bond".[6] The greater selectivity of the symmetric 3,6-dimethoxybenzyne as compared to the unsymmetric 3,4-dimethoxybenzyne is due, partly, to the cancelling of the inductive effect of the two methoxy groups polarizing the "triple bond".

In order to obtain further information on the influence of two or more substituents on the regioselectivity and reactivity of benzyne, the reactions of 4-bromo-1,3-dimethoxybenzene (1), 4-bromo-1,2,3-trimethoxybenzene (2), and 2-bromo-4-methylanisole (3), with various amines and niiriles under aryne-forming conditions were studied.

Results and Discussion

Reaction of 1, 2, and 3 with Primary and Secondary Amines. The results of the reaction of 1, 2, and 3 with various amines are listed in Table I. The data show that each haloarene undergoes predominantly cine substitution,

---

(1) Han, Y. X.; Jovanovic, M. V.; Biehl, E. R. *J. Org. Chem.* **1985**, *50*, 1334.

(2) Han, Y. X.; Biehl, E. R. *J. Org. Chem.* **1983**, *48*, 4397.

(3) Biehl, E. R.; Razzuk, A.; Jovanovic, M. V.; Khanapure, S. P. *J. Org. Chem.* **1986**, *51*, 5157.

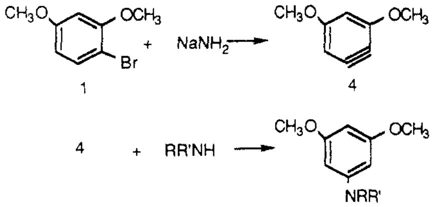
(4) Khanapure, S. P.; Biehl, E. R. *J. Org. Chem.* **1987**, *52*, 1333.

(5) Roberts, J. D.; Vaughan, C. W.; Carlsmith, L. A.; Semonov, D. A. *J. Am. Chem. Soc.* **1956**, *78*, 601, 611.

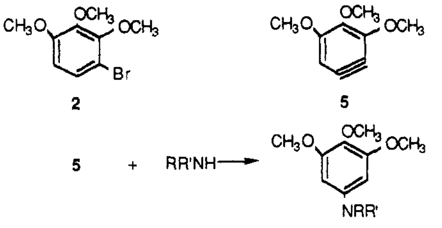
(6) Biehl, E. R.; Nieh, E. *J. Org. Chem.* **1970**, *34*, 3595.

0022-3263/87/1952-2619$01.50/0

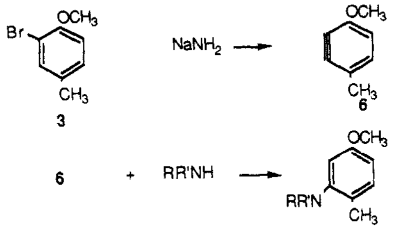
that is, substitution occurs at a different position than at that occupied previously by the halogen atom. Such substitution confirms that each these reactions proceeds by regioselective amination of an unsymmetric aryne intermediate. Thus, the reaction of 1 with primary and secondary amines and sodamine yields *N*-alkyl- and *N*,-*N*-dialkyl-3,5-dimethoxyanilines **7** and **8**, respectively, via 3,5-dimethoxybenzyne (4). *N*-alkyl- and *N*,*N*-dialkyl-3,4,5-trimethoxyanilines **9** and **10**, respectively, were obtained by nucleophilic addition of primary and secondary amines, respectively, onto 3,4,5-trimethoxybenzyne (**5**) generated by the action of sodamide on **2**. Similarly, **3** gave 3-methoxy-6-methylbenzyne (**6**) which yielded *N*-alkyl- and *N*,*N*-dialkylmethylanisidines **11** and **12**, respectively, when treated with primary and secondary amines, respectively. GC analysis of each reaction mixture indicated only trace amounts (less than 5%) of the bromine-substituted aminated products were formed.



7. R = Alkyl, R' = H
8. R and R' = Alkyl



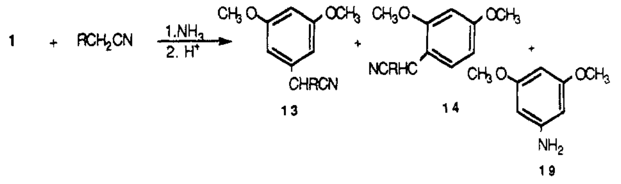
9. R = Alkyl, R' =H
10. R and R' = Alkyl

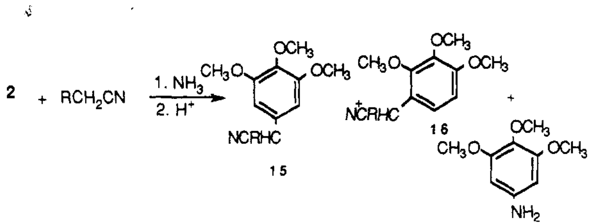


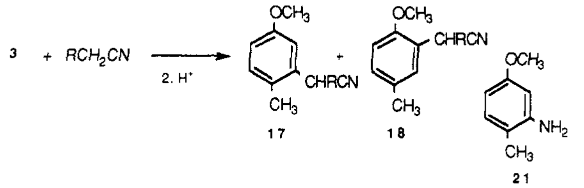
11. R = Alkyl, R' = H
12. R and R' = Alkyl

Perusing the data listed in Table I reveals that those reactions in which modest size amines were used produced the corresponding anilines in good yields; whereas the yields of those reactions which employed bulky amines were generally lower in comparison to the former amines. For example, the reaction of **2** with isobutylamine and diisobutylamine gave *N*-isobutyl-3,4,5-trimethoxyaniline and *N*,*N*-diisobutyl-3,4,5-trimethoxyaniline in yields of 84% and 40%, respectively. The major factor contributing to the lower yields in the reaction involving bulky amines as compared to those using modest size amines was that dehalogenation of **1**, **2**, and **3**, a competing side reaction, occurred to a greater extent in the former case. The products, **7–12**, were identified on the basis of their ^{1}H NMR, ^{13}C NMR, IR, and mass spectra; they are included in the supplementary material in tabular form.

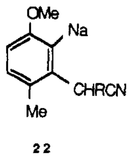
Reaction of 1, 2, and 3 with Nitrile Anions. The results of the reaction of haloarenes **1**, **2**, and **3** with various nitriles and sodamide in liquid ammonia are listed in Table II. The data reveal that isomeric nitrile mixtures (**13**, **14**, **15** + **16**, and **17** + **18**, respectively) are obtained in each case in which the cine-substituted isomer **13**, **15**, or **17** predominates over the bromine-substituted isomer **14**, **16**, or **18**. The ratios are generally greater than 90:10, respectively, except in the case of **3** in which the ratios are ca. 85:15, respectively. In addition, these haloarenes are aminated regioselectively to the cine-substituted aniline **19**, **20**, and **21**, respectively. The overall yields of these nitriles appear to be a function of the number of methoxy groups present in the haloarene, with largest yields of nitriles (ca. 45%) from the monomethoxy arene **3**, intermediate yields of nitriles (16–23%) from the dimethoxyarene **1**, and lowest yields of nitriles (>5%) from the trimethoxyarene **2**. The decrease in yields of nitriles was accompanied by an increase in both the yields of the aminated products, 6-methyl-*m*-anisidine (*21*), 3,5-dimethoxyaniline (**19**), and 3,4,5-trimethoxyaniline (**20**), respectively, and in the amount of intractible tar. The direct relationship observed between the aniline/nitrile ratio and the number of methoxy groups is consistent with that previously observed for other methoxyhaloarenes[6] and indicates that increasing the number of these groups on aryne decreases the selectivity of the arynes so substituted toward nitriles.







Meyers[7] has observed that (*m*-chlorophenyl)oxazoline reacts with lithioalkyl nitriles via 3-oxazolinylbenzyne to yield 3-cyano-2-alkylbenzoic acids, after remoal of the oxazoline group. The key steps in this reacton were presumed to be the initial formation of a 3-lithio-2-alkylcyano adduct that undergoes spontaneous ring closure to a benzocyclobutenimine. We looked for but did not find similar products from the reaction of nitriles with **1**, **2**, and **3**. The ammonia probably quenched the sodio salt **22**, preventing its ring closure to the appropriate benzocyclobutenimine. In principle, the aryne reaction of po-



22

---

[7] Meyers, A. I.; Pansegrau, P. D. *Tetrahedron Lett.* **1984**, *25*, 2941.

Table I. Yields and Physical Properties of 7–12[a]

		yield, % (bp, °C [torr], or mp, °C)		
	primary amine	7	9	11
a	*n*-propyl	86 (116–117 [0.10])	82 (140 [0.15])	94 (70–72 [0.02])
b	isopropyl	80 (103–104 [0.03])	79 (127–129 [0.12])	93 (72–75 [0.07])
c	*n*-butyl	89 (120–122 [0.03])	84 (154–156 [0.25])	96 (102–105 [0.08])
d	isobutyl	85 (36–38)	84 (150–152 [0.35])	89 (104–106 [0.12])
e	*sec*-butyl	67 (115–117 [0.50])	57^b (147–149 [0.32])	67 (89–91 [0.01])
f	*tert*-butyl	77 (52–53)	36 (116–118 [0.10])	53 (70–72 [0.10])
g	octyl	71 (155–158 [0.18])	51 (197–199 [0.70])	55 (135–137 [0.17])
h	cyclohexyl	68 (43–44)	45^b (160–164 [0.20])	97 (138–140 [0.26])

		yield, % (bp, °C [torr], or mp, °C)		
	secondary amine	8	10	12
a	*N*-methylbutyl	60 (120–121 [0.11])	67 (119–121 [0.20])	88 (74–77 [0.03])
b	*N*-ethylbutyl	65 (111–113 [0.02])	39^b (122–124 [0.18])	57 (85–88 [0.12])
c	diethyl	83 (50–52)	77 (122–124 [0.30])	83 (57–61 [0.05])
d	di-*n*-propyl	71 (122–124 [0.11])	51^b (119–123 [0.20])	74 (70–74 [0.04])
e	di-*n*-butyl	66 (139 [0.25])	53^b (133–135 [0.20])	66 (90–93 [0.03])
f	diisopropyl	46^b (121–122 [0.27])	26^b (97–99 [0.06])	43^b (66–68 [0.01])
g	diisobutyl	40^b (56–57)	40^b (118–121 [0.07])	71^b (79–82 [0.01])
h	piperidine	70 (127–130 [0.35])	85 (152–154 [0.24])	77^b (88–90 [0.10])
i	morpholine	77 (84–86)	68 (81–82)	97 (85–86 [0.01])
j	dicyclohexyl	40^b (36–37)	17 (145–147 [0.18])	40^b (35–36)

[a] Structures were established by IR, ^{1}H NMR, ^{13}C NMR, and MS spectrometry. Satisfactory C, H, N analyses were obtained and are supplied as supplementary material. [b] Required refluxing.

Table II. Yields and Physical Properties of 13, 15, and 17[a]

		yields, % (bp, °C [torr], or mp, °C)		
	nitrile	13	15	17
a	acetonitrile	14 (51–52)	5 (77–79)	45 (86–96)^c
b	propionitrile	$18^{b,d}$	$5^{b,e}$	43 (105–106 [0.100])^c
c	butyronitrile	$22^{b,d}$	$3^{b,e}$	44 (115–118 [0.150])^c
d	valeronitrile	$14^{b,d}$	$4^{b,e}$	43 (130–133 [0.150])^c

[a] Structures were established by IR, ^{1}H NMR, ^{13}C NMR, and MS spectrometry. Satisfactory C, H, N analyses were obtained and are supplied as supplementary materials. [b] Decomposed upon attempted distillation. [c] About 6% of corresponding 18 isomer obtained. [d] Less than 1% of corresponding 14 isomer obtained. [e] Less than 0.5% of corresponding 16 isomer obtained.

lymethoxyhaloarenes affords a convenient method of introducing a nitrile functional group meta to one of the methoxy group. Further, these haloarenes are easily prepared by bromination of readily available polymethoxyarenes; bromination generally occurring ortho to one of the methoxy groups. In contrast, Jung[8] has reported that of the three isomeric bromoanisoles, only 3-bromoanisole underwent the aryne reaction using lithium diisopropylamide (LDA), indicating the necessity of meta methoxy substitution in that system. However, it appears that the use of the aryne reaction for preparing aromatic nitriles containing two or more methoxy groups readily in liquid ammonia may be limited to 2-bromo-1,4-dimethoxybenzene (from which the symmetric aryne, 3,6-dimethoxybenzyne can be generated) and perhaps 2 (from which aryne 5 can be produced), if one can tolerate yields in the range of 25%. The aryne reaction of 3 with nitriles may be synthetically useful since it introduces nitrile functionality ortho to a methyl substituent. We[4] have recently prepared compounds containing substituted nitrile groups ortho to a CH_2OMe group by such an aryne reaction and demonstrated that these compounds are hydrolyzed to 3-isochromanones, which are key precursors in the synthesis of various natural products.

Experimental Section

Proton nuclear magnetic spectra (^{1}H NMR) were measured in $CDCl_3$ solution on a Perkin-Elmer R-32 spectrometer at 90 MHz or on a WP 200-SY Bruker spectrometer. Carbon NMR spectra (^{13}C NMR) were recorded on a WP 200-SY Bruker spectrometer. All chemical shifts are reported in parts per million downfield from internal tetramethylsilane. Infrared spectra (IR) were recorded on a Perkin-Elmer 283 grating spectrometer as a liquid film or in a solution cell. Chroatographic analysis and mass spectra (70 eV) were obtained on a Hewlett-Packard Model 5988A chromatograph/mass spectrometer equipped with a 12 m × 0.2 mm i.d. capillary column containing cross-linked methyl silicone of 0.33-μm film thickness. Data reported are the m/z values for the most abundant peaks. E. Merck silica gel 9385 (230–400 mesh) was used for flash chromatography. All reagents and solvents were purified and distilled according to standard methods. Reported boiling points are uncorrected; melting points were determined on an electrothermal apparatus and are uncorrected. All reactions were carried ont in flame-dried flasks under nitrogen atmosphere. Since the reactions performed are all similar in many respects, typical reactions will be described as specific examples.

Starting Materials. The amines, nitriles, *m*-methoxybenzene, pyrogallol, and *p*-methylanisole were purchased from Aldrich Chemical Co. The amines were distilled and dried over calcium hydride and stored over 4-Å molecular sieves prior to use. The remaining organics were distilled before using. 1,2,3-Trimethoxybenzene was prepared by treatment of pyrogallol with dimethyl sulfate in a mixture of 10% aqueous sodium hydroxide and methylene chloride containing Adogen 464 catalyst. Bromoarenes 1–3 were prepared by the action of bromine in chloroform at −10 to 0 °C.

General Procedure for the Reaction of 1, 2, and 3 with Nitriles. Sodamide (0.04 mol) was prepared from sodium (0.04 mol) in 50 mL of liquid ammonia containing 0.01 g of ferric chloride contained in a 250-mL flask equipped with a mechanical stirrer and dry ice condenser. After the discharge of the initial blue solution to gray, indicating the conversion of sodium to sodamide, the appropriate nitrile (0.02 mol) was added over a period of 5 min and the mixture stirred for an additional 5 min. Then, 0.01 mol of haloarene 1, 2, or 3 was added, and after stirring for 15 min, the mixture was quenched with ammonium chloride (0.06 mol) and the ammonia removed on a steam bath. The residue was extracted with three 25-mL portions of methylene chloride, and the combined extracts were washed with brine, dried (Na_2SO_4) and concentrated under reduced pressure (rotary evaporator) to provide an oil that consisted of a mixture of nitrile and anilines. Purification of the nitrile products was accomplished by flash column chromatography using a mixture of hexane/ethyl acetate (9:1 to 4:1 depending on the polarity of the nitrile product) as eluent.

---

(8) Jung, M. E.; Lowen, G. T. *Tetrahedron Lett.* **1986**, *27*, 5319.

Reaction of 1, 2, and 3 with Amines. To a stirred solution containing 200 mL of the appropriate amine under nitrogen was added somamide (0.05 mol), and the mixture was stirred for 15 min. Haloarene **1**, **2**, or **3** (0.025 mol) was added, and the mixture was stirred at room temperature, in the case of modest sized amines, or at refluxing temperatures, in the case of bulky amines. The progress of the reaction was monitored by analyzing small aliquots (ca. 0.5 mL), taken periodically from the reaction mixture, by GLC analysis. After the reaction was complete (0.5-1 h), 2 mL of methanol and 75 mL of methylene chloride were added succesively, and the resulting mixture was stirred vigorously for 10 min and then filtered through a medium-sized fritted glass funnel. The mother liquor was concentrated (rotary evaporator) to yield an oil from which the amine products were obtained by flash chromatography (19:1 hexane/methylene chloride).

Acknowledgment. This work was sponsored partly by Grant N-118 from the Welch Foundation, Houston, TX.

Supplementary Material Available: Elemental analyses and IR, ^1H NMR, ^{13}C NMR, and MS spectral data for amines **7**–**13**, **15**, and **17** (20 pages). Ordering information is given on any current masthead page.

Enol Form of 2,3-Butadione (Biacetyl)[1]

Neal Sleszynski[2] and Petr Zuman*

Department of Chemistry, Clarkson University, Potsdam, New York 13676

Received February 10, 1987

Information concerning keto–enol equilibria in aqueous solutions of 1,2-diketones[3] is much more limited than for 1,3-diketones. Existing data show an unusual relationship between the structure of the diketone and the extent of the enolization. Spectrophotometry[3c,d,4] and NMR spectra[4,5] indicate that biacetyl exists in aqueous solutions predominantly (more than 99%) in the diketo form, with one keto group about 77% hydrated,[3f] while 1,2-cyclohexanedione is present 60% in the enol form, 39% in the monohydrate form and less than 1% in the free diketo form.[3e] For 1,2-cyclopentanedione the content of the enol form is somewhat smaller;[3a] 1,2-cycloheptadione[3b] on the other hand is present in more than 98% in the diketo form and resembles straight-chain diones. No quantitative information was available for the p*K* value corresponding to the formation of a carbanion–enolate. In the course of investigation of the reaction of biacetyl with arginine,[6] which is useful both for determination of guanidine groups in biological materials and for the synthetic use of biacetyl for protecting such groups, the understanding of the nature of the species predominating in individual pH ranges became important.

Decrease of absorption spectra of biacetyl or polarographic limiting currents with increasing pH indicated formation of a carbanion–enolate with $pK_a = 13.8$. This reaction (eq 3 and 4) is preceded by base-catalyzed dehydration (eq 1 and 2). Carbanion–enolate present undergoes subsequently aldolization (eq 5). Rates of all reactions studied increased with pH. Polarographic data[4] indicate that base catalyzed dehydration (eq 1 and 2) has a half-life of less than 1 s and occurs rapidly when compared with subsequent reactions. Formation of the carbanion in reaction 3 has in 1 M NaOH a half-life about 10 s, consecutive aldolization in the same solution containing 2×10^{-4} M biacetyl has a half-life of about 20 min.

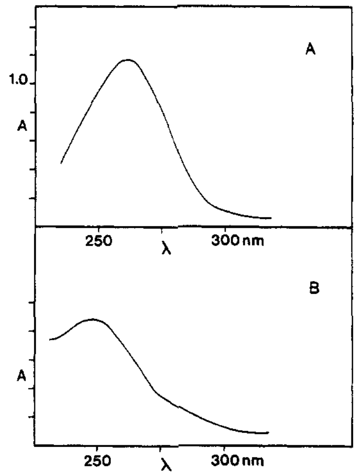
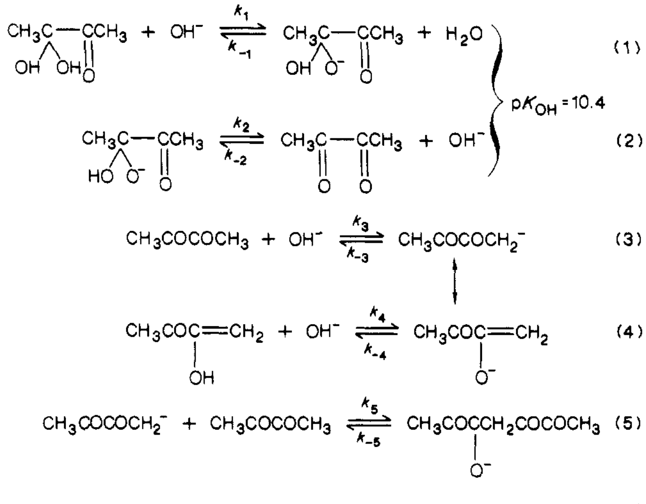


Figure 1. Electronic spectra of (A) 0.5 mM 2-hydroxy-1-cyclohexen-3-one in 0.01 M HCl and (B) 1.96 mM biacetyl in 0.1 M NaOH neutralized after 120 s to pH 3.2 by addition of phosphoric acid.



$$CH_3\underset{OH\ OH}{C}-\underset{O}{\overset{\|}{C}}CH_3 + OH^- \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} CH_3\underset{OH\ O^-}{C}-\underset{O}{\overset{\|}{C}}CH_3 + H_2O \quad (1)$$

$$CH_3\underset{HO\ O^-}{C}-\underset{O}{\overset{\|}{C}}CH_3 \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} CH_3\underset{O}{\overset{\|}{C}}-\underset{O}{\overset{\|}{C}}CH_3 + OH^- \quad (2)$$

$$pK_{OH} = 10.4 \quad (1),(2)$$

$$CH_3COCOCH_3 + OH^- \underset{k_{-3}}{\overset{k_3}{\rightleftharpoons}} CH_3COCOCH_2^- \quad (3)$$

$$CH_3CO\underset{OH}{C}{=}CH_2 + OH^- \underset{k_{-4}}{\overset{k_4}{\rightleftharpoons}} CH_3CO\underset{O^-}{C}{=}CH_2 \quad (4)$$

$$CH_3COCOCH_2^- + CH_3COCOCH_3 \underset{k_{-5}}{\overset{k_5}{\rightleftharpoons}} CH_3CO\underset{O^-}{C}CH_2COCOCH_3 \quad (5)$$

Formation of the carbanion–enolate in eq 3, which can produce the desired enol after acidification, was measured from the increase of the carbanion–enolate absorption band at 250 nm, from the decrease of polarographic limiting current of biacetyl and from the increase in concentration of the monoenol species determined by bromometric titration after acidification of biacetyl solution in 0.01 M NaOH after chosen time intervals. Reaction was proved to be first order in biacetyl and first in hydroxide ions with second-order rate constant ($k_3 + k_{-3}$) of about 3×10^{-3} L mol^{-1} s^{-1}.

Understanding of the details of the processes involved made it possible to prepare solutions containing the biacetyl partly in the monoenol–monoketo form. The enol form was produced and identified after acidification. Alkaline conversion to carbanion–enolate was most effective at low concentrations of biacetyl (less than 10^{-3} M) and low sodium hydroxide concentration (0.01–0.1 M), as under such conditions the second order reaction 5 was least

---

[1] Partly based on M.Sc. Thesis of N.S., Clarkson College of Technology, Potsdam, NY, 1978.

[2] Present address: Abbott Laboratories, North Chicago, IL 60064.

[3] (a) Schwarzenbach, G.; Wittwer, Ch. *Helv. Chim. Acta* **1974**, *30*, 663, 669. (b) Hesse, G. *Ann. Chem.* **1955**, *593*, 35, 42. (c) Bakule, R.; Long, F. A. *J. Am. Chem. Soc.* **1963**, *85*, 2309. (d) Long, F. A.; Bakule, R. *Ibid.* **1963**, *85*, 2313. (e) Segretario, J. P.; Sleszynski, N.; Zuman, P. *J. Electroanal. Chem. Interfacial Electrochem.* **1986**, *214*, 259. (f) Segretario, J. P.; Sleszynski, N.; Partch, R. E.; Zuman, P.; Horak, V. *J. Org. Chem.* **1986**, *51*, 5393.

[4] Segretario, J. P. Ph.D. Thesis, Clarkson College of Technology, Potsdam, NY, 1982.

[5] (a) Greenzaid, P.; Rapport, Z.; Samuel, D. *Trans. Faraday Soc.* **1967**, *63*, 2131. (b) Hooper, D. L. *J. Chem. Soc. B.* **1967**, 169.

[6] Veivia, D., M.S. Thesis, Clarkson University, Potsdam, NY, 1985.

0022-3263/87/1952-2622$01.50/0