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G. F. D'alelio[a]; T. Kurosaki[a]; R. K. Schoenig[a]
[a] DEPARTMENT OF CHEMISTRY, UNIVERSITY OF NOTRE DAME, NOTRE DAME, INDIANA

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Polymeric Schiff Bases. IV. The Prototype Syntheses of Schiff Bases by Reactions of Aromatic Acetals with Aromatic Amines or Their Acyl Derivatives

G. F. D'ALELIO, T. KUROSAKI,* and R. K. SCHOENIG
DEPARTMENT OF CHEMISTRY
UNIVERSITY OF NOTRE DAME
NOTRE DAME, INDIANA

Summary

The acetals of aryl aldehydes react with aryl amines to produce Schiff bases in quantitative yields. This reaction was also facile with diamines and diacetals. It involves a two-step elimination of alcohol; kinetic data indicate that k_2 is equal to or greater than k_1 and this complicates the isolation of any intermediate compound.

Because of overlap of absorption bands, the existence of intermediates was not confirmed by infrared spectral measurements. Adducts of the acetals and the aniline hydrochlorides were isolated as hydrochlorides; their molecular weights, as well as the products obtained by neutralization, indicated that the intermediate is not a monoalkoxy compound. The acetals react, also, with N-acyl aniline by the elimination k_1 of the alcohol and k_2 of the ester, in which $k_1 > k_2$, to produce Schiff bases in less than quantitative yields. These reactions of acetals with amines and their N-acyl derivatives are of interest in the syntheses of polymers.

The ease of the acetal-Schiff base exchange as well as the amine-, aldehyde-, and bis-Schiff base exchange reactions previously reported (*1*) suggested that the amines, $ArNH_2$, and their aliphatic acylamides, ArNHOCR, should be investigated in reactions with

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[*] NASA Postdoctoral Research Associate, 1963–1965.

acetals. These postulated reactions can be written

$$\mathrm{ArCH(OR)_2 + ArNH_2 \rightarrow ArCH{=}NAr + 2ROH} \qquad (1)$$

$$\mathrm{ArCH(OR)_2 + ArNHOCR \rightarrow ArCH{=}NAr + ROH + RCOOR} \qquad (2)$$

Neither of these reactions appears to be described in the literature, and since they were considered of potential value in the synthesis of Schiff base polymers, they were investigated. To apply these reactions to the preparation of polymers, it was necessary to confirm that they would be substantially free of side reactions which could lead to undesirable by-products and that the yields would be, at least very high, if not quantitative. Accordingly, they were studied in monomeric systems as prototypes for the polymer reactions.

It was also considered that it might be possible to establish the existence of intermediate reaction products before Schiff bond formation, since such intermediates, if stable, would contribute high solubility to the polymer intermediates.

The acetal reaction with amines as given in Eq. (1) was found to proceed readily, with or without Lewis acid catalysts, over a wide range of temperatures and in the presence or absence of solvents to give quantitative yields of crude products, if all the by-product alcohol was removed. The reaction was performed simply by heating the reagents in a suitable apparatus, removing the alcohol, and isolating the product. Table 1 summarizes the synthesis of a number of mono-Schiff bases prepared by reacting the corresponding acetals and anilines. The melting points of the products were de-

TABLE 1

Synthesis of $\mathrm{ArCH{=}NAr}$ by Reaction of $\mathrm{ArNH_2}$ with $\mathrm{ArCH(OR)_2}$

Product	Solvent	Catalyst	Reaction temp.	Reaction time, hr	Yield crystallized product, %	M.p., °C	
						Found[a]	Lit. (*1,2*)
$C_6H_5CH{=}NC_6H_5$	C_6H_6	TsOH[b]	Reflux	2.0	91	49	49
$C_6H_5CH{=}NC_6H_5$	C_6H_6	$ZnCl_2$	Reflux	3.0	96	49	49
$C_6H_5CH{=}NC_6H_5$	None	TsOH	55°C	2.5	92	49	49
$C_6H_5CH{=}NC_6H_5$	None	None	100°C	0.17	91	49	49
$p\text{-}ClC_6H_4CH{=}NC_6H_4Cl\text{-}p$	None	None	100°C	0.5	96	112	112
$p\text{-}ClC_6H_4CH{=}NC_6H_5$	None	None	100°C	0.5	94	61	61
$C_6H_5CH{=}NC_6H_4NO_2\text{-}m$	None	None	100°C	0.5	92	73	73
$m\text{-}O_2NC_6H_4CH{=}NC_6H_5$	None	None	100°C	0.6	93	66	66

[a] All melting points were taken on a calibrated Fisher-Johns melting point apparatus.

[b] TsOH, *p*-toluenesulfonic acid.

TABLE 2

Some Bifunctional Schiff Bases Prepared by Reaction of Acetals with Diamines in Absence of Solvent and Catalyst

Product	% Yield crystallized product	M.p., °C	
		Found[a]	Lit. (*1,2*)
$p\text{-}C_6H_5CH{=}NC_6H_4N{=}HCC_6H_5\text{-}p$	96	140	140
$p\text{-}C_6H_5N{=}HCC_6H_4CH{=}NC_6H_5\text{-}p$	94	166	166
$p\text{-}CH_3OC_6H_4N{=}HCC_6H_4CH{=}NC_6H_4OCH_3\text{-}p$	97	221	221
$p\text{-}ClC_6H_4CH{=}NC_6H_4N{=}HCC_6H_4Cl\text{-}p$	93	199	199
$p\text{-}ClC_6H_4N{=}HCC_6H_4CH{=}NC_6H_4Cl\text{-}p$	95	180	180
$m\text{-}O_2NC_6H_4CH{=}NC_6H_4N{=}HCC_6H_4NO_2\text{-}m$	95	251	251

[a] *All melting points were taken on a calibrated Fisher-Johns melting point* apparatus.

termined on recrystallized samples. The melting points of 50–50 wt. % mixtures with authentic samples previously reported (*1,2*) showed no depression of the melting temperature. A comparison of their infrared spectra with those of authentic samples showed that they were identical.

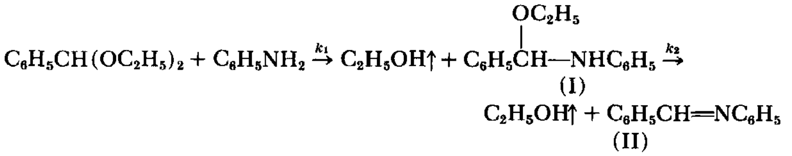
This reaction was found also to be facile with difunctional molecules for which the reactions can be written

$$2ArCH(OR)_2 + H_2NAr'NH_2 \rightarrow ArCH{=}NAr'N{=}HCAr + 4ROH \tag{3}$$

$$(RO)_2HCAr'CH(OR)_2 + 2H_2NAr \rightarrow ArN{=}HCAr'CH{=}NAr + 4ROH \tag{4}$$

Table 2 summarizes a number of difunctional Schiff bases preby the reaction of acetals and diamines. The products were identified by comparison of their infrared spectra and melting points with authentic samples (*1,2*).

The reaction of the acetal and the amine produces the Schiff base by a double elimination for which the following mechanism may be postulated:



$$C_6H_5CH(OC_2H_5)_2 + C_6H_5NH_2 \xrightarrow{k_1} C_2H_5OH\uparrow + \underset{\text{(I)}}{C_6H_5\overset{\overset{OC_2H_5}{|}}{C}H\text{—}NHC_6H_5} \xrightarrow{k_2} C_2H_5OH\uparrow + \underset{\text{(II)}}{C_6H_5CH{=}NC_6H_5} \tag{5}$$

This reaction was studied in some detail with the expectation that the intermediate (I) could be isolated or its existence established.

If this were possible, the reaction could be utilized with difunctional monomers for polymer synthesis in which the intermediate polymer would be soluble to a high molecular weight stage; thereafter, the reaction could be continued to produce the polymeric Schiff base by elimination of the second molecule of alcohol. The reaction was studied with and without catalysts, and at various temperatures and times in attempts to isolate the intermediate as a physical entity; these studies were not successful. Then studies were undertaken to confirm the existence of the intermediate by physical methods: (1) the decay in specific absorption bands in the infrared spectrum, and (2) the kinetics of the reaction.

INFRARED STUDIES

A series of reactions was performed using $C_6H_5CH(OC_2H_5)_2$ and $C_6H_5NH_2$ in a 1:1 mole ratio, with and without catalysts at various temperatures. The reaction mixture was sampled at various times and the infrared spectra of the reaction products then compared for specific wavelengths to the spectra of the individual starting reagents and mixtures of the reagents. The spectral data of these studies are summarized in Table 3.

The data in Table 3 failed to offer conclusive proof for the existence of a stable isolable intermediate. The bands at 3480 cm^{-1} and 3395 cm^{-1} are characteristic of —NH_2 structures, and a decrease in the ratio of 3480 cm^{-1} to 3395 cm^{-1} would show a disappearance of the primary amine, —NH_2—, and only indirectly would indicate the formation of a secondary amine in the reaction process by the disappearance of the 3395 cm^{-1} band. However, as the reaction proceeded, alcohol was liberated even in the first stage and its presence was observed at 3400 cm^{-1} in the form of a wide band which masked the area and prevented interpretation of the changes in the 3480 cm^{-1} to 3395 cm^{-1} ratio. The peaks at 1100 cm^{-1} and 1050 cm^{-1} are characteristic of the acetal linkage and at least one of them should disappear when compound (I) or (II) is formed. When reaction occurred, the peak at 1100 cm^{-1} was found to disappear but that at 1050 cm^{-1} persisted and was shown to be attributable to the —CH_2O— structure of the liberated ethyl alcohol. The peak at 1630 cm^{-1} is one of the —C=N— absorption bands and the wide band at 3400 cm^{-1} is characteristic of ethyl alcohol. From these results the actual existence of intermediate compound (I) cannot be

TABLE 3

Absorption Bands in the Spectra[a] of the Reaction of $C_6H_5CH(OC_2H_5)_2$ with $C_6H_5NH_2$

Materials examined	Reaction time, hr	Ratio of 3480 cm^{-1} to 3395 cm^{-1}	Presence of band at			
			1100 cm^{-1}	1050 cm^{-1}	1630 cm^{-1}	3400 cm^{-1} wide
$C_6H_5NH_2$	—	0.80	No	No	No	No
$C_6H_5CH(OC_2H_5)_2$	—	—	Yes	Yes	No	No
Unreacted mixture of $C_6H_5NH_2$ and $C_6H_5CH(OC_2H_5)_2$	—	0.70	Yes	Yes	No	No
Reaction at 55°C, no catalyst	0.50	0.70	Yes	Yes	No	No
	2.50	0.75	Yes	Yes	No	No
	23.50	—	No	Yes	Yes	Yes
Reaction at 55°C with $CH_3C_6H_4SO_3H$ catalyst	1.00	—	No	Yes	Yes	Yes
	2.50	—	No	Yes	Yes	Yes
	23.00	—	No	Yes	Yes	Yes
Reaction at 100°C, no catalyst	0.33	—	No	Yes	Yes	Yes
Reaction at 20°C with $H_3CC_6H_4SO_3H$ catalyst	0.25	—	Yes	Yes	No	No
	1.25	0.75	Yes	Yes	No	No
	4.50	0.70	Yes	Yes	No	No
	6.00	0.74	Yes	Yes	No	No
	46.50	0.80	Yes	Yes	No	No

[a] Taken on a Perkin-Elmer Model 421 infrared spectrometer.

confirmed, especially because of the overlap of the 3480 cm^{-1} and the wide 3400 cm^{-1} bands, and of the closeness of the 1630 cm^{-1} band with an —N—H stretching band in aniline at 1600 cm^{-1}. In these experiments it was observed that when the temperature was low, such as at 20°C, the reaction was sluggish, even in the presence of a catalyst, and no reaction occurred in 46½ hr.

At 55°C the reaction was sluggish in the absence of a catalyst and no reaction was observed for 2½ hr, whereas in the presence of a catalyst at 55°C the reaction was rapid. At 100°C the reaction was rapid even in the absence of a catalyst. In those cases in which reaction occurred, the reaction in this system appeared to proceed through the two stages at rates whose specific rate relationships were such that the intermediate compound (I) could not be confirmed by spectral means. Accordingly, an attempt was made to establish the existence of intermediate (I) from observations on the rates of elimination of alcohol in the reaction, as shown in Eq. (5). When k_1 is much larger than k_2, the overall rate of elimination of alcohol should be different before and after the generation of (I); and when $k_1 = k_2$ or $k_1 < k_2$ no change of the overall rate of the elimination should be expected. The reaction of $C_6H_5CH(OC_2H_5)_2$ and $C_6H_5NH_2$ was performed at reflux in benzene catalyzed by *p*-toluenesulfonic acid. During the reaction heating was so controlled that the azeotropic mixture of benzene and the alcohol formed in the reaction distilled off at an approximately constant rate of 1 ml/min; the vapor temperature during the distillation was recorded.

Under these restrictions, if $k_1 > k_2$, the vapor temperature would tend to increase, after the formation of (I), up to the boiling point of benzene because of the deficiency of alcohol required to maintain the normal azeotrope. If, however, $k_1 = k_2$ or $k_1 < k_2$, no change in vapor temperature should occur. The relationship between vapor temperature and volume of distillate illustrated in Fig. 1 is based on the experimental data given later in Table 10.

It will be noted in Fig. 1 that there is no marked change in the

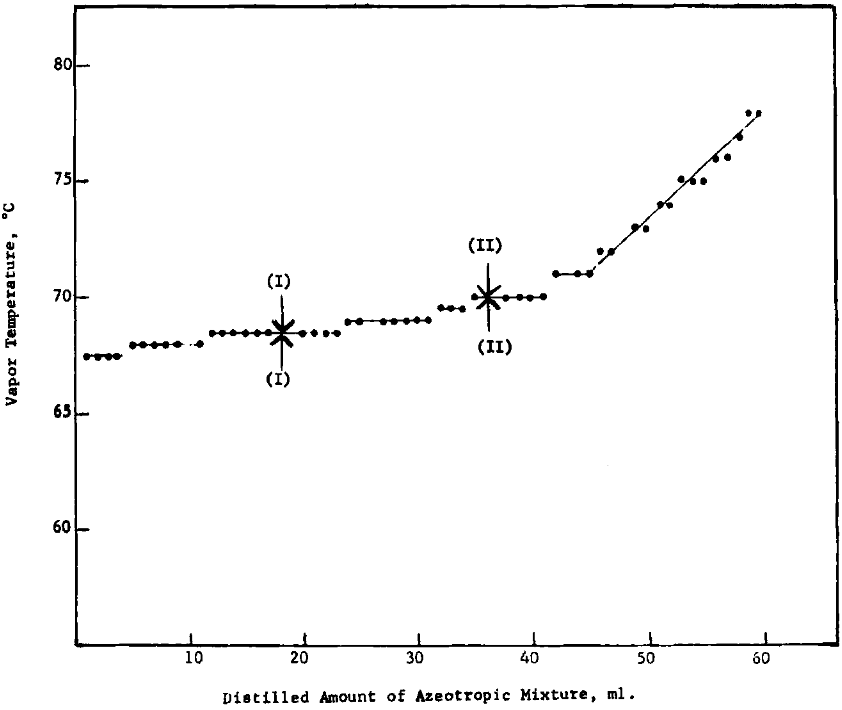
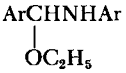


FIG. 1. Relationship between vapor temperature and volume of distillate in acetal-amine reaction.

rate of alcohol elimination before or after the point corresponding to the calculated amount of alcohol at which the intermediate (I) is formed. Rather, the data indicate that $k_2 = k_1$ or $k_2 > k_1$ and that isolation of the intermediate should be difficult indeed.

The reactions of the acetals with aniline hydrochlorides were also examined in attempts to isolate the intermediates,

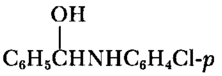


$$\underset{\mathrm{OC_2H_5}}{\mathrm{ArCHNHAr}}$$

In a number of cases the intermediate,

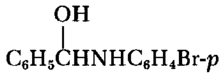
$$\underset{\mathrm{OH}}{\mathrm{ArCHNHAr}}$$

had been isolated when the aniline hydrochlorides, rather than the free amines, were reacted with the aldehydes. Erlenmeyer (3) isolated the adducts,



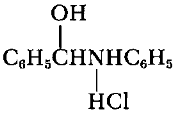
$$\overset{\mathrm{OH}}{\mathrm{C_6H_5CHNHC_6H_4Cl}\text{-}p}$$

and



$$\overset{\mathrm{OH}}{\mathrm{C_6H_5CHNHC_6H_4Br}\text{-}p}$$

by reacting benzaldehyde and p-$ClC_6H_4NH_2 \cdot HCl$ and p-BrC_6H_4-$NH_2 \cdot HCl$, respectively, in a mixture of benzene and water and then neutralizing the product with sodium carbonate. Dimroth and Zoeppritz also reported (4) the isolation of



$$\underset{\mathrm{HCl}}{\overset{\mathrm{OH}}{\mathrm{C_6H_5CHNHC_6H_5}}}$$

from the reaction of benzaldehyde with aniline hydrochloride, but when the product was neutralized, decomposition to aniline and benzaldehyde occurred:

$$C_6H_5CHO + C_6H_5NH_2 \cdot HCl \rightarrow C_6H_5CHOHNHC_6H_5 \cdot HCl \xrightarrow{1/2Na_2CO_3} C_6H_5CHO + C_6H_5NH_2 + NaCl + CO_2 + H_2O \quad (6)$$

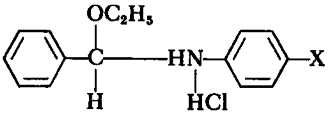
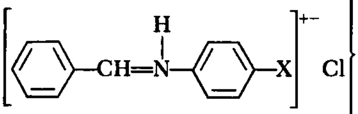
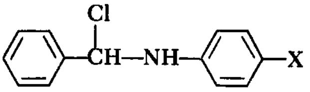
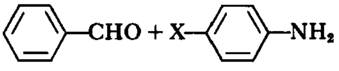
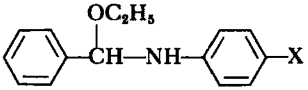
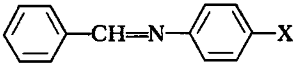
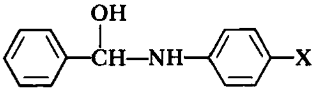
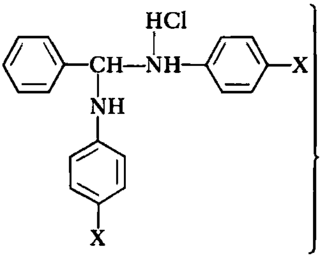
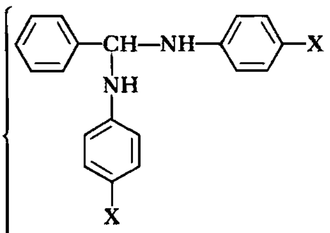
This is in contrast to the isolation of 2,4,6-$(NO_2)_3C_6H_2CHOHNH$-C_6H_5 (5) and of $C_6H_5CHOHNHC_6H_4NO_2$-p (6), p-HOC_6H_4CHOH-NHC_6H_5 (6), and m-$HOC_6H_4CHOHNHC_6H_5$ (6) as neutralization products of the corresponding hydrochloride intermediates.

Accordingly, studies were made of the reactions of the acetals and the aniline hydrochlorides in bulk as well as in aqueous and nonaqueous organic solvents in attempts to isolate non-Schiff-base-type intermediates. The reaction of $C_6H_5CH(OC_2H_5)_2$ and X—C_6H_4-NH_2·HCl could lead to a number of postulated chlorine-containing adducts, which, when treated with a base, could yield a number of neutralization products, as shown in Table 4; all of these could, by further reaction and elimination, lead to a Schiff base.

A number of adducts were prepared by reacting the acetal with aniline and some substituted anilines, and the adducts isolated.

TABLE 4

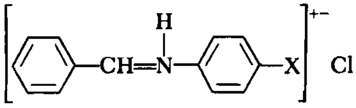
Possible Compounds from Reaction of $C_6H_5CH(OC_2H_5)_2$ and X—$C_6H_4NH_2$·HCl

Intermediate adducts	Neutralization products
(III)  (IV)  (V) 	 Decomposition reaction  Intermediate formation  Schiff base formation  Hydroxyl formation
(VI) 	 Disubstitution

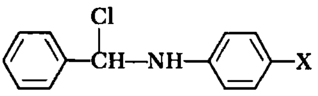
Since the molecular weights of proposed adducts (IV) and (V) are identical and lower than the molecular weights of adducts (III) and (IV), molecular weight determinations were considered as being useful in assigning the structures of the adducts to one of these groups.

The molecular weight data obtained for a number of adducts prepared at various temperatures and in various solvents are shown in Table 5.

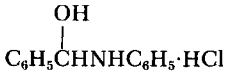
The data of Table 5 show that the adducts are either type (IV) or (V),



or



and not types (III) or (VI). The deviations found when X = H are attributable to the instability of the neutralized adduct similar to that reported (*4*) by Dimroth in the neutralization of



$$C_6H_5\overset{OH}{\overset{|}{C}}HNHC_6H_5{\cdot}HCl$$

TABLE 5

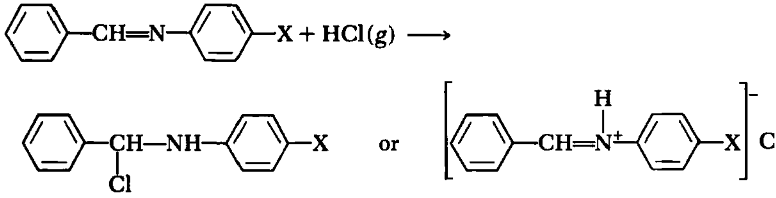
Molecular Weights of Adducts of $C_6H_5CH(OC_2H_5)_2$ and X—$C_6H_4NH_2{\cdot}HCl$

Substituent X	Reaction medium	Reaction temp., °C	Molecular weight	
			Found	Calcd. for adduct IV or V
H	Water	0	188	218
H	Alcohol	0	200	218
H	Dioxane	25	201	218
p-NO_2	Water	0	262	262
p-NO_2	Alcohol	25	248	262
p-Cl	None added	25	252	252
p-Cl	Water	25	246	252
p-Cl	Toluene	25	250	252
p-Cl	Alcohol	25	248	252
p-Cl	Dioxane	25	252	252
p-Cl	Dimethylformamide	25	248	252

The minor deviations in calculated and found molecular weights noted in a few of the other adducts is due to the fact that in all cases the unpurified crude adduct had to be used, since all attempts to purify the products by crystallization resulted in some decomposition of the adduct. The deviations found are on the low side of the calculated value; this would indicate further the absence of type (III) and (VI) adducts, since their presence would augment the values rather than decrease them.

The reaction of the amine hydrochlorides was also evaluated with the difunctional acetal, *p*-xylylidenetetraethylether, and the data summarized in Table 6 indicate that the adduct formed also is of either the (IV) or (V) type.

This conclusion was confirmed by comparing the infrared spectra of the adducts with products obtained by the addition of hydrogen chloride to preformed substituted Schiff bases:



(7)

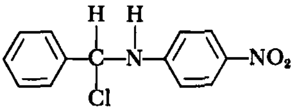
The infrared spectra of the adduct of $C_6H_5CH(OC_2H_5)_2$ with *p*-nitroaniline hydrochloride was completely identical to the reaction product of $C_6H_5CH{=}NC_6H_4NO_2$-*p* with HCl(*g*); and the infrared spectra of the adduct of $C_6H_5CH(OC_2H_5)_2$ with *p*-chloroaniline hydrochloride was also found to be completely identical with the reaction product of $C_6H_5CH{=}NC_6H_5Cl$-*p* with HCl(*g*). An interpretation of absorption bands of these spectra seems to

TABLE 6

Adducts of $(C_2H_5O)_2CHC_6H_4CH(OC_2H_5)_2$ and X—$C_6H_4NH_2$

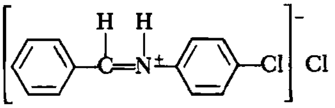
Substituent X	Solvent	Reaction temp., °C	Molecular weight Found	Molecular weight Calcd. as adduct IV or V
—H	None	60	344	356
p-Cl	None	60	408	424

indicate that the nitroaniline adduct has the structure



(—C—N— at 1250 cm^{-1})

and the chloroaniline adduct has the structure

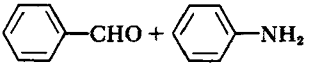
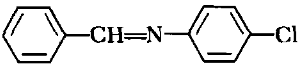
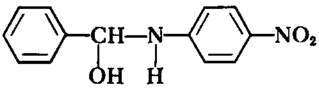


(—C=N— at 1625 cm^{-1})

An evaluation of the products obtained from the adducts on neutralization with aqueous sodium carbonate was also made. The constitutions of the products were determined from their infrared spectra, and the data are summarized in Tables 7 and 8. The products of neutralization shown in Table 7 appear to confirm the structures assigned to the adducts of the nitro- and chloro-substituted compounds. Also, the formation of benzaldehyde and aniline on the neutralization of the adduct when X is H confirms the instability of the adduct obtained with the unsubstituted aromatic compounds compared to those more stable adducts which contain electron-withdrawing substituents. This observation is substantiated by the data in Table 8. In view of the results shown in Table 7 obtained on

TABLE 7

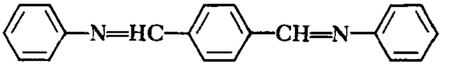
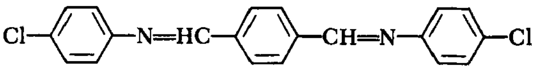
Products from Neutralization of Adducts of $C_6H_5CH(OC_2H_5)_2$ with X—$C_6H_4NH\cdot HCl$

Substituent X	Products of neutralization	M.p., °C	
		Found[a]	Lit.
—H		—	—
p-Cl		62	62 (2)
p-NO$_2$		118	117–118 (*4*)

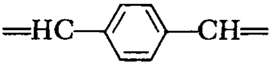
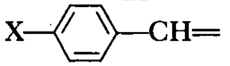
[a] Melting points were taken on a calibrated Fisher-Johns melting point apparatus.

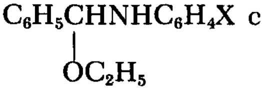
TABLE 8

Products from Neutralization of Adducts of $(C_2H_5O)_2CHC_6H_4CH(OC_2H_5)_2 + X{-}C_6H_4NH{\cdot}HCl$

Substituent X	Product of neutralization	M.p., °C Found[a]	M.p., °C Lit. (*1*,*2*)
—H		166	166
p-Cl		180	180

[a] Melting points were taken on a calibrated Fisher-Johns melting point apparatus.

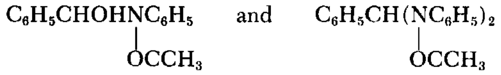
the aniline hydrochloride adduct, one would be led to assume that neutralization of the aniline hydrochloride adduct with $(C_2H_5O)_2$-$CHC_6H_4CH(OC_2H_5)_2$ would lead to the regeneration of $OHCC_6$-H_4CHO and aniline; however, the  moiety in the adduct behaves as substituted  with an electron-withdrawing capacity in its para substitution.

The results obtained from the reaction of the acetals with the aniline hydrochlorides lead to the same conclusion obtained in the reaction of the acetals with the free bases—it is improbable that the monoethoxy intermediate,  $C_6H_5\underset{\displaystyle OC_2H_5}{\underset{|}{C}}HNHC_6H_4X$ can be readily isolated physically; however, these reactions are well suited to the preparation of Schiff bases.

The successful synthesis of Schiff bases by the reaction of aromatic acetals with the aniline and their hydrochlorides led to the consideration of evaluating other aniline derivatives. The substituent should be a group attached to the nitrogen of the aniline that could be displaced or eliminated in a reaction with the acetal. The N-acyl derivatives appear to meet this requirement and the acetyl group was selected as the substituent for evaluation. The overall reaction for the proposed reaction may be written

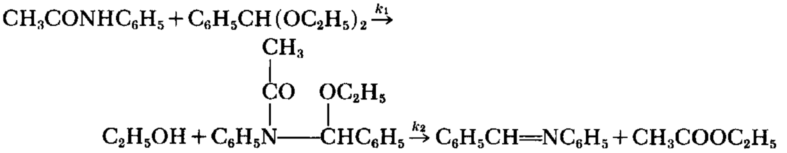
$$CH_3CONHC_6H_5 + C_6H_5CH(OC_2H_5)_2 \rightarrow C_2H_5OH + CH_3COOC_2H_5 + C_6H_5CH{=}NC_6H_5 \quad (8)$$

This reaction of acetanilide with benzylidenediethyl ether was found to be sluggish at temperatures below 150°C and to proceed readily in the temperature range 150–220°C. At the start of the reaction, the distillate was essentially only ethyl alcohol. As the reaction proceeded, the quantity of alcohol in the distillate progressively decreased and the amount of ethyl acetate progressively increased. The results of the uncatalyzed reaction of 0.044 mole of acetanilide with 0.044 mole of the acetal at 200°C are given in Table 9. The distillate was collected as several fractions and its composition determined from its infrared spectra. The amount of distillate corresponded to approximately 90% of the calculated amount. The amount of crude benzylidene aniline isolated also amounted to approximately 90%. Unidentified by-products amounted to about 10%. This high yield of Schiff base was unexpected, since the reaction of the corresponding benzaldehyde with acetanilide produced (*7,8*) primarily



$$\mathrm{C_6H_5CHOH\underset{\underset{OCCH_3}{|}}{N}C_6H_5} \quad \text{and} \quad \mathrm{C_6H_5CH(\underset{\underset{OCCH_3}{|}}{N}C_6H_5)_2}$$

This reaction, obviously, involves a double elimination, first of the ethanol and then of the ethyl acetate, for which the following mechanism can be proposed:



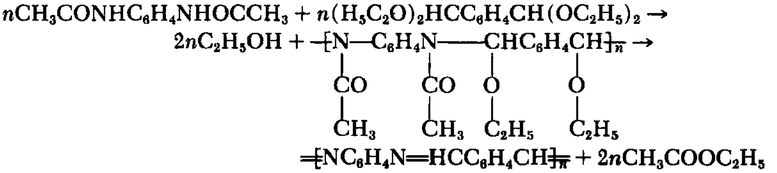
$$\mathrm{CH_3CONHC_6H_5 + C_6H_5CH(OC_2H_5)_2} \xrightarrow{k_1} \mathrm{C_2H_5OH + C_6H_5\overset{\overset{\overset{CH_3}{|}}{CO}}{\overset{|}{N}}\!-\!\!-\!\overset{\overset{OC_2H_5}{|}}{C}HC_6H_5} \xrightarrow{k_2} \mathrm{C_6H_5CH{=}NC_6H_5 + CH_3COOC_2H_5} \quad (9)$$

TABLE 9

Composition of Distillate from Reaction of Acetanilide and Benzylidenediethyl Ether at 200°C

Fraction	Volume (ml) of distillate	Composition
1	0.1	Ethanol
2	0.5	Ethanol
3	0.5	Ethanol > acetate
4	0.5	Ethyl acetate > ethanol
5	0.5	Ethyl acetate > ethanol
6	0.5	Ethyl acetate

The appearance of alcohol exclusively in the early stages of the reaction and of ethyl acetate later in the reaction leads to the conclusion that $k_1 > k_2$, and, if this is so, then the application of this reaction through the use of polyfunctional reagents, to the synthesis of soluble, fusible, polymeric intermediates which could undergo the elimination to polymeric Schiff base, such as



$$nCH_3CONHC_6H_4NHOCCH_3 + n(H_5C_2O)_2HCC_6H_4CH(OC_2H_5)_2 \rightarrow 2nC_2H_5OH + -[\underset{\substack{|\\CO\\|\\CH_3}}{N}-C_6H_4\underset{\substack{|\\CO\\|\\CH_3}}{N}-\underset{\substack{|\\O\\|\\C_2H_5}}{C}HC_6H_4\underset{\substack{|\\O\\|\\C_2H_5}}{C}H]_n- \rightarrow =[NC_6H_4N{=}HCC_6H_4CH]_n= + 2nCH_3COOC_2H_5 \quad (10)$$

Since about 10% of by-products were obtained in the reaction involving monofunctional reagents, the following reactions involving polyfunctional molecules were evaluated:

$$(H_5C_2O)_2HCC_6H_4CH(OC_2H_5)_2 + 2CH_3CONHC_6H_5 \rightarrow 2C_2H_5OH + 2CH_3COOC_2H_5 + \underset{(VII)}{H_5C_6N{=}HCC_6H_4CH{=}NC_6H_5} \quad (11)$$

$$CH_3CONHC_6H_4NHOCCH_3 + 2C_6H_5CH(OC_2H_5)_2 \rightarrow 2C_2H_5OH + 2CH_3COOC_2H_5 + \underset{(VIII)}{C_6H_5CH{=}NC_6H_4N{=}HCC_6H_5} \quad (12)$$

In both cases, ethanol was first eliminated and this was followed by ethyl acetate; however, the amount of by-products obtained was higher than in the case of the monofunctional system and the yields of bi-Schiff bases (VII) and (VIII) were reduced to 78 and 82%, respectively, of the calculated value. Although mono- and di-Schiff bases can be produced by this acetal-anilide reaction, it does not appear, because of by-product formation, to be as suitable for the synthesis of polymers as the reaction of the acetals with the free amines or the other exchange reactions previously reported (*1*).

The syntheses of Schiff base polymers by use of these reactions will be reported in a separate communication (9).

EXPERIMENTAL

The synthesis of reagents and intermediates used in this study have been reported recently (*1,2*).

Reaction of Acetals with Anilines

Since the procedure used was substantially the same for all the reactions using the acetal and the amine, the procedure will be described in general terms and illustrated by a few specific examples. The mixture of the acetal, the aniline, solvent, and catalyst, if used, is mixed in a ground-glass flask equipped with a reflux condenser, and heated for ½ to 3 hr at 50–100°C. Then the alcohol is removed by distillation and the Schiff base recovered, weighed, and recrystallized from benzene or 95% alcohol or a mixture of both. The products are characterized by comparison of their infrared spectra and melting points with authentic samples (*1,2*) as well as by the melting temperature of 50 wt. % mixtures with authentic samples.

1. A mixture of 60 g (0.33 mole) of $C_6H_5CH(OC_2H_5)_2$, 31 g (0.33 mole) of aniline, 120 ml of dry benzene, and 0.10 g of *p*-toluenesulfonic acid or zinc chloride was placed in a ground-glass 500-ml flask equipped with a reflux condenser and the mixture refluxed for 2 hr. Then 50 ml of alcohol-benzene was removed by distillation at atmospheric pressure and the remainder of the benzene removed at 15 mm Hg pressure. The yield, 60 g, of crude product, $C_6H_5CH{=}NC_6H_5$, was quantitative. The product was recrystallized from 95% ethanol, m.p. 49°C; lit. (*1,2*) 49°C.

2. A mixture of 90.0 g (0.5 mole) of $C_6H_5CH(OC_2H_5)_2$ and 46.5 g (0.5 mole) of aniline was placed in a ground-glass flask to which was attached a Dean-Stark trap fitted with a reflux condenser. The flask was heated by an electric mantle controlled by a Variac. The reaction mixture was heated to approximately 100°C and the elimination of alcohol assured by the 76°C temperature of the distillate vapor. The reaction was continued for 90 min. The yield, 90.2 g of crude product, was approximately quantitative; m.p. of recrystallized product, $C_6H_5CH{=}NC_6H_5$, was 49°C.

3. A mixture of 18.0 g (0.1 mole) of $C_6H_5CH(OC_2H_5)_2$, 9.0 g (0.1 mole) of aniline, and 0.05 g of *p*-toluenesulfonic acid was heated in a ground-glass-stoppered flask in a mineral oil bath thermostatically maintained at 55 ± 0.1°C. Samples of the reaction product were withdrawn at intervals of 1, 2½, and 23 hr, and the infrared spectra of the samples recorded.

4. A mixture of 28.2 g (0.1 mole) of *p*-xylylidenetetraethyl ether and 25.3 g (0.2 mole) of *p*-chloroaniline was placed in a 100-ml ground-glass flask and reacted at 150°C by procedure 2. Yield of crude *p*-$ClC_6H_4N{=}HCC_6H_4CH{=}NC_6H_4Cl$-*p* was quantitative. M.p. recrystallized product 180°C, lit. (*1,2*) 180°C.

5. Measurements of elimination rate of ethyl alcohol: A mixture of 18 g (0.1 mole) of benzylidenediethyl ether, 9.3 g (0.1 mole) of

aniline, 200 ml of dry redistilled benzene, and 1.0 g of *p*-toluenesulfonic acid was placed in a 200-ml flask attached to a 3-in. distilling head, a condenser, and a calibrated receiver. The reaction flask was heated by an electric mantle with a Variac control so that approximately 1 ml of liquid was distilled per minute; the vapor temperature of the distillate was recorded as a function of the amount of distillate and is given in Table 10 (shown previously graphically in Fig. 1).

TABLE 10

Rate Data on the Elimination of Alcohol

Reaction time, min	Vol. of azeotropic mixture, cc	Temp. of azeotropic mixture, °C	Reaction time, min	Vol. of azeotropic mixture, cc	Temp. of azeotropic mixture, °C
5.0	1	67.0	30.5	31	69.0
6.5	2	67.0	31.5	32	69.5
7.5	3	67.5	32.0	33	69.5
8.0	4	67.5	32.5	34	69.5
8.5	5	68.0	33.5	35	70.0
9.0	6	68.0	34.5	36	70.0
9.5	7	68.0	35.0	37	70.0
10.0	8	68.0	36.0	38	70.0
10.5	9	68.0	36.5	39	70.0
11.0	10	68.0	37.5	40	70.0
12.5	11	68.0	38.5	41	70.0
13.0	12	68.5	39.0	42	70.0
15.0	13	68.5	39.5	43	71.0
16.0	14	68.5	40.5	44	71.0
17.0	15	68.5	41.5	45	71.0
18.0	16	68.5	42.5	46	71.0
18.5	17	68.5	43.5	47	71.0
19.0	18	68.5	44.5	48	72.0
20.0	19	68.5	47.0	49	73.0
21.0	20	68.5	47.5	50	73.0
21.5	21	68.5	48.5	51	74.0
22.5	22	68.5	50.0	52	74.0
23.0	23	68.5	52.0	53	75.0
23.5	24	69.0	53.0	54	75.0
25.0	25	69.0	54.0	55	75.0
26.5	26	69.0	55.0	56	76.0
27.0	27	69.0	55.5	57	76.0
27.5	28	69.0	56.0	58	77.0
28.0	29	69.0	57.0	59	77.5
29.5	30	69.0	57.5	60	77.5

Reaction of Acetals with Aniline Hydrochlorides

1. Substantially the same procedure was used in all cases. The variations consisted in the nature of the solvent used or the temperature at which the reaction was performed. The procedure consisted of reacting at 0°C or at 25°C a mixture of the acetal and the aniline hydrochlorides for 1 to 2 hr. On mixing the reactants, a clear, homogeneous solution first formed, and on standing the product precipitated and was removed by filtration and dried to constant weight in a vacuum oven at room temperature. Since these adducts were unstable and could not be recrystallized without some decomposition, the concentrations used in the reaction were selected so that the product crystallized directly from the reaction solution, and was then isolated. Under these conditions, the isolated yield was low. Evaporation of the filtrate under reduced pressures of 5 to 15 mm *without heat* afforded more product of almost quantitative yield. However, only those crystals that precipitated as a first crop were used in the study. The molecular weights of the adducts were determined by alkalimetry using 0.1 *N* NaOH as the titrant and a Beckman Model 76 Zeromatic expanded-scale pH meter as the instrument. Typical results are summarized in Table 11.

2. Neutralization of adducts: The procedure consisted of preparing a solution of 1.0 g of sodium carbonate in 10.0 g of water and cooling the solution to 5–10°C. Then 1.0 g of the adduct was added

TABLE 11

Reactions of Acetals and Aniline Hydrochlorides

Acetal	Wt. used, g	Amine hydrochloride	Wt. used, g	Solvent	Wt. used, g	°C temp. of reaction	Grams adduct isolated as ppt.
$C_6H_5CH(OC_2H_5)_2$	5.0	$C_6H_5NH_2$	2.0	H_2O	1.0	0	1.1
$C_6H_5CH(OC_2H_5)_2$	7.0	$C_6H_5NH_2$	2.5	C_2H_5OH	10.0	0	3.0
$C_6H_5CH(OC_2H_5)_2$	5.0	$C_6H_5NH_2$	1.5	Dioxane	5.0	25	1.6
$C_6H_5CH(OC_2H_5)_2$	10.0	p-$O_2NC_6H_4NH_2$	5.0	None	—	0	5.0
$C_6H_5CH(OC_2H_5)_2$	5.0	p-$O_2NC_6H_4NH_2$	2.5	C_2H_5OH	16.0	0	3.0
$C_6H_5CH(OC_2H_5)_2$	2.0	p-$ClC_6H_4NH_2$	0.5	None	—	25	0.7
$C_6H_5CH(OC_2H_5)_2$	2.0	p-$ClC_6H_4NH_2$	0.5	H_2O	2.0	25	0.7
$C_6H_5CH(OC_2H_5)_2$	2.0	p-$ClC_6H_4NH_2$	0.5	$C_6H_5CH_3$	2.0	25	0.8
$C_6H_5CH(OC_2H_5)_2$	2.0	p-$ClC_6H_4NH_2$	0.5	C_2H_5OH	2.0	25	0.6
$C_6H_5CH(OC_2H_5)_2$	2.0	p-$ClC_6H_4NH_2$	0.5	Dioxane	2.0	25	0.7
$C_6H_5CH(OC_2H_5)_2$	5.0	p-$ClC_6H_4NH_2$	1.0	DMA[a]	5.0	25	1.2
$C_6H_4[CH(OC_2H_5)_2]_2$	5.0	$C_6H_5NH_2$	1.0	None	—	60	1.9
$C_6H_4[CH(OC_2H_5)_2]_2$	5.0	$ClC_6H_4NH_2$	1.0	None	—	60	1.5

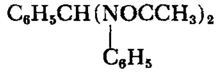
[a] DMA, dimethylacetamide.

with vigorous stirring to the sodium carbonate solution and cooling continued for about 20 min, after which the precipitate was removed by filtration, washed three times with distilled water, and the product dried in a vacuum oven at room temperature. Yield of the product was 0.7–0.9 g. The products were characterized by comparison of melting points and infrared spectra with those of authentic samples (*1*,*2*).

Reaction of Acetals with Acetanilides

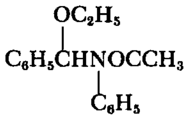
The general procedure consisted of reacting the mixture of acetal and the anilide in a reaction flask in the temperature range 180–225°C until ethanol and ester were no longer eliminated. The crude products were then recrystallized and their melting points and infrared spectra compared with authentic samples. The following are representative examples:

1. A mixture of 12.0 g (0.088 mole) of acetanilide and 16.0 g (0.088 mole) of benzylidenediethylether was heated in a distilling flask at 200°C for 3 hr, at which time 5 ml of distillate had been collected. The cooled reaction product was extracted with hexane to yield 14.3 g (~90% yield) of crude benzalanilide; recrystallized m.p. 49°C, lit. (*1*) 49°C. The hexane-insoluble fraction amounted to 1.6 g (10% of calculated yield), which was recrystallized from 95% ethanol to yield 0.3 g of resinous material and 1.3 g of a white solid which melted over a broad range of 90–116°C and whose elemental analysis more closely approached that of the compound



$$C_6H_5CH(\underset{C_6H_5}{N}OCCH_3)_2$$

than of



$$C_6H_5\overset{OC_2H_5}{C}H\underset{C_6H_5}{N}OCCH_3$$

Analysis: Calcd. for $C_{23}H_{21}N_2O_2$: C, 77.31%; H, 5.88%; N, 7.84%
Calcd. for $C_{16}H_{18}NO_2$: C, 75.00%; H, 7.03%; N, 5.47%
Found: C, 76.85%; H, 5.96%; N, 7.59%

2. A mixture of 28.2 g (0.1 mole) of *p*-xylylidenetetraethylether and 27 g (0.2 mole) of acetanilide was heated at 220°C for 3 hr as in

(1). The crude product was isolated and extracted with a 50:50 mixture of benzene hexane from which was isolated 21.8 g, 78%, of crude $p\text{-}C_6H_5N{=}HCC_6H_4CH{=}NC_6H_5\text{-}p$. Recrystallized m.p. 166°C, lit. (*1*) at 166°C. The benzene-hexane-insoluble material amount to 6.1 g (~21%), which appeared to be amorphous and did not melt at temperatures up to 250°C.

Acknowledgments

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REFERENCES

1. G. F. D'Alelio, J. V. Crivello, T. Kurosaki, and R. K. Schoenig, *J. Macromol. Sci.*, **A1**, 1259 (1967).
2. G. F. D'Alelio, J. V. Crivello, R. K. Schoenig, and T. F. Huemmer, *J. Macromol. Sci.*, **A1**, 1251 (1967).
3. E. Erlenmeyer, *Ber.*, **34**, 817 (1901).
4. O. Dimroth and R. Zoeppritz, *Ber.*, **35**, 984 (1902).
5. A. Lowy and E. H. Bolz, *J. Am. Chem. Soc.*, **43**, 341 (1921).
6. A. Darnow and A. Frese, *Ann.*, **578**, 122 (1952).
7. G. Pulvermacher, *Ber.*, **25**, 304 (1892).
8. A. Einhorn, Ger. Pat. 157,355 (1902).
9. G. F. D'Alelio, T. Kurosaki and T. Ostdick, *J. Macromol. Sci.*, **A2** (1968), in press.

Zussammenfassung

Die Acetale von Arylaldehyden reagieren mit Arylaminen unter quantitativer Bildung von Schiff'schen Basen. Diese Reaktion geht ebenso leicht mit Diaminen und Diacetalen. Hierbei tritt eine zweistufige Eliminierung von Alkohol ein; kinetische Daten zeigen, dass k_2 gleich oder grösser als k_1 ist, was die Isolierung von irgendwelchen Zwischenprodukten erschwert.

Wegen Überlappung von Absorbtionsbanden konnte die Existenz von Zwischenprodukten nicht durch Ultrarotmessungen bestätigt werden. Addukte zwischen den Acetalen und dem Anilinhydrochlorid wurden als Hydrochloride isoliert. Die Molekulargewichte dieser Produkte als auch bei der Neutralisation erhaltener Substanzen weisen darauf hin, dass das Zwischenprodukt keine Monoalkoxyverbindung ist. Ebenso reagieren die Acetale mit N-Acylanilin unter Eliminierung von, k_1, Alkohol und, k_2, Ester, wobei $k_1 > k_2$, unter Bildung von Schiff'schen Basen, wobei die Ausbeute nicht quantitativ ist. Diese Reaktion von Acetalen mit Aminen und deren N-Acylderivaten sind für die Synthese von Polymeren von Interesse.

Résumé

Les acétals des aldéhydes aryl réagissent avec les aryl amines et donnent des bases de Schiff avec un rendement quantitatif. Cette réaction est aussi facile avec les diamines et les diacetals. Elle comporte une élimination d'alcool en deux stades; les données cinétiques indiquent que k_2 est egal ou plus grand que k_1 et ce fait complique l'élimination de n'importe quel produit intermédiaire.

En raison du chevauchement des bandes, l'existence des intermédiaires n'a pas pu être confirmée par des mésures spectrales dans l'infrarouge. On a isolé des adducts entre les acétals et les chlorhydrates d'aniline sous forme des chlorhydrates; leur poids moléculaire et les produits obtenus par neutralisation indiquent que l'intermédiaire n'est pas un composé monoalcoxy. Les acétals réagissent aussi avec les N-acyl anilines par élimination du k_1 de l'alcool et k_2 de l'ester, ou $k_1 > k_2$, et donnent des bases de Schiff avec un rendement plus faible que quantitatif. Ces réactions entre les acétals et las amines et leurs derives N-acyles présentent un intérêt dans la synthèse des polymerès.

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