*Studies of trans-Dicyanodiethoxycarbonylethylene. II. Reactions with Ammonia and Primary Aromatic Amines**

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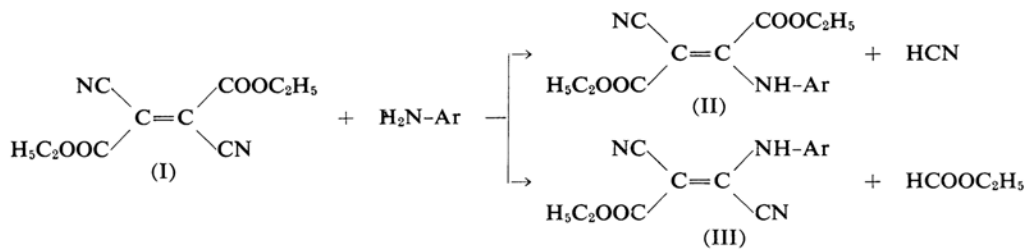
As has been described in a previous paper[1], the reactions of *trans*-dicyanodiethoxycarbonylethylene (I) with tertiary aromatic amines resulted in the addition of a benzene nucleus to the ethylenic double bond with the formation of 4-α, β-dicyano-α, β-diethoxycarbonyl-*N*, *N*-dialkylanilines. In the present paper, the reactions of I with ammonia or primary aromatic amines are investigated.

Reactions with Primary Aromatic Amines. — When a mixture of primary aromatic amine

* This work was presented at the 14th Annual Meeting of the Chemical Society of Japan, Tokyo, April, 1961.

1) Part I, K. Kudo, This Bulletin, 35, 1490 (1962).



II Ar; *p*-CH_3O-C_6H_4, *p*-CH_3-C_6H_4, or *p*-Cl-C_6H_4
III Ar; *p*-CH_3O-C_6H_4, *p*-CH_3-C_6H_4, *p*-Cl-C_6H_4, *m*-NO_2-C_6H_4, or β-$C_{10}H_7$

and I in an organic medium was heated, *N-trans*-α, β-diethoxycarbonyl-β-cyanovinylamines (II) and *N-trans*-α, β-dicyano-β-ethoxycarbonylvinylamines (III) were obtained. In these reactions, when the molar ratio of I to primary amine was 1 : 2, II products, resulting from the substitution of a cyano group with an amine group, predominated. On the other hand, III products, resulting from the substitution of an ethoxycarbonyl group, predominated when the molar ratio of I to primary amine was 2 : 1. Neither II nor III products were obtained by the reaction of I with α-naphthylamine or *p*-nitroaniline, while with *m*-nitroaniline or β-naphthylamine only III products were obtained. These results are shown in Table I.

The structures of III and II were determined in the following manner. By the hydrolysis of II or III with a 10% aqueous sodium hydroxide solution, the parent amine was recovered in a good yield. This result suggests that the vinyl group is attached to the nitrogen atom rather than to the carbon atom. The infrared absorption spectrum of III (Ar; *p*-CH_3-C_6H_4) showed an NH band at 3115 cm^{-1}, C≡N bands at 2227 and 2247 cm^{-1}, and a C=O band at 1680 cm^{-1} (Fig. 1). The infrared absorption spectrum of II (Ar; *p*-CH_3-C_6H_4) showed an NH band at 3185 cm^{-1}, a C≡N band at 2227 cm^{-1}, and C=O bands at 1672 and 1754 cm^{-1} (Fig. 1). The facts that the ester groups of II showed two bands at 1672 and 1754 cm^{-1} and that of III only a band at 1680 cm^{-1} suggest that the bands at 1754 and 1672 cm^{-1} are to be attributed to the ester groups attached to the α- and β-carbon atoms in the aromatic amine group respectively. Similarly, it is expected that the C≡N bands at 2247 and 2227 cm^{-1} are to be attributed to the C≡N groups attached to the α- and β-carbon atoms respectively. (Incidentally, it is generally known that the carbonyl and nitrile frequencies are shifted from their normal positions toward longer wavelengths by conjugation with the vinyl group and also by strongly electronegative substituents on the α-carbon atom, while the α,β-unsaturated carbonyl and nitrile frequencies shift from their normal position toward shorter

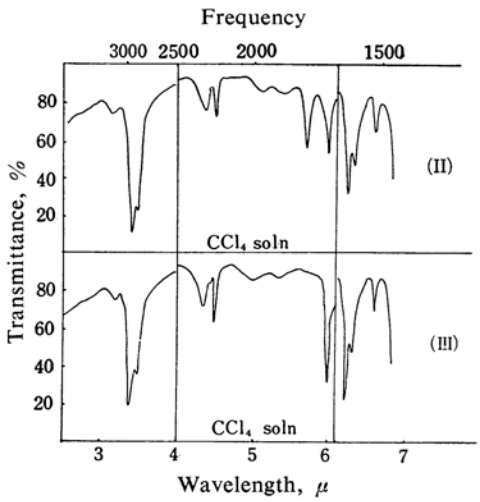
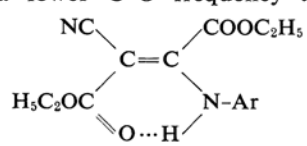


Fig. 1. The infrared absorption spectra of (II, Ar; *p*-CH_3-C_6H_4) and (III, Ar; *p*-CH_3-C_6H_4). A lithium fluoride prism was used for the measurement of C=O and C≡N bands in carbon tetrachloride and one of rock salt for the other bands in Nujol mull.

wavelength in the case of sterically hindered compounds[2].) The geometrical structures of II and III were established on the basis of the considerations of the C=O frequencies of the β-esters of II and III. It was already known that a C=O frequency of β-amino-α, β-unsaturated ester is shifted toward a low frequency by the formation of a chelate hydrogen-bond structure[3]. Thus, the evidence that the β-ester of II had a lower C=O frequency than that of

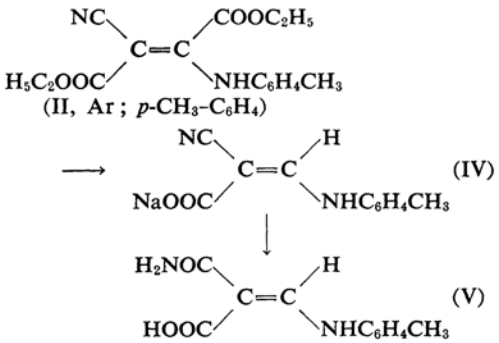


III would indicate that II had an intramolecular chelate structure II'. Accordingly, it should be concluded that II and III have ester-ester and nitrile-nitrile trans geometries respectively.

Further chemical evidence for II was obtained

2) D. G. I. Felton and S. F. D. Orr, *J. Chem. Soc.*, **1955**, 2170.
3) B. Witkop, *J. Am. Chem. Soc.*, **78**, 2873 (1956).

by step by step hydrolysis and decarboxylation of II (Ar; p-CH_3-C_6H_4) to β-p-toluidino-α-carbamoylacrylic acid (V) via sodium β-p-toluidino-α-cyanoacrylate (IV). While the



(II, Ar; p-CH_3-C_6H_4)

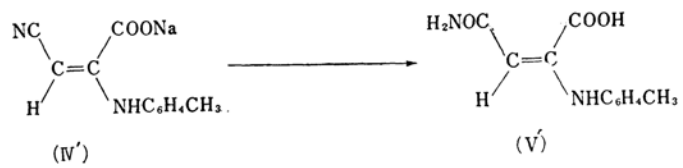
(IV)

(V)

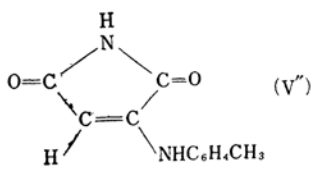
infrared absorption spectra of IV and V did not exclude the possibility that these compounds may possess the corresponding isomeric forms, IV′ and V′, this possibility was rejected when cyclic imide V″, the expected product from IV′, was not obtained by the hydrolysis of IV′ with dilute hydrochloric acid.

III (Ar; p-CH_3-C_6H_4) was also hydrolyzed with a 10% methanolic potassium hydroxide solution to give potassium β-p-toluidino-β-cyano-α-potashcarbamoylacrylate (VI). When the solution of VI was acidified, α-p-toluidino-α'-carbamyl maleimide (VII) was formed readily by the intramolecular cyclization of the CN and COOH groups. If the VI′ structure were correct, the C=O frequency would be shifted toward a shorter wavelength by deviation from the planar configuration which was attributed to the steric repulsion between the aryl and the amide C=O groups. Consequently, the VI′ structure should be excluded on the evidence that the spectrum showed its low frequency at 1650 cm^{-1}.

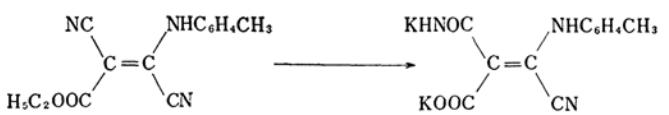
Kissinger and Ungnade[4] discovered that α, α-dinitro-ester, $RC(NO_2)_2COOC_2H_5$, undergoes the substitution of an ethoxycarbonyl group with alcoholic hydrazine hydrate. Thesing[5] and Dornow[6] described how the displacement of a nitrile group of acylcyanides occurs readily in reaction with nucleophilic reagents in a neutral and especially in a weak alkaline



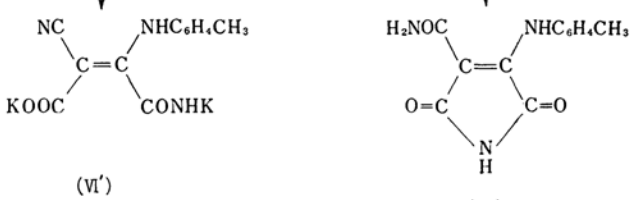
(IV′) (V′)



(V″)

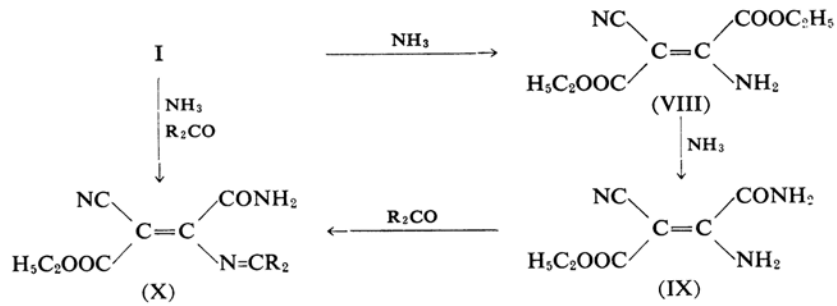


(III, Ar; p-CH_3-C_6H_4) (VI)



(VI′) (VII)

4) L. W. Kissinger and H. E. Ungnade, *J. Org. Chem.*, **23**, 1340 (1958).
5) J. Thesing and D. Witzel, *Angew. Chem.*, **68**, 425 (1956).
6) A. Dornow and H. Grabhöfer, *Ber.*, **91**, 1824 (1958); A. Dornow, *Angew. Chem.*, **70**, 400 (1958).



solution. Thus, as indicated by Middleton[7], if the $\rangle C{=}C\langle^{CN}_{COOC_2H_5}$ group may be analogous to the $\rangle C{=}O$ group in its electron-drawing effects, the formation of II or III respectively by the substitution of C≡N or $COOC_2H_5$ with aromatic amine derivatives seems to be reasonable.

The mechanism of these substitution reactions would be similar to the reaction mechanism of the formation of 4-*trans*-α, β-diethoxycarbonyl-β-cyanovinyl-*N*, *N*-dialkylaniline from I described in the previous paper[1]. Namely, these reactions would be initiated by the formation of the π-complexes between I and primary aromatic amines, since the intense electronic absorption bands of the reaction mixture at λ_{max} 315~365 mμ and λ_{max} 440~510 mμ are attributable to neither the I products nor to the primary aromatic amines, but to the π-complex itself as a new molecular species. The second step in the reaction appears to be an addition of primary aromatic amine to give an adduct, although the adduct as an intermediate was not isolated. The final step is an elimination of hydrogen cyanide or ethyl formate to yield II or III respectively.

Reaction with Ammonia.—The reaction of I and ammonia with a molar ratio of 1 : 1 gave only one product, *trans*-α, β-diethoxycarbonyl-β-cyanovinylamine (VIII), in a good yield. By a similar procedure, α-carbamoyl-β-cyano-β-ethoxycarbonylvinylamine (IX) was obtained from I via VIII by ammonolysis of an ester group with the excess of ammonia in a good yield, but diamide derivatives of VIII were not obtained. The infrared absorption spectrum of VIII showed NH bands at 3401 and 3279 cm^{-1}, a C≡N band at 2212 cm^{-1}, and C=O bands at 1761 cm^{-1} (α-ester) and 1687 cm^{-1} (β-ester) (Fig. 2). The infrared absorption spectrum of IX had NH bands at 3448, 3356, 3257 and 3185 cm^{-1}, a C≡N band at 2222 cm^{-1}, and C=O bands at 1695 (β-ester) and 1667 cm^{-1} (α-amide) (Fig. 2). In these spectral data, the evidence that the β-esters of VIII and IX had low C=O frequencies is to be attributed to the formation of an intramolecular hydrogen-bond[3] between the C=O and amino groups. Further chemical evidence for VIII and IX was supplied by the synthesis of the acetyl derivatives and by the formation of Schiff bases X respectively. X products were also obtained directly from I. The X structures were established on the bases of the synthesis of the acetyl derivatives and supported by the fact that X products were hydrolyzed with an aqueous sodium hydroxide solution to give the parent ketone, which would indicate that the ketone was attached to the nitrogen atom rather than to the carbon atom.

The mechanism of the formation of VIII products would be similar to the reaction mechanism of the formation of II products described above.

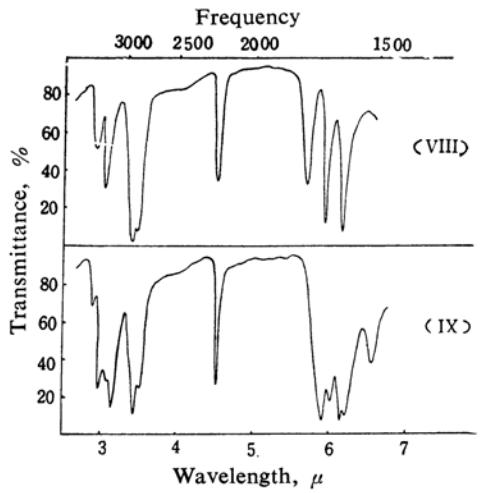


Fig. 2. The infrared absorption spectra of VII and IX.

Experimental

***N*-*trans*-α, β-Dicyano-β-ethoxycarbonylvinylamines (III).**—III products were generally prepared by the reaction of primary aromatic amines with the excess of I in dimethylformamide at 50~60°C. Other solvents, such as pyridine, acetonitrile and ethyl formate, were also used. In a typical experiment, a mixture of 4.3 g. (0.04 mol.) of *p*-toluidine

7) W. J. Middleton and V. A. Engelhart, *J. Am. Chem. Soc.*, **80**, 2788 (1958).

TABLE I. PROPERTIES OF II, $H_5C_2OOC(NC)C:C(COOC_2H_5)NHAr$ AND III, $H_5C_2OOC(NC)C:C(CN)NHAr$

Compound Ar		Yield* %	M. p. °C	λ_{max} mμ	log ε	Formula	Found (Calcd.) Mol. wt.	C, %	H, %	N, %
p-CH_3-C_6H_4	II	28	103 ~104	310	4.184	$C_{16}H_{18}O_4N_2$	315 (302)	63.36 (63.56)	5.98 (6.00)	9.13 (9.27)
	III	92	116.5~116.7	225 355	3.915 4.059	$C_{14}H_{13}O_2N_3$	246 (255)	65.82 (65.87)	5.18 (5.13)	16.54 (16.46)
p-CH_3O-C_6H_4	II	30	92.5~ 93.5	225 305	4.029 4.175	$C_{16}H_{18}O_5N_2$	314 (318)	60.11 (60.36)	5.75 (5.72)	8.90 (8.79)
	III	43	141 ~143.5	230 360	4.087 4.080	$C_{14}H_{13}O_3N_3$	274 (271)	61.88 (61.96)	4.77 (4.83)	15.77 (15.48)
p-Cl-C_6H_4	II	11	99.5~100.5	225 310	3.859 4.154	$C_{15}H_{15}O_4N_2Cl$	322 (323)	55.88 (55.79)	4.63 (4.67)	8.89 (8.73)
	III	36	165 ~165.5	230 360	4.280 4.314	$C_{13}H_{10}O_2N_3Cl$	261 (275)	56.62 (56.63)	3.70 (3.66)	15.27 (15.22)
m-NO_2-C_6H_4	III	trace	120.5~121.5	230 345	4.145 4.224	$C_{13}H_{10}O_4N_4$	275 (286)	54.37 (54.55)	3.68 (3.52)	—
β-$C_{10}H_7$	III	trace	148 ~150	358	4.239	$C_{23}H_{17}O_2N_3$	289 (291)	70.02 (70.09)	4.47 (4.50)	—

* In the media of dimethylformamide

and 18 g. (0.08 mol.) of I in 30 ml. of dimethylformamide was heated at 50~60°C while being stirred for 30 min. The solvent was distilled off in vacuo, and the red residue was kept in an ice-box for several days. The solidified residue was recrystallized from ethanol-water to give 9 g. (92%) of III (Ar; p-CH_3-C_6H_4) (m. p. 116.5~117°C) in the form of yellow crystals (Table I).

***N*-*trans*-α, β-Diethoxycarbonyl-β-cyanovinylamines (II).**—II products were prepared from I with an excess of primary aromatic amines by a similar procedure. For example, from 12 g. (0.06 mol.) of I and 12 g. (0.12 mol.) of p-toluidine, II (Ar; p-CH_3-C_6H_4) (m. p. 103~104°C) was obtained in a 5 g. (28%) yield (Table I).

Hydrolysis of III (Ar; p-Cl-C_6H_4) to p-Chloroaniline.—A mixture of 1 g. of III (Ar; p-Cl-C_6H_4) and 50 ml. of a 10% sodium hydroxide solution was refluxed for 3.5 hr. and then steam distilled. The distillate was cooled to give 0.3 g. (77%) of p-chloroaniline; m. p., 68~69°C. The p-chloroaniline was dissolved in a solution of 4 ml. of pyridine and a small quantity of ether. The addition of 0.3 ml. of acetyl chloride to the solution gave p-chloroacetanilide (m. p. 177~179°C, alone or mixed with an authentic sample). Similarly, the other II and III products also gave the corresponding parent amines.

Hydrolysis of II (Ar; p-CH_3-C_6H_4) to Sodium β-p-Toluidino-α-cyanoacrylate (IV).—A mixture of 3 g. of II (Ar; p-CH_3-C_6H_4) and 5 g. of sodium carbonate in 45 ml. of water was heated under reflux for 2.5 hr. and then cooled to 0°C. The precipitated IV was filtered off and recrystallized from ethanol-water to give colorless crystals (m. p. 232~233.5°C (decomp.)).

Found: C, 58.82; H, 4.23. Calcd. for $C_{11}H_{19}O_2N_2Na$: C, 58.93; H, 4.05%.

Its infrared absorption spectrum had bands at 3230 cm^{-1} (NH), 2200 cm^{-1} (C≡N) and 1640 cm^{-1} (C=O).

Hydrolysis of Sodium β-p-Toluidino-α-cyanoacrylate (IV) to β-p-Toluidino-α-carbamoylacrylic Acid (V).—A clear solution of 2 g. of IV in 100 ml. of water was acidified with hydrochloric acid to pH 3. The precipitated crystals were recrystallized from ethanol. There was obtained 1 g. of V (m. p. 166.5~168.5°C) as yellow crystals.

Found: C, 60.08; H, 5.48. Calcd. for $C_{11}H_{12}O_3N_2$: C, 59.99; H, 5.49%.

Its infrared absorption spectrum showed bands at 3330 cm^{-1} and 3170 cm^{-1} (NH), and 1655 and 1645 cm^{-1} (C=O).

Hydrolysis of III (Ar; p-CH_3-C_6H_4) to Potassium β-p-Toluidino-β-cyano-α-potashcarbamoylacrylate (VI).—A mixture of 2.6 g. of III (Ar; p-CH_3-C_6H_4), 5 g. of potassium hydroxide, 25 ml. of methanol, and 25 ml. of water was heated on a boiling water bath for 2 hr. After cooling, the precipitated crystals were recrystallized several times from ethanol-water to give 1.3 g. of VI (m. p. 274~275°C) as colorless crystals.

Found: C, 42.20; H, 3.43; N, 12.40. Calcd. for $C_{12}H_{11}O_4N_3K_2$: C, 42.45; H, 3.27; N, 12.38%.

Its infrared absorption spectrum showed peaks at 3480, 3340, 3200, 2160 and 1650 cm^{-1}.

Cyclization of Potassium β-p-Toluidino-β-cyano-α-potashcarbamoylacrylate (VI) to α-p-Toluidino-α'-carbamoylmaleimide (VII).—A solution of 3 g. of VI in 100 ml. of water was acidified with hydrochloric acid. The precipitated crystals were collected, washed with water, and recrystallized from dimethylformamide-ethanol to give VII (m. p. 276~277°C) as yellow crystals.

Found: C, 58.77; H, 4.60; N, 17.25. Calcd. for $C_{12}H_{13}O_3N_3$: C, 58.77; H, 4.52; N, 17.14%.

Its infrared absorption spectrum showed bands at 3420 and 3200 cm^{-1} (NH), 1760 and 1730 cm^{-1} (succinimide type C=O), and 1665 cm^{-1} (amide C=O).

***N*-*trans*-α, β-Diethoxycarbonyl-β-cyanovinylamine (VIII).**—*With Ammonium Hydroxide.*—Three grams (0.05 mol.) of 28% ammonium hydroxide were slowly stirred into a mixture of 11 g. (0.05 mol.) of I and 60 ml. of acetonitrile at 5~8°C. The solvent was evaporated at room temperature, and the residue was crystallized to give 10 g. (94%) of VIII (m. p. 78~79°C).

Found: C, 50.82; H, 5.65; N, 13.33. Calcd. for $C_9H_{12}O_4N_2$: C, 50.94; H, 5.70; N, 13.20%.

With Ammonia Gas.—A mixture of 2.8 g. (0.013 mol.) of I and 15 ml. of acetonitrile was placed in a 50 ml. three-necked flask equipped with a mechanical stirrer and a gas inlet tube. After the flask had been cooled in an ice-salt bath at −10~15°C and the mechanical stirring had been started, ammonia gas was slowly passed into the mixture for 2~3 min. until an orange color appeared; the reaction was then allowed to proceed for 20 min. When the acetonitrile was removed by vacuum distillation, the residue solidified to give 2.1 g. (75%) of VIII (m. p. 78~79°C) as colorless crystals.

α-Carbamoyl-β-cyano-β-ethoxycarbonylvinylamine (IX).—A mixture of 11 g. (0.05 mol.) of I and 60 ml. of acetonitrile was placed in a three-necked flask equipped with a sealed mechanical stirrer, a gas inlet tube, and a gas outlet tube protected with a calcium chloride tube. Ammonia gas was vigorously passed for 2 hr. into the mixture, which had been cooled throughly in an ice-salt bath. The solvent was removed by distillation, and the residue was crystallized. After recrystallization from alcohol, the yield of IX (m. p. 145~146°C (decomp.)) as colorless crystal was 7.5 g. (82%).

Found: C, 46.09; H, 5.03; N, 22.66. Calcd. for $C_7H_9O_3N_3$: C, 45.90; H, 4.95; N, 22.94%.

Preparation of Schiff Bases (X).—*From I.*—A mixture of 11 g. (0.05 mol.) of I and 100 ml. of acetone was treated with ammonia gas by a procedure similar to that used in the preparation of IX. The yield of X (R; CH_3) (m. p. 235~236°C) as colorless crystals was 3.2 g. (30%).

Found: C, 53.82; H, 6.02; N, 18.77. Calcd. for $C_{10}H_{13}O_3N_3$: C, 53.80; H, 5.87; N, 18.83%.

The infrared absorption spectrum of X (R; CH_3) had bands at 3322, 3226, 2220, 1733 and 1692 cm^{-1}.

In a similar procedure, X (R; C_2H_5) was obtained in a 84% yield.

Found: C, 57.06; H, 6.90; N, 16.75. Calcd. for $C_{12}H_{17}O_3N_3$: C, 57.38; H, 6.82; N, 16.72%.

From N-trans-α, β-Diethoxycarbonyl-β-cyanovinylamine (VIII) and α-Carbamoyl-β-cyano-β-ethoxycarbonylvinylamine (IX).—In a similar procedure, the yields of X from VIII and from IX were 86 and 79% respectively.

Hydrolysis of Schiff Bases (X).—A mixture of 1 g. of X and 100 ml. of a 5% aqueous sodium hydroxide solution was placed in a two-necked flask equipped with a gas inlet tube and a condenser with a gas outlet tube leading to a trap containing a 2,4-dinitrophenylhydrazine solution. The mixture was refluxed, and nitrogen gas was slowly passed into the mixture. Acetone 2,4-dinitrophenylhydrazone (m. p. 126°C) was precipitated as red needle crystals.

Acetylation of *N*-*trans*-α, β-Diethoxycarbonyl-β-cyanovinylamine (VIII).—*With Acetic Anhydride.*—A mixture of 4.2 g. (0.02 mol.) of VIII, 10 ml. of acetic anhydride, and three drops of concentrated sulfuric acid was heated under reflux for 8 hr. After cooling, the dark brown residue was crystallized to give 1.8 g. (33%) of α-ethoxycarbonyl-α'-diacetylaminomaleimide (m. p. 173~174°C) as colorless crystals.

Found: C, 49.45; H, 4.95; N, 10.52. Calcd. for $C_{11}H_{12}O_6N_2$: C, 49.25; H, 4.51; N, 10.45%.

Its infrared absorption spectrum had bands at 3344, 1812, 1779, 1745, 1704 and 1681 cm^{-1}.

With Acetyl Chloride.—A two-necked flask, equipped with a dropping funnel and a reflux condenser protected with a calcium chloride tube, was charged with 17 g. (0.08 mol.) of VIII and 200 ml. of acetone. The mixture was heated under reflux, and 150 ml. of acetyl chloride was added over a period of a few minutes. After the mixture had been refluxed for an additional 2 hr., the solvent was removed by vacuum distillation at room temperature and a dark red residue was crystallized. By recrystallization several times from acetone, α, β-diethoxycarbonyl-β-cyanovinylacetylamine (m. p. 215~216°C) was obtained in a 2.2 g. (11%) yield.

Found: C, 51.90; H, 5.42. Calcd. for $C_{11}H_{14}O_5N_2$: C, 51.96; H, 5.55%.

Its infrared absorption spectrum had bands at 3226, 2222, 1802, 1709 and 1654 cm^{-1}.

Acetylation of Schiff Bases X with Acetyl Chloride.—A mixture of 1 g. (0.004 mol.) of X, 10 ml. of acetic anhydride, and a few drops of concentrated sulfuric acid was refluxed for 10 min. After cooling, the mixture was crystallized to give α-*N*-acetylcarbamoyl-β-ethoxycarbonyl-β-cyanovinylisopropylidenamine (m. p. 200~201°C) in a 10% yield.

Found: C, 54.38; H, 6.05; N, 15.80. Calcd. for $C_{12}H_{15}O_4N_3$: C, 54.33; H, 5.70; N, 15.84%.

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