[CONTRIBUTION FROM THE RESEARCH AND DEVELOPMENT DEPARTMENT OF THE SUN CHEMICAL CORPORATION]

A Reaction of Formaldehyde with Nitriles

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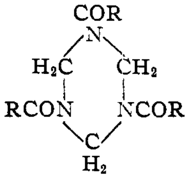
A study of the reaction between formaldehyde precursors and nitriles has led to an organic reaction not described in the literature.[1] It has been found that in the presence of catalytic quantities of concentrated sulfuric acid, the main products are adducts of formaldehyde and the respective nitriles. They are substituted hexahydro-*s*-triazines having the general formula



R =
I, CH_3—
II, CH_3CH_2—
III, CH_2ClCH_2—
IV, $CH_2{=}CH$—
V, $CH_2{=}C(CH_3)$—
VI, C_6H_5—

The hexahydro-*s*-triazine structure for this class of compounds is supported by chemical analysis and infrared data. Further, the reaction product obtained with benzonitrile and formaldehyde proved to be identical with a compound prepared by Duden and Scharff[2] by another method. These authors claimed VI as the structure of their product.

Concentrated sulfuric acid and chlorosulfonic acid have been found to be catalysts for this reaction; 75% sulfuric acid gave no reaction.

The quantity of sulfuric acid influences the course of the reaction. Thus it was found, as described in the literature, that formaldehyde and nitriles mixed with five times as much by weight of sulfuric acid as reactants, yield the corresponding methylene-bis-amides.[3,4,5,6] In fact, minute quantities of methylene-bis-propionamide have been isolated when working with the small quantities of sulfuric acid necessary to produce II.

The reaction was shown to be applicable to alkyl, aryl, unsaturated and halogen substituted nitriles. Using excess nitrile does not change the course of the reaction. It was possible to substitute paraformaldehyde for trioxane in the reaction but poorer yields were obtained.

Experimental

The following specific example is generally applicable to the preparation of the hexahydro-*s*-triazines.

Hexahydro-1,3,5-tripropionyl-*s*-triazine.—In a three-necked flask provided with a thermometer, mercury-sealed stirrer, dropping funnel and condenser, 27.5 g. propionitrile (0.5 mole) was mixed with 1.3 g. sulfuric acid. The temperature of the mixture was raised to 95°. A solution of 30 g. of trioxane (1 mole formaldehyde) in 27.5 g. of propionitrile was dropped in. An exothermic effect was observed which subsided as the addition was continued. The mixture was brought to reflux during addition. The internal temperature gradually rose while refluxing and when it reached 155°, at which temperature refluxing had virtually ceased, heating was stopped. The dark brown, heavy fluid was treated with 70 cc. of 90% ethanol, yielding a solid, which on recrystallization from 50 cc. 90% ethanol gave 39 g. of a white crystalline solid.

Using two moles of propionitrile to one of formaldehyde the same product was obtained in 59% yield based on trioxane. Substantially all of the excess nitrile was recovered by distillation.

When concentrated sulfuric acid was substituted by 2 g. of chlorosulfonic acid, II was obtained in 24% yield.

In a run with 4 moles of propionitrile and 4 moles of formaldehyde (as trioxane) it was possible to isolate a small quantity of material from the concentrated mother liquor after isolation of II which on recrystallization from ethanol gave a white solid, m. p. 201–202°. When mixed with methylene-bis-propionamide (m. p. 202°) in 1:1 ratio, it gave no depression.

Hexahydro-1,3,5-triacetyl-*s*-triazine.—In this preparation 2.4 g. of concentrated sulfuric acid was used with a 1:1 molar ratio of reactants. Addition of trioxane solution was started at the reflux temperature of acetonitrile (80°).

The heavy liquid product crystallized from 25 cc. of water and recrystallized twice with 25-cc. portions of hot water gave a hydrate, m. p. 71.5–73.5°. Dehydration yielded the anhydrous I in 66% yield. This substance melted at 96–98°.

Crystallization of the heavy liquid from absolute ethanol or recrystallization of the hydrate from this solvent yielded the anhydrous product. This, on exposure to moisture, reverted to the hydrate.

When paraformaldehyde was used in this reaction, the solid was added in small portions to all the nitrile and sulfuric acid while refluxing. Yields of the desired product were poor. Loss of paraformaldehyde by sublimation occurred.

When concentrated sulfuric acid was substituted for by as much as 10 g. of 75% sulfuric acid no I was isolated.

Hexahydro-1,3,5-tri-(β-chloropropionyl)-*s*-triazine.—A 1:1 molar ratio of reactants with 2.4 g. of concentrated sulfuric acid was employed. Reaction started when internal temperature reached 80°. The product during reaction crystallized out and was recrystallized from 300 cc. of ethanol, yielding 90 g. of product.

Hexahydro-1,3,5-triacrylyl-*s*-triazine.—This reaction was run with one mole of the reactants and 0.5 g. of concentrated sulfuric acid. A solution of the trioxane in 40 cc. of benzene was added to the nitrile and sulfuric acid at the reflux temperature. Heat of reaction during addition was sufficient to maintain refluxing. The product is insoluble in benzene and crystallized out during addition. Recrystallization from 200 cc. of ethanol, yielded 34 g.; no m. p. was observed; compound polymerized on heating.

Note: Acrylonitrile was freshly distilled. Impurities delay or inhibit reaction. Delayed reactions can get out of control if appreciable quantities of trioxane have been added before reaction starts.

Hexahydro-1,3,5-trimethacrylyl-*s*-triazine.—The reaction was carried out without inert solvent in 1:1 molar ratio of reactants with 2.4 g. of concentrated sulfuric acid. An exothermic effect was observed but heating was neces-

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(1) After completion of the preparation of the compounds described in this paper a report was released (Report F-TS-3466-RE, p. 636, Air Materiel Command, Wright Field, Dayton, Ohio, June, 1947) abstracting a German patent application dealing with hexahydro-1,3,5-triarylyl-*s*-triazine.

(2) Duden and Scharff, *Ann.*, **288**, 247 (1895).

(3) Hepp and Spiess, *Ber.*, **9**, 1424 (1876).

(4) Hepp, *ibid.*, **10**, 1649 (1877).

(5) Kraut, *Ann.*, **258**, 109 (1890).

(6) Thiesing, *J. prakt. Chem.*, [2] **44**, 570 (1891).

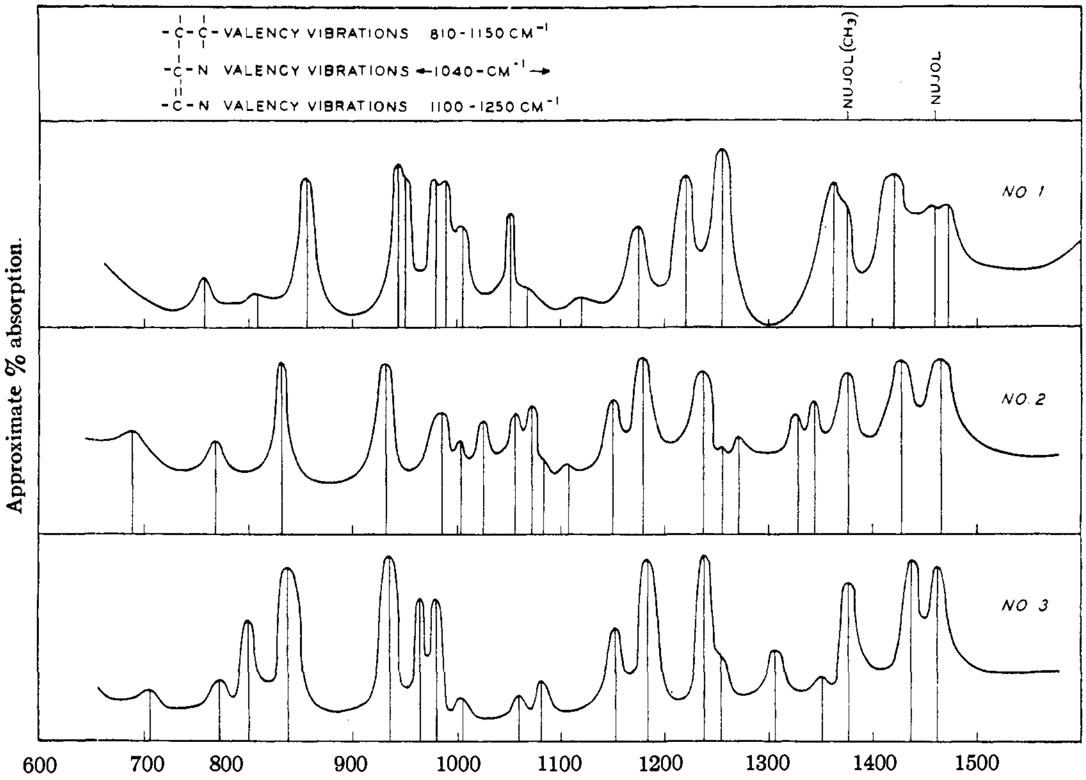

Fig. 1.—Infrared absorption spectra.

sary throughout addition to maintain reflux temperature (92°). After recovering 30% of unreacted nitrile by distillation, the heavy liquid crystallized from ethanol by solution in 100 cc. of this solvent and evaporation to one-half the original volume. After three recrystallizations from ethanol, using a total of 100 cc. of solvent, there was obtained a white crystalline product, yield 10 g.

Note: Methacrylonitrile was freshly distilled.

Hexahydro-1,3,5-tribenzoyl-*s*-triazine.—This reaction was carried out by mixing 0.2 mole of the benzonitrile and 0.2 mole of the formaldehyde (as trioxane) adding the catalytic quantity of sulfuric acid (0.4 g.) and heating on a boiling water-bath. A vigorous reaction ensued leaving a dark solid product. After extracting impurities with alcohol, the remaining white solid was recrystallized by solution in chloroform and precipitation with ether; yield 10 g.

Methylene-bis-benzamide was prepared, m. p. 220–222°. It was mixed in 1:1 ratio with VI; the melting range was 191–212°.

The product obtained by Duden and Scharff[2] from ammonium chloride, formalin and benzoyl chloride was prepared, m. p. 220–222.5°. Mixed with VI in 1:1 ratio it melted at 220–223°. When the former was mixed with methylene-bis-benzamide, however, it gave a melting point depression; the melting range was 192–212°.

Nitriles and Trioxane Reacted in the Presence of Larger Quantities of Concentrated Sulfuric Acid.—The general procedure described for propionitrile was followed but 50–150 g. of concentrated sulfuric acid per mole of formaldehyde was used and less heat or even cooling was applied during the addition. In all cases (aceto-, propio- and benzonitrile) the methylene-bis-amide was isolated. No formation of a corresponding hexahydro-*s*-triazine was observed.

Infrared Analyses.—The samples were prepared by grinding them with Nujol and placing the resulting Nujol paste between rocksalt plates. The Nujol, used in this manner, cuts down the scattering of a crystalline sample and absorbs only in the C-H stretching and deformational regions of the spectrum at 2920, 2855, 1460 and 1375 cm.$^{-1}$.

All other absorption bands appearing in the spectra are due to the samples. The exact wave numbers (cm.$^{-1}$) of the bands are as follows: I, 757, 810, 855.6, 945.4, 951.3, 981, 988.5, 1002.7, 1053, 1067, 1120, 1176, 1218, 1253, 1363, 1374 (Nujol), 1419, 1459 (Nujol), 1472, 1655, 2430, 2855 (Nujol), 2919 (Nujol), 2952, 3027, 3077, 3300; II, 690, 770, 821, 833.5, 932.7, 987, 1006.5, 1027.5, 1056, 1074, 1084, 1108, 1153, 1180, 1239, 1257, 1273, 1328, 1346, 1376 (Nujol), 1427, 1464 (Nujol), 1654, 2850 (Nujol), 2915 (Nujol), 3047, 3272; IV, 705, 772.2, 800, 836.5, 936, 965.5, 981.7, 1004.3, 1063, 1081.5, 1152,

Table I

Data for Some Hexahydro-1,3,5-triacyl-*s*-triazines

Nitrile used	Formula	Yield,[a] %	M. p.,[b] °C.	Nitrogen, % Calcd.	Nitrogen, % Found
Aceto-[c]	$(C_3H_5NO)_3$	66	96–98	19.72	19.61
Propio-[d]	$(C_4H_7NO)_3$	47	169–171	16.47	16.33
Chloro-propio-	$(C_4H_6ClNO)_3$	75	170–171	11.72	11.80
Acrylo-	$(C_4H_5NO)_3$	40	None	16.86	16.71
Meth-acrylo-	$(C_5H_7NO)_3$	15	149–151	14.43	14.36
Benzo-[e]	$(C_8H_7NO)_3$	37.5	220–222	10.53	10.38

[a] Objective was to establish the general character of the reaction and no attempt has been made to obtain optimum yields. [b] Uncorrected. [c] Calcd.: mol. wt. 213. Found: mol. wt., 219.1. [d] Calcd.: C, 56.46; H, 8.23; mol. wt., 255. Found: C, 56.75; H, 8.13; mol. wt., 258.7 (ebullioscopic, methanol). [e] Calcd.: C, 72.18; H, 5.26. Found: C, 72.08; H, 5.37.

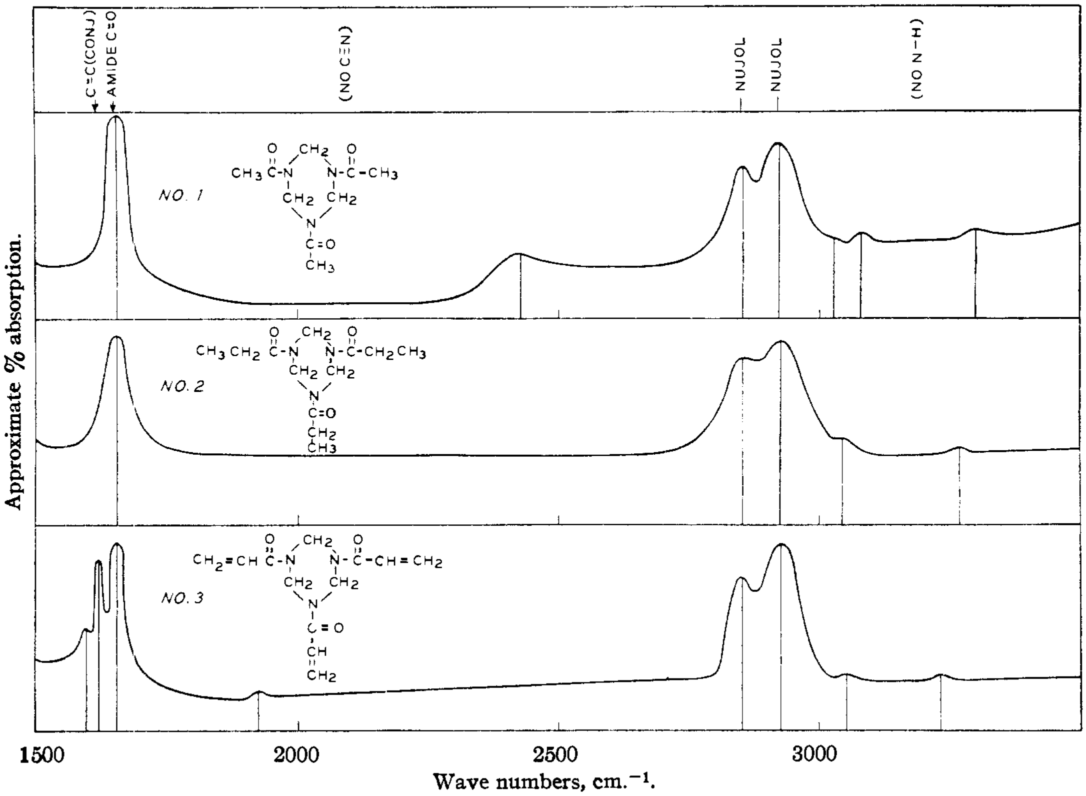

Fig. 2.—Infrared absorption spectra.

1181.5, 1239.5, 1254, 1307, 1351, 1377 (Nujol), 1438, 1463 (Nujol), 1595, 1618, 1651, 1924, 2850 (Nujol), 2915 (Nujol), 3052, 3232.

Comparison of the spectra shows a marked similarity in the position of the regions of strong absorption. The amide C═O frequencies are at 1655, 1654 and 1651 cm.$^{-1}$. Lack of absorption between 1510 and 1570 cm.$^{-1}$, rules out the possibility of a monosubstituted amide. Moreover, the absorption bands between 3100 and 3500 cm.$^{-1}$ are too weak to be due to —NH or —NH_2 stretching vibrations. Therefore, the amide must be disubstituted. Lack of absorption between 2200 and 2300 cm.$^{-1}$ eliminates the possible presence of —C≡N. IV shows additional absorption in the "double bond region" at 1618 cm.$^{-1}$ and, weakly, at 1595 cm.$^{-1}$. Conjugated C═C bands usually fall somewhere between about 1610 and 1635 cm.$^{-1}$ and, as here, are weaker than C═O bands.

In the lower frequency region, below the 1375 cm.$^{-1}$ —CH_3 absorption, the differences in the three spectra are more pronounced. Here the absorption bands are characteristic of vibrations involving extensive parts of the molecule and thus are more sensitive to variations in molecular configuration than the C—H, C═O and C═C stretching vibrations. Vibrations of the trimethylene triazine ring, for example, would fall in this low frequency region.

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Summary

A reaction between nitriles and formaldehyde in presence of small amounts of concentrated sulfuric acid is described. The properties of a series of these compounds are reported.

Data are given which show that the reaction products are substituted hexahydro-*s*-triazines.

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