rides seems to eliminate altogether the possibility that these reactions are of a chain character. The activation energies are of course quite different, but this is in complete qualitative agreement with the greater strength of the C–OH than the C–Cl bond; the essential thing is that the A factors agree perfectly. It will indeed require a very vivid imagination to construct chain mechanisms which will give identical kinetics and nearly identical chain length in these reactions occurring at temperatures different by about 200°.

Summary

The thermal decompositions of tertiary butyl and tertiary amyl chlorides have been investigated in the temperature region of 543–645°K.

The reactions are homogeneous, unimolecular, and have activation energies of 45,000 ± 1900 and 46,200 ± 700 calories, respectively, which are identical within experimental error.

The rate expressions are: $k = 1.9 \times 10^{14} e^{-46,000/RT}$ sec.$^{-1}$ for tertiary butyl chloride, and $k = 4.5 \times 10^{14} e^{-46,000/RT}$ sec.$^{-1}$ for tertiary amyl chloride if the activation energies are regarded as identical.

The data are compared to those recorded for *t*-butyl and *t*-amyl alcohols, and a possible meaning of the variation in the values of the A factor in the rate equation is discussed, the conclusion being reached that the activation energies of *t*-amyl compounds are slightly less than those of the *t*-butyl compounds.

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[CONTRIBUTION FROM THE CHEMO-MEDICAL RESEARCH INSTITUTE, GEORGETOWN UNIVERSITY]

The Colored Compound Formed in the Sullivan Reaction for Guanidine

BY M. X. SULLIVAN AND W. C. HESS

In a study of the relation of guanidine to health and disease, with particular reference to muscular dystrophies, Sullivan[1] devised a highly specific colorimetric test for guanidine, $NH{=}C(NH_2)_2$, not given by methyl guanidine or any other substituted guanidine, and sensitive to 0.1 mg. per cubic centimeter.

In order to determine the structure of the colored compound formed in the guanidine reaction, the complex was made on a larger scale, first in dilute solutions in the proportions used in the test and second in concentrated solutions of each reactant.

Experiment I.—To 165 mg. of guanidine hydrochloride (approximately 100 mg. of guanidine) in 100 cc. of water was added 100 cc. of 1% 1,2-naphthoquinone-4-sodium sulfonate. After the careful addition of 40 cc. of *N* sodium hydroxide, slowly with stirring, the mixture was brought to 90° and held there for one minute. On cooling and adding 50 cc. of concentrated hydrochloric acid and 50 cc. of concentrated nitric acid, a precipitate formed. This was centrifuged and washed five times with 10-cc. portions of water, with centrifuging after each addition, and with 20 cc. of acetone.

Experiment II.—To 165 mg. of guanidine hydrochloride in 10 cc. of water was added 1 gram of 1,2-naphthoquinone-4-sodium sulfonate suspended in 10 cc. of water and 1 cc. of 5 *N* sodium hydroxide, added dropwise with stirring. The mixture was brought to 90° and held there for one minute, cooled, acidified with 5 cc. of concentrated hydrochloric acid and 5 cc. of concentrated nitric acid and centrifuged. The precipitate was washed with 30 cc. of water in 10-cc. portions, with centrifuging after each addition, then with 10 cc. of equal parts of water and acetone followed by 20 cc. of acetone.

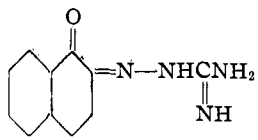
The materials dried to constant weight over calcium chloride in a desiccator, in both cases decomposed at about 250°. The nitrogen content was 19.33 and 19.19%, respectively.

Other samples were made with higher concentration of alkali and with the precipitant, hydrochloric acid alone, nitric acid alone, and mixtures of these acids. In all cases the decomposition point was the same and the nitrogen found was of the same order as given above. The average of six such preparations was 19.24% nitrogen for samples dried over calcium chloride in a desiccator. The average nitrogen for three preparations, one precipitated by concentrated hydrochloric acid, one by concentrated nitric acid, and one by hydrochloric acid and nitric acid was 19.10 for the desiccator dried sample and 19.59 for the same samples dried at 80–105°. Part of the apparent moisture on heating is due to slight decomposition.

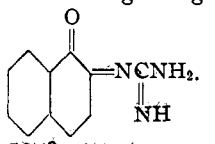
Several possibilities as to the structure are possible. Thiele and Barlow[2] had prepared a beta naphthoquinone derivative of aminoguanidine by mixing a fresh solution of beta-naphthoquinone in alcohol with a mole of aminoguanidine in water in the presence of a few drops of nitric acid, boiling until an orange-yellow precipitate formed. To this complex they assigned the formula $C_{11}H_{10}N_4O$,

(1) Sullivan, *Proc. Soc. Expll. Biol. Med.*, **33**, 106 (1935).

(2) Thiele and Barlow, *Ann.*, **302**, 311 (1898).

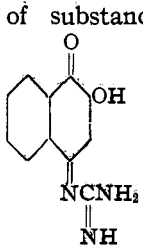


Following the same procedure we prepared the analogous guanidine derivative, $C_{11}H_9N_3O$,



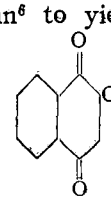
This compound melted at 265–267° with decomposition. It contained 21.19% N, theoretical 21.11%. The nitrogen content and the melting point of this complex definitely ruled out this structure for the compound formed in the Sullivan test for guanidine. Further, the naphthoquinone compound prepared from beta-naphthoquinone and guanidine in the presence of a little nitric acid according to the procedure of Thiele and Barlow yields more or less alpha-naphthol on hydrolysis with 20% hydrochloric acid, while the condensation product made in the guanidine test yields no alpha-naphthol.

A greater probability is that the guanidine had replaced the sulfonic acid in the beta-naphthoquinone sulfonate along lines laid down by Böniger[3] for aniline and aniline derivatives and amplified by Ehrlich and Herter[4] for a number of substances. This would give $C_{11}H_9N_3O_2$,



or 4-guanidonaphthoquinone-1,2.

Such types of compounds were shown by Zincke[5] and Liebermann[6] to yield hydroxynaphthoquinone, $C_{10}H_6O_3$



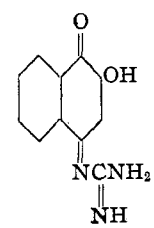
on acid hydrolysis. Liebermann found the melting point of the hydroxynaphthoquinone to be 190°, Baltzer[7] 187–189°.

(3) Böniger, *Ber.*, **27**, 23 (1894).
(4) Ehrlich and Herter, *Z. physiol. Chem.*, **41**, 379 (1904).
(5) Zincke, *Ber.*, **14**, 1493 (1881).
(6) Liebermann, *ibid.*, **14**, 1664 (1881).
(7) Baltzer, *ibid.*, **14**, 1899 (1881).

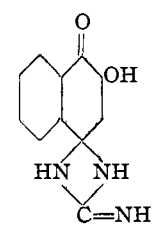
Accordingly, 200 mg. of the 4-guanidonaphthoquinone-1,2 compound (made by hydrochloric acid precipitation and containing 19.33% N) was hydrolyzed for three hours with a mixture containing 19 cc. of 95% alcohol and 1 cc. of concentrated sulfuric acid following the procedure used by Zincke[5] and Baltzer[7] for hydrolyzing anilidonaphthoquinones. The hydrolysate plus 10 cc. of water was concentrated to 10 cc. on the water-bath to remove the alcohol. A reddish-brown precipitate formed and was filtered off. This precipitate (A) washed with water and dried had a melting point of 187–188° which agrees with the melting point of hydroxynaphthoquinone (B) obtained from the anilidonaphthoquinone made from 1,2-naphthoquinone-4-sodium sulfonate and aniline. A mixture of (A) and (B) melted at 187–188°. (The yield of hydroxynaphthoquinone was 74% of the theoretical.) After filtration from precipitated hydroxynaphthoquinone, the clear solution was extracted three times with 20 cc. of ether. The ether extract evaporated to dryness, was taken up with water and filtered to remove a small amount of hydroxynaphthoquinone extracted by the ether. The aqueous solution was then precipitated with picric acid. This picrate was guanidine picrate, proved by the character of the crystals, the melting point 318°, the positive color reaction with the Sullivan guanidine test, and the unchanged melting point when mixed with guanidine picrate. With no attempt to find the best hydrolyzing procedure the yield of guanidine picrate was about 55% of the theoretical.

The fact that the 4-guanidonaphthoquinone-1,2 formed from 1,2-naphthoquinone-4-sodium sulfonate and guanidine contained between 19.24 and 19.59% nitrogen and on hydrolysis yielded hydroxynaphthoquinone and free guanidine indicates the following constitution

(1)



or (11)



The 4-guanidonaphthoquinone-1,2 forms an ammonium salt, melting point 285–288°, a sodium salt, melting point 297–300°.

The 4-guanidonaphthoquinone-1,2 is rose-colored in acid, purple in alkali. It is reduced to yellow by sodium hyposulfite ($Na_2S_2O_4$) in alkaline solution and is speedily oxidized to purple on shaking in air.

Summary

The nitrogen determination and the products of acid hydrolysis indicate that the colored compound formed in the Sullivan reaction for guanidine is 4-guanidonaphthoquinone-1,2.

WASHINGTON, D. C. RECEIVED OCTOBER 28, 1935