α-Acetamino-α-carboxy-γ-(3-indole)-butyric Acid (V).—A reaction mixture consisting of 4 g. of IV, 2.2 g. of sodium hydroxide and 25 ml. of water was refluxed for four hours. The hot mixture was treated with Darco, filtered hot and the filtrate was then cooled to 5°. The addition of 5.7 ml. of cold concentrated hydrochloric acid to the filtrate caused precipitation of slightly pink crystals of V. The mixture, after standing fifteen hours at 5°, was filtered. The solid was washed with 50 ml. of ice-water and dried for two hours at 60°; m. p. 140–141°; yield 3.3 g. (97.5%) of material suitable for conversion to VI.

A sample of pure V, recrystallized from 30% ethanol, melted at 153–154°.

Anal. Calcd. for $C_{15}H_{16}O_5N_2$: N, 9.21. Found: N, 8.94.

α-Acetamino-γ-(3-indole)-butyric Acid (*dl*-N-Acetylhomotryptophan) (VI).—Decarboxylation of the substituted malonic acid V was readily effected by refluxing a suspension of 3.0 g. of V in 25 ml. of water for three hours. The homogeneous reaction mixture was cooled to 5° and made acidic (congo red paper) by the careful addition of 18% hydrochloric acid. The acetyl derivative (VI) separated from the acidic solution as an oil which slowly crystallized. The mixture was filtered and the crude product (2.0 g.) was recrystallized from 40% ethanol. The product isolated from this recrystallization was the monohydrate of VI, m. p. 112–113°; yield, 1.60 g. (58.3%).

Anal. Calcd. for $C_{14}H_{16}O_3N_2 \cdot H_2O$: N, 10.05. Found: N, 10.12.

For the above analysis the crystals were dried for two hours at 25° under 2 mm. pressure. When the crystals were finely pulverized and dried for an additional two hours at the same temperature and pressure the hydrate apparently decomposed to anhydrous VI.

Anal. Calcd. for $C_{14}H_{16}O_3N_2$: N, 10.77. Found: N, 10.53.

α-Amino-γ-(3-indole)-butyric Acid (*dl*-Homotryptophan) (VII).—Recrystallized *dl*-N-acetylhomotryptophan monohydrate (VI, 1.60 g.), sodium hydroxide (1.00 g.) and water (10 ml.) were combined and the solution was refluxed for twenty hours. The hot reaction mixture was treated with Darco, filtered and the filtrate was cooled to 5°. Glacial acetic acid (1.50 g.) was added to the filtrate which was then allowed to stand at 5° for twelve hours to ensure complete precipitation of the amino acid VII. The reaction mixture was filtered and the white solid was found to be almost pure *dl*-homotryptophan, m. p. 306–310°; yield 1.21 g. (96.5%). It was recrystallized from a large volume of 50% ethanol. The glistening platelets of pure VII melted sharply at 308° with decomposition.

Anal. Calcd. for $C_{12}H_{14}O_2N_2$: C, 66.0; H, 6.47; N, 12.84. Found: C, 66.15; H, 6.51; N, 13.16.

Summary

dl-Homotryptophan [α-amino-γ-(3-indole)-butyric acid] has been synthesized *via* the sequence: indole, tryptophol, β-(3-indole)-ethyl bromide, ethyl α-acetamino-α-carbethoxy-γ-(3-indole)-butyrate, α-acetamino-α-carboxy-γ-(3-indole)-butyric acid, α-acetamino-γ-(3-indole)-butyric acid, *dl*-homotryptophan.

URBANA, ILLINOIS RECEIVED JANUARY 2, 1948

NOTES

Correlation of Rates of Halogenation of Methylbenzenes

BY FRANCIS E. CONDON

The rate of chlorination of toluene relative to that of benzene is 345[1]; relative to that at only one position in benzene, it is 345 × 6 = 2070. The product has been reported to be 42% *p*- and 58% *o*-chlorotoluene.[2] Hence the partial relative rate of chlorination of toluene at the para position is 0.42 × 2070 = 870; similarly, the ortho partial relative rate is (0.58/2) × 2070 = 600. The meta partial relative rate may be approximated as 5, which seems reasonable in view of the value of 3 found for meta nitration.[3]

If each of the methyls in a polymethylbenzene exerts the same activating influence as the one in toluene, a partial relative rate of chlorination at each available nuclear position may be calculated as a product of two or more partial relative rates, each corresponding to a methyl and its position. The rate for the polymethylbenzene relative to that for benzene is then one-sixth the sum of the partial relative rates for all available positions.

TABLE I

RELATIVE RATES OF HALOGENATION OF POLYMETHYLBENZENES (BENZENE = 1)

	p-Xylene	*o*-Xylene	*m*-Xylene	Mesitylene	Pentamethylbenzene
Calculated	2.0×10^3	2.5×10^3	2.4×10^5	1.6×10^8	13×10^8
Experimental[1]	2.2×10^3	4.6×10^3	4.3×10^5	1.8×10^8	7.8×10^8
	Pseudocumene	Hemimellitine	Durene	Prehnitene	Isodurene
Calculated	7.4×10^5	8.7×10^5	3.0×10^6	4.4×10^7	5.2×10^8

In *p*-xylene, for example, each of the four available positions is influenced by two methyls, one ortho and one meta. The calculated partial rela-

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(1) De la Mare and Robertson, *J. Chem. Soc.*, 270 (1943).

(2) Wertyporoch, *Ann.*, **493**, 153–165 (1932); *C. A.*, **26**, 2177 (1932).

(3) Ingold, Lapworth, Rothstein and Ward, *J. Chem. Soc.*, 1959 (1931).

tive rate at each position is therefore 600 × 5 = 3000; and the rate for *p*-xylene relative to that for benzene is 4 × 3000/6 = 2000. Similarly, inasmuch as the single available position in pentamethylbenzene is influenced by one para, two meta, and two ortho methyls, the rate of chlorination of pentamethylbenzene relative to that of benzene is 870 × 5 × 5 × 600 × 600/6 = 1.3 × 10^9. Such calculated relative rates are compiled in Table I, together with available experimental values[1] for chlorination or bromination. The agreement between the calculated and the experimental values, which is good in view of the 350,000-fold range, inspires considerable confidence in the five values for which experimental confirmation is at present unavailable.

A product of relative rates as calculated above is mathematically related to a sum of activation energy differences calculated from Arrhenius-type equations for the individual rate constants

$$k = Ae^{-E/RT}$$

For

$$k_i/k = (A_i/A)e^{(E-E_i)/RT}$$

and

$$\Sigma(E - E_i) = \Sigma RT \ln (k_i/k) - \Sigma RT \ln (A_i/A) = RT \ln \Pi(k_i/k) - RT \ln \Pi(A_i/A)$$

If the several A terms are equal,[4] the relationship simplifies to

$$\Sigma(E - E_i) = RT \ln \Pi(k_i/k)$$

According to the theory of absolute reaction rates[5]

$$k = (KT/h)e^{-F/RT}$$

where K = Boltzmann constant, h = Planck constant, and F = difference in free energy between initial and activated states, or "activation free energy." Consequently, without any assumption of constancy for an A term, or "frequency factor"[5]

$$k_i/k = e^{(F-F_i)/RT}$$

and

$$\Sigma(F - F_i) = RT \ln \Pi(k_i/k)$$

so that a product of relative rates is simply related to a sum of activation free energy differences.

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[4] *Cf.* Bradfield and Jones, *J. Chem. Soc.*, 1006, 3073 (1928); *Trans. Faraday Soc.*, **37**, 737 (1941).

[5] Glasstone, Laidler and Eyring, "The Theory of Rate Processes," McGraw-Hill Book Co., Inc., New York, N. Y., 1941.

BARTLESVILLE, OKLAHOMA RECEIVED NOVEMBER 28, 1947

Liquid Nitrosyl Chloride as an Ionizing Solvent

BY ANTON B. BURG AND GEORGE W. CAMPBELL, JR.[1]

Liquid nitrosyl chloride is expected to be a fairly effective ionizing solvent, for its dielectric constant (18.2 at 12°)[1a] is comparable to that of liquid ammonia. The acid–base system would be defined by the neutralization equation $NO^+ + Cl^- \rightarrow NOCl$. As in the analogous case of carbonyl chloride,[2] the chloride ion should not be appreciably solvated, for the electronic structure of NOCl (resonance between $:\underset{\cdot\cdot}{O}{=}\underset{\cdot\cdot}{N}{}^{+}Cl^{-}$ and $:\underset{\cdot\cdot}{O}{=}\underset{\cdot\cdot}{N}{-}\underset{\cdot\cdot}{\ddot{Cl}}:$)[1,3] will not be affected by an electron-donor so weak as chloride. In agreement with this prediction, potassium chloride is insoluble in liquid nitrosyl chloride, contributing no conductance effect.

The nitrosyl ion, on the other hand, should be solvated very strongly, on account of the resonance structures $\left[:\underset{\cdot\cdot}{O}{=}\underset{\cdot\cdot}{N}{-}\underset{\cdot\cdot}{\ddot{Cl}}{-}\underset{\cdot\cdot}{N}{=}\underset{\cdot\cdot}{O}:\right]^{+}$, $\left[:\underset{\cdot\cdot}{O}{=}\underset{\cdot\cdot}{N}{-}\underset{\cdot\cdot}{\ddot{Cl}}:\right]\ :\overset{+}{N}{\equiv}O:$, and $:O{\equiv}\overset{+}{N}:\ \left[:\underset{\cdot\cdot}{\ddot{Cl}}{-}\underset{\cdot\cdot}{N}{=}\underset{\cdot\cdot}{O}:\right]$. Hence it is expected that nitrosyl salts, many of which have been recognized,[4] should be soluble in liquid nitrosyl chloride, with high electrical conductance.

Experimental Results.—These ideas have been tested in a preliminary investigation of the electrical conductance of solutions of typical nitrosyl salts in liquid nitrosyl chloride. The mononitrosyl salts $NOAlCl_4$, $NOFeCl_4$ and $NOSbCl_6$ are readily soluble strong electrolytes, as demanded by the theory (see Table I). The solvation is indicated by the reaction $NOAlCl_4(s) + NOCl(g) \leftrightarrows NOAlCl_4{\cdot}NOCl(s)$, recently discovered in our laboratories by Donald E. McKenzie. The dissociation pressure of the product is approximately 240 mm. at 0°.

Less favorable results were obtained with $(NO)_2SnCl_6$, $(NO)_2TiCl_6$, and $(NOSO_4H)$, all of which appeared quite insoluble and non-conducting. Dinitrosyl pyrosulfate, $(NO)_2S_2O_7$,[5] showed a slight conductance which very slowly passed through a maximum (see Table II). Sulfuric acid was inert.

The inert character of potassium chloride was not changed by an "acid" solution of nitrosyl chloroantimonate, which, by analogy with carbonyl "acids" in carbonyl chloride, should have dissolved it. The reason might be a protective coating of $KSbCl_6$.

In an attempt to establish chloride ions in liquid NOCl, the base-action of water was tried. However, the water only dissolved without conductance and was recovered by evaporating the nitrosyl chloride. The usual hydrolysis reaction $H_2O + 2NOCl \rightarrow NO + NO_2 + 2HCl$ is slow at room temperature and the products are nonconducting in nitrosyl chloride.

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[1] This note is based upon a thesis submitted by George W. Campbell, Jr., to the Graduate Faculty of the University of Southern California, in partial fulfillment of the requirements for the degree of Master of Science, June, 1947.

[1a] Ketelaar, *Rec. trav. chim.*, **62**, 289 (1943).

[2] (a) Germann and Gagos, *J. Phys. Chem.*, **28**, 965 (1924); (b) Germann and Timpany, *ibid.*, **29**, 1423 (1925); (c) Germann and Birosel, *ibid.*, **29**, 1469 (1925); (d) Germann, THIS JOURNAL, **47**, 2465 (1925); (e) Germann and Timpany, *ibid.*, **47**, 2275 (1925).

[3] Ketelaar and Palmer, *ibid.*, **59**, 2629 (1937).

[4] (a) Willke-Dörfurt and Balz, *Z. anorg. allgem. Chem.*, **159**, 219 (1927); (b) Gall and Mengdehl, *Ber.*, **60B**, 86 (1927); (c) Rheinboldt and Wasserfuhr, *ibid.*, **60B**, 732 (1927); (d) Angus and Leckie, *Proc. Roy. Soc.* (*London*), **A150**, 615 (1935); (e) Klingenberg, *Rec. trav. chim.*, **56**, 749 (1937).

[5] Jones, Price and Webb, *J. Chem. Soc.*, **135**, 312 (1929).