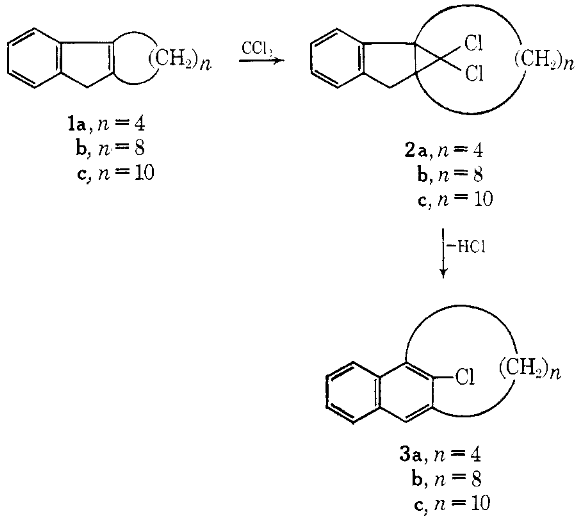
1,3-Bridged Aromatic Systems. II. A New Synthesis of Metacyclophanes[1]

William E. Parham and J. Kent Rinehart[2]

Contribution from the School of Chemistry of the University of Minnesota, Minneapolis, Minnesota 55455. *Received May 22, 1967*

Abstract: The synthesis of the new class of metacyclophanes (**3**), in which the value of *n* is at least 8, is realized in high yield by reaction of the corresponding indene **1** with reagents generally assumed to provide dichlorocarbene. The spectra and proof of structure of **3b** and **3c** are discussed, together with extensive studies of 2,3-dimethylindene used as a model.

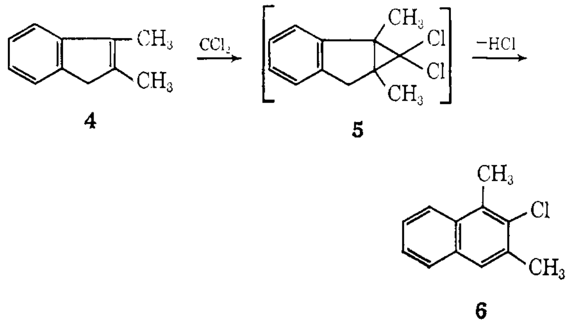
Ring expansion reactions of 1,1-dihalocyclopropanes are thought to occur by rate-determining ionization of the carbon-to-chlorine bond,[3,4] with concerted disrotatory[5,6] ring opening to products; consequently, it was concluded that the reaction sequence shown in eq 1, where the number of methylene groups (value of *n*) is large enough to accommodate the steric requirements of the system, should provide a convenient synthesis for a new class of metacyclophanes (**3**). This has been shown to be the case, and the synthesis and proof of structure of the new cyclophanes **3b** and **3c**, together with studies of model compounds, constitute the subject of this report.



(1)

The reaction of 2,3-dimethylindene (**4**) with dichlorocarbene was examined as a model for the metacyclophane synthesis, and to provide reference compounds to be used for the proof of structure of **3**.

Reaction of **4** with 1 equiv of phenyl(trichloromethyl)mercury[7] gave phenylmercuric chloride (98% yield) and an approximate equal mixture of recovered **4** and **6** (~33 and 49% isolated, respectively). It was apparent that the cyclopropane **5** was unstable in boiling benzene and that approximately one-half of the dichlorocarbene (or its precursor) was consumed by reaction with hydrogen chloride formed during the reaction.[8] The naphthalene **6** was most conveniently prepared (100% conversion, 80–97% yield) by reaction of **4** with a twofold excess of chloroform[9] and a fourfold excess of potassium *t*-butoxide. The only evidence for the intermediate **5** was in one reaction with ethyl trichloroacetate and sodium methoxide;[10] an oil was obtained which spontaneously lost hydrogen chloride at room temperature to give **6**.



(2)

2-Chloro-1,3-dimethylnaphthalene (**6**) was converted, through the intermediate Grignard reagent formed by entrainment with ethylene bromide, to 1,3-dimethylnaphthalene (**7**). Attempts to oxidize **6** directly to **9** by action of aqueous sodium dichromate,[11] potassium permanganate in aqueous alkali (10%) at 100°, alkaline potassium permanganate in hot water–*t*-butyl alcohol, 20% aqueous nitric acid,[12] and by potassium ferrocyanide[13] were unsuccessful. The acid **9** was obtained in high over-all yield as shown in **6** → **8** → **9**, and its structure was confirmed by its subsequent conversion to 2-chloronaphthalene by decarboxylation in boiling quinoline in the presence of copper chromite.[14]

---

[1] Supported by the National Science Foundation Grants GP-3357 and GP-6169X. For the preceding article in this series, see W. E. Parham and J. F. Dooley, *J. Am. Chem. Soc.*, **89**, 985 (1967).

[2] From the Ph.D. Thesis of J. K. Rinehart, The University of Minnesota, 1967.

[3] (a) W. E. Parham, H. E. Reiff, and P. Swartzentruber, *J. Am. Chem. Soc.*, **78**, 1437 (1956); (b) P. S. Skell and S. R. Sandler, *ibid.*, **80**, 2024 (1958).

[4] W. E. Parham and E. Schweizer, *Org. Reactions*, **13**, 55 (1963).

[5] R. B. Woodward and R. Hoffman, *J. Am. Chem. Soc.*, **87**, 4006 (1965).

[6] (a) C. H. DePuy, L. G. Swnack, J. W. Hausser, and W. Wiedemann, *ibid.*, 87, 4006 (1965); (b) S. J. Cristol, R. M. Sequevia, and C. H. DePuy, *ibid.*, 87, 4007 (1965); (c) W. E. Parham and R. J. Sperley, *J. Org. Chem.*, 32, 924 (1967).

[7] D. Seyferth, J. M. Burlitch, and J. K. Heeren, *ibid.*, 27, 1491 (1962).

[8] In subsequent reactions with **2b** and **2c**, an excess of phenyl(trichloromethyl)mercury was employed to permit more complete conversion of starting olefin.

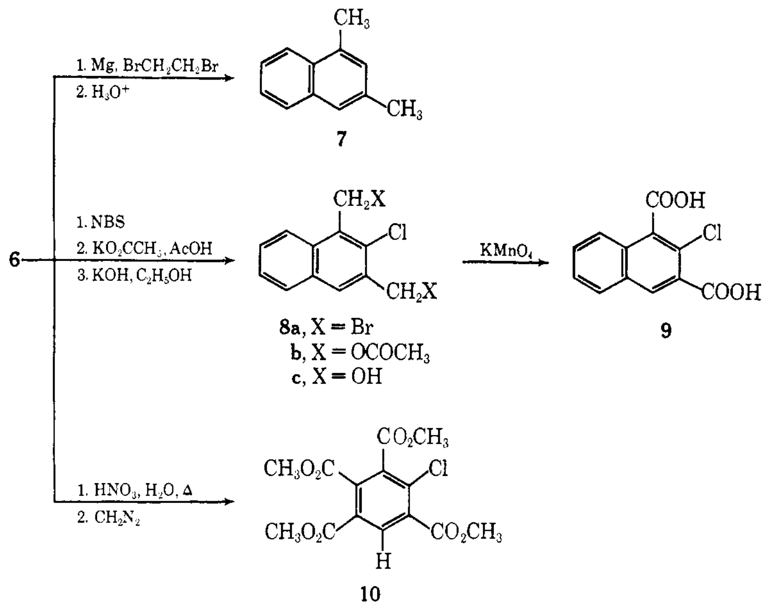
[9] W. von E. Doering and A. K. Hoffmann, *J. Am. Chem. Soc.*, **76**, 6162 (1954).

[10] W. E. Parham and E. E. Schweizer, *J. Org. Chem.*, **24**, 1733 (1959).

[11] L. Friedman, D. L. Fishel, and H. Shechter, *ibid.*, **30**, 1453 (1965).

[12] R. Huisgen and V. Vossius, *Monatsh.*, **88**, 517 (1957).

[13] L. Ruzicka and J. A. van Melsen, *Helv. Chim. Acta*, **14**, 397 (1931).



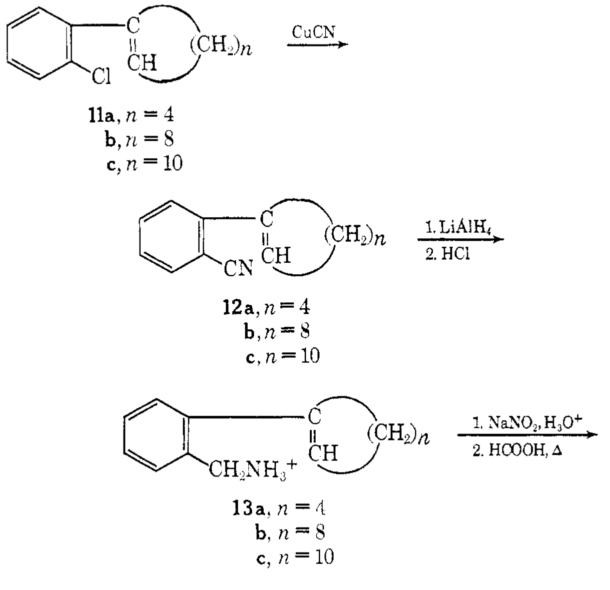
(3a)

(3b)

(3c)

Oxidation of **6** with 40% nitric acid at 180°, with subsequent esterification of the acid products with diazomethane, gave a mixture of esters composed principally of dimethyl phthalate, dimethyl nitrophthalates, and the tetraester **10**. These esters were partially resolved by preparative gas chromatography and **10** was obtained pure.

The synthesis of the condensed hydrocarbons **1b** and **1c** were achieved by improvement and extension of the



(4)

procedure[15] previously used for **1a**, as outlined in eq 4. All intermediates were isolated and characterized, and the nmr spectra of the hydrocarbons **1** confirmed that they were free of possible olefin position isomers (no vinyl hydrogen).

The reaction of **1c** with 2 equiv of phenyl(trichloromethyl)mercury in boiling benzene gave **3c**, which was isolated as a crystalline solid (100% crude, 73%, mp 55–57°). The ultraviolet spectrum of **3c** was quite similar to that of **6**, with an observed loss of some fine structure. The nmr spectrum of **3c** showed broad and complex methylene absorption at τ 6–10. Inspection of models (Stuart–Briegleb) showed that the methylene bridge cannot pass over the chlorine atom, thereby hindering mobility of the bridge and resulting in considerable nonequivalence of the ring methylene protons. The very high-field absorption is expected, since the central bridging atoms are held rather closely over the face of the ring to which they are attached. As a consequence, the central bridging atoms are held in the shielding cone of the aromatic ring.

The metacyclophane **3c** did not react with magnesium even when an entrainment agent (ethylene bromide) was employed. Attempts to convert **3c** to the dibasic acid **9**, by the sequence of reactions shown in eq 3b, were unsuccessful; bromination with 2 equiv of N-bromosuccimide did not proceed appreciably beyond the monobromo derivative. This monobromo derivative was not isolated pure; however, the nmr spectrum of the product was consistent with this interpretation, and molecular models showed only one α-hydrogen atom in **3c** to be unhindered. The structure of the cyclophane **3c** was confirmed by its oxidation with 40% nitric acid. The same spectrum of products was obtained as with the model **6** and a mixture melting point of the derived tetraester **10** with an authentic sample obtained from **6** was not depressed.

Inspection of molecular models show that cyclophanes smaller than **3c** ($n = 10$) can be formed; however, the definition of n will have to be confirmed experimentally. Stuart–Briegleb models of **3b** ($n = 8$) reveal very close packing of the methylene chain in the face of the naphthalene ring, a consequence which should result in further shielding of the bridging methylene groups in the nmr spectrum of **3b** as compared with **3c**. This conclusion was confirmed by the synthesis of **3b** (89% yield) by reaction of **1b** with phenyl(trichloromethyl)mercury. The structure of **3b** was not confirmed by oxidative degradation; however, its structure was evident by comparison of the ultraviolet and nmr spectra of this cyclophane with those of **3c**.

The ultraviolet spectrum of **3b** was similar to that of **3c** with considerable loss of fine structure. The methylene proton absorption in the nmr spectrum of **3b** occurred at τ 6.15–10.48, and it is assumed that the high-

---

(14) M. H. Hubacher, *Anal. Chem.*, **21**, 945 (1949).

(15) W. E. Parham, C. D. Wright, and D. A. Bolon, *J. Am. Chem. Soc.*, **83**, 1751 (1961).

field methylene absorption (near τ 10) is attributed to the methylene groups in the center of the bridge which are strongly shielded by the π electrons of the attached aromatic ring.

The reaction of **1a** with chloroform and potassium *t*-butoxide, and with 1 equiv of phenyl(trichloromethyl)-mercury, led to high yields of **2a**. Since it is evident, by inspection of molecular models, that steric requirements preclude decomposition of **2a** to the cyclophane **3a**, the observed stability of **2a** was expected. Samples of **2a** were recovered from boiling quinoline (86% recovery) and from hot ethanolic silver nitrate.

Further work is in progress to define the scope of this synthesis and to examine the properties of the derived metacyclophanes.

Experimental Section[16-18]

2,3-Dimethylindene (4) was prepared in 86% yield [bp 92° (7.6 mm), lit.[19] 85% yield, bp 99.5–100° (11 mm)] as previously described. The infrared and ultraviolet spectra of **4** were identical with those reported.[20] The ultraviolet spectrum of **4** showed $\lambda_{max}^{95\%\ alcohol}$ 209 mμ (log ϵ 4.19) and λ_{max} 258 mμ (log ϵ 4.10); the nmr spectrum[16c] (10% in CCl_4) showed: C_6H_4 (complex, τ 2.68–2.86, wt 4), benzylic CH_2 (broad singlet, τ 6.88, wt 2), and CH_3 (sharp singlet, τ 8.01, wt 6).

2-Chloro-1,3-dimethylnaphthalene (6). A. Chloroform–Potassium *t*-Butoxide. Chloroform (11.94 g, 0.10 mole) in anhydrous benzene (50 ml) was added over a period of 30 min to a cold (~0°), stirred mixture of **4** (7.21 g, 0.05 mole), potassium *t*-butoxide[9] (from 7.8 g, 0.2 g-atom of potassium), and anhydrous benzene (150 ml) under nitrogen. The brown reaction mixture was stirred in the cold for 1 hr and then at 30° for 1 hr. The mixture was poured into water, and the organic layer was separated with ether. The ether extract was washed with water, dried ($MgSO_4$), and concentrated. The ether was removed (rotary evaporator), and the dark residue was chromatographed on alumina (500 g) using petroleum ether (bp 60–68°) as eluent (2.5 l.). The infrared spectrum of the recovered yellow oil (9.43 g) was essentially identical with that of authentic **6**, and glpc[17] (Apiezon L, 200°) showed the product to be >99% pure (97% yield). Distillation of this oil gave 7.52 g (79% yield, 87% in a subsequent run) of **6** [bp 83–86° (0.1–0.2 mm), n^{25}D 1.6266].

Anal. Calcd for $C_{12}H_{11}Cl$: C, 75.59; H, 5.82; Cl, 18.60. Found: C, 75.74; H, 5.83; Cl, 19.45.

The ultraviolet spectrum[16a] of **6** showed: [$\lambda_{max}^{95\%\ alcohol}$ (log ϵ)] 226 (sh)[21] (4.88), 231 (5.03), 255 (sh) (3.39), 265 (sh) (3.52), 274 (3.73), 284 (3.77), 296 (3.60), 309 (inf) (2.61), 314 (inf) (2.48), 320 (inf) (2.48), and 323 (inf) mμ (2.31); the nmr spectrum[16a] (30% in CCl_4) showed: aromatic H (complex τ 2.23–2.95, wt 5), 1-CH_3 (singlet, τ 7.48, wt 3), 3-CH_3 (singlet, τ 7.65, wt 3).

B. Phenyl(trichloromethyl)mercury[22] (7.92 g, 0.02 mole) and **4** (2.88 g, 0.02 mole) in anhydrous benzene (50 ml) were heated under nitrogen at reflux temperature for 41 hr.[10] The pungent odor of hydrogen chloride was noted at the end of the reaction. Phenylmercuric chloride (6.16 g, 98.4%) was removed by filtration and benzene by distillation (rotary evaporator). The infrared spectrum of the product suggested that it was a mixture of **4** and **6** in approximately equal proportions. The mixture was chromatographed on alumina (100 g) using petroleum ether (1 l.) as eluent. Distillation of the recovered yellow oil (3.35 g) gave **4** [0.64 g, bp 92° (7.6 mm), 22% yield] and **6** [2.04 g, bp 81–84° (0.13 mm), 53% yield]. The sample of **6** was contaminated (nmr spectra) with ~9% **4**.

C. Ethyl Trichloroacetate and Sodium Methoxide.[10] Ethyl trichloroacetate (19.15 g, 0.10 mole) was added over a 20-min period to a cold (0°), stirred mixture of **4** (7.71 g, 0.054 mole), commercial sodium methoxide (5.94 g, 0.11 mole from a fresh bottle), and olefin-free pentane (150 ml) under nitrogen. The mixture was stirred at 0° for 8 hr and allowed to warm to room temperature overnight. The solid was removed by filtration, and the filtrate was concentrated on a rotary evaporator at 30°. The yellow oil (14.45 g) spontaneously liberated hydrogen chloride. The resulting oil was processed by several procedures (see A and B, above) and was shown to be mixture (glpc, Apiezon L, 200°) containing **4** (~56%) and **6** (~42%).

1,3-Dimethylnaphthalene (7). A solution[23] of 1,2-dibromoethane (18.8 g, 0.1 mole) in anhydrous ether (50 ml) was added over a 22-hr period through a Herschberg funnel to a stirred mixture of **6** (4.76 g, 0.025 mole), magnesium (2.68 g, 0.11 g-atom), and anhydrous ether (50 ml) maintained at very gentle reflux under nitrogen. The mixture was poured into aqueous ammonium chloride, the layers were separated, and the aqueous layer was extracted with ether. The ether solution was dried (Na_2SO_4) and concentrated. Distillation of the crude product through a short-path column gave recovered **6** (2.47 g, 52%) and 1,3-dimethylnaphthalene [1.25 g, 32% yield, bp 62–66° (0.2 mm), n^{25}D 1.6070]. The infrared and nmr spectra of this product were identical with those of authentic 1,3-dimethylnaphthalene[24] [bp 79–80° (1 mm), n^{25}D 1.6071]. The nmr spectrum[16c] of 1,3-dimethylnaphthalene showed: aromatic H (complex, τ 2.07–2.90, wt 5), 2-H (broad singlet, τ 3.06, wt 1), CH_3 (singlets at τ 7.56 and 7.72, wt 6).

Conversion of 6 to 2-Chloro-1,3-naphthalenedicarboxylic Acid (9). The procedure used was similar to that described by Wenner.[25] Reaction of **6** (4.76 g, 0.025 mole) with N-bromosuccinimide (8.80 g, 0.049 mole) in carbon tetrachloride gave a near-quantitative yield of **1,3-bis(bromomethyl)-2-chloronaphthalene (8a**, mp 175.5–176.5° from petroleum ether, bp 60–68°).

Anal. Calcd for $C_{12}H_9Br_2Cl$: C, 41.36; H, 2.66; Br, 45.87; Cl, 10.18. Found: C, 41.64; H, 2.83; Br, 45.84; Cl, 10.20.

Reaction of **8a** (1.0 g, 2.87 mmoles) and potassium acetate (1.0 g, 10.2 mmoles) in glacial acetic acid (10 ml) gave 0.88 g (100% yield) of crude **8b** (mp 108–112°). One recrystallization of this product from ethanol gave **1,3-bis(acetoxymethyl)-2-chloronaphthalene (8b**, mp 115.5–116.5°; 0.65 g, 74% yield).

Anal. Calcd for $C_{16}H_{15}ClO_4$: C, 62.65; H, 4.93; Cl, 11.56. Found: C, 62.92; H, 4.75; Cl, 11.67.

Reaction of **8b** (0.91 g, 3.0 mmoles) in 1 *N* alcoholic potassium hydroxide gave 0.63 g (98.5% yield) of **8c** (mp 129–137.5°). One recrystallization of this product gave 0.61 g (95.4% yield) of nearly pure **8c**. The melting point of pure **1,3-bis(hydroxymethyl)-2-chloronaphthalene (8c)** was 144.5–146°.

Anal. Calcd for $C_{12}H_{11}ClO_2$: C, 64.73; H, 4.98; Cl, 15.92. Found: C, 64.44; H, 5.11; Cl, 16.13.

A solution of potassium permanganate (1.90 g, 12.0 mmoles) in water (100 ml) was added with stirring over a 2.5-hr period to a solution of **8c** (1.00 g, 4.50 mmoles) and sodium hydroxide (0.1 g) in 50% aqueous *t*-butyl alcohol (50 ml) at 60–70°. The alcohol was removed by distillation and the manganese dioxide by filtration through Supercel. The filtrate was acidified with hydrochloric acid, and the aqueous solution was extracted with five 100-ml portions of ether. Concentration of the dried ($MgSO_4$) ether extract gave crude **9** as a yellow solid (0.75 g, 66% yield, mp 172–191°). The acid was recrystallized from water to give pure **2-chloro-1,3-dicarboxynaphthalene (9)** (mp 209.5–211.5°).

Anal. Calcd for $C_{12}H_7ClO_4$: C, 57.50; H, 2.82; Cl, 14.15; neut equiv, 125.3. Found: C, 57.32; H, 3.10; Cl, 13.91; neut equiv, 130.4.

Conversion of 9 to 2-Chloronaphthalene. A mixture of **9** (1.01 g, 4.03 mmoles), copper chromite (50 mg), and quinoline (10 ml) was placed in a 25-ml, pear-shaped, two-necked flask equipped with an air condenser and a nitrogen bubbler. The mixture was heated to[26] 235° under a small stream of nitrogen. After 15 min the exit gases caused no precipitation when passed into aqueous barium

---

(16) (a) All melting points were corrected. (b) Ultraviolet spectra were obtained on a Cary Model 11, using 1-cm cells. (c) The nmr spectra were obtained using a Varian A-60 with 1% tetramethylsilane as internal standard; peak weights were obtained by integration.

(17) Gas-liquid partition chromatography (glpc) were obtained on a Beckman GC-4 using a dual flame detector with helium as a carrier (17 cc/min or 50 cc/min). The columns used were: (a) 1/8 in. × 6 ft Apiezon (20%) on Chromosorb W (80–100 mesh), and (b) SE-30 (20%) on Chromosorb W (80–100 mesh). Percentages were determined with the aid of a Disc integrator.

(18) Mass spectra were obtained on a Hitachi-Perkin-Elmer RMU-6D.

(19) J. Cologne and G. Weinstein, *Bull. Soc. Chim. France*, 462 (1952).

(20) T. L. Yarboro, C. Karr, Jr., and P. A. Estep, *J. Chem. Eng. Data*, **6**, 421 (1961).

(21) Shoulder and inflection are indicated by (sh) and (inf), respectively.

(22) T. L. Logan, *J. Org. Chem.*, **28**, 1129 (1963).

(23) The procedure used was similar to that described by D. E. Pearson and D. Cowan, *Org. Syn.*, **44**, 78 (1964).

(24) Obtained from the Aldrich Chemical Co.

(25) J. Wenner, *J. Org. Chem.*, **17**, 523 (1952).

(26) M. H. Hubacher, *Anal. Chem.*, **21**, 945 (1945).

carbonate, and the mixture was cooled to room temperature. The mixture was poured into ether, and the ethereal solution was washed with three 25-ml portions of 10% hydrochloric acid. The yellow solid obtained by removal of ether from the dried ($MgSO_4$) organic layer was treated with 10% sodium hydroxide and ether was added. The ether layer was dried ($MgSO_4$) and concentrated. The oil thus obtained (0.18 g) was chromatographed on alumina (20 g). Elution of the column with petroleum ether (bp 60–68°) gave an oil (0.14 g, 21% yield) which was nearly pure 2-chloronaphthalene (by infrared). Recrystallization of this product from ethanol–water gave pure 2-chloronaphthalene (mp and mmp 58–59°).

Conversion of 6 to 10. A mixture of **6** (0.75 g, 3.94 mmoles) and 40% aqueous nitric acid (15 ml) was divided into three equal portions, which were added to three Carius tubes (25 cm × 10 mm, i.d.). The tubes were heated to 180° for 12 hr. The tubes were cooled, and the blue tube contents were frozen (Dry Ice–acetone bath). The tubes were opened (torch) but there was a considerable pressure release (*caution:* heavy gloves and face shield were employed). The contents of the tubes were warmed to room temperature, and the contents were removed with water. Evaporation of the combined water extracts gave 0.72 g (63.5% calculated as tetraacid) of product, mp 144–164°. The solid was dissolved in absolute methanol (10 ml) and excess ethereal diazomethane was added to the cooled mixture. After evaporation of the solvent there was obtained an orange-red viscous oil which was dissolved in ether, filtered, washed with 10% hydrochloric acid, and dried (Na_2SO_4). After evaporation of solvent, there was obtained 0.837 g of orange viscous liquid. Gas chromatography[17b] (helium, flow 50 cc/min, temperature program, 1°/min isothermal at 100°, then 5°/min to 200°) showed a complex mixture of 15 components with three major peaks (see also oxidation of **3c**).

For preparative gas chromatography a Varian Aerograph 712 was employed with flame detector. A $^{3}/_{8}$ in. × 50 ft, 20% SE-30 on Chromosorb W (60) column was used with column temperature 250°, isothermal. The collection was programmed so that fraction 1 contained the first major peak, fracton 2 the second major peak, fraction 3 many minor peaks, and fraction 4 the third major peak. Several 0.30-ml injections of the mixture in chloroform were made.

Fraction 1. Glpc analysis[17b] showed this material (25 mg) to be 90% pure, and the major component had the same retention time as authentic **dimethyl phthalate.** The nmr spectrum of this material (20% in CCl_4) showed CH_3O at τ 6.14 (impurities at τ 6.03 and 6.12). Authentic dimethyl phthalate showed CH_3O at τ 6.18.

Fraction 2. The nmr spectrum[16c] (~6% in CCl_4) of this material (50 mg of yellow liquid) suggested a mixture of two compounds, which were assumed to be dimethyl 3-nitrophthalate and dimethyl 4-nitrophthalate. There appeared two sharp singlets at τ 6.06 and 6.10, which were attributed to the two nonequivalent methyl groups of the dimethyl esters. When the spectrum was run at sweep width 50, the τ 6.06 peak remained a singlet, but the τ 6.10 peak was split into three distinct peaks. These data suggest four different methyl groups from two different dimethyl esters. The infrared spectrum of the mixture showed $\nu_{C=O}$ 1730 cm^{-1} and ν_{NO_2} 1540 and 1360 cm^{-1}.

Fraction 3 (55 mg) was not examined.

Fraction 4 (70 mg of viscous yellow oil) was identified as the **tetraester 10.** Gas chromatography[17b] of this material showed one major component (~91%) and one minor component (~9%). The nmr spectrum[16c] (8% in CCl_4) showed three sharp singlets for CH_3O at τ 6.06, 6.12, and 6.17, weighted 1:2:1 by area (12 protons). The spectrum at sweep width 50 showed the same three peaks in the same relative areas. The aromatic region showed only a sharp singlet at τ 1.77 (wt 0.9).

The infrared spectrum of the product showed $\nu_{C=O}$ at 1735 cm^{-1}. The mass spectrum showed the molecular ion at *m/e* 344 (theory for **10** is 344.69). A secondary molecular ion appeared at *m/e* 346 with an intensity of one-third that at 344. These data are consistent with one chlorine atom in the molecule.

The oil was crystallized from ether–petroleum ether (bp 60–68°) and pure **tetramethyl 4-chloro-1,2,3,5-benzenetetracarboxylate (10)** (45 mg, mp 82–83.5°) was obtained.

Anal. Calcd for $C_{14}H_{13}ClO_8$: C, 48.78; H, 3.80; Cl, 10.29. Found: C, 48.57; H, 3.89; Cl, 10.34.

Synthesis of 11 was carried out by reaction of the Grignard reagent, prepared from *o*-bromochlorobenzene (0.5 mole), with the appropriate ketone [0.25–0.5 mole in ether (250 ml)] essentially as described previously[15] for **11a**. The mixtures were heated at reflux temperature for 2–6 hr, and the reaction mixtures were poured into an ammonium chloride–ice water slurry. The crude product was chromatographed on alumina and the column was eluted with petroleum ether (bp 60–68°) to remove Grignard coupling and/or benzyne products. The *o*-(1-cycloalkanol)chlorobenzene was eluted from the column with ether. The crude alcohol was dehydrated by heating at reflux in 88% formic acid (100 ml) for 1 hr. The cooled mixture was diluted with water, ether was added, and the layers were separated. The organic layers were washed well with water and finally with aqueous sodium bicarbonate and were dried ($MgSO_4$). Crude **11** was chromatographed on alumina (500 g); the product was eluted with petroleum ether (bp 60–68°) and was distilled (**11a**, **11b**) or recrystallized (**11c**).

***o*-(1-Cyclohexenyl)chlorobenzene (11a)** was obtained in 49% yield [46.9 g, bp 80–83° (0.5 mm), $n^{25}D$ 1.5609; lit.[15] bp 77° (0.7 mm), $n^{25.5}D$ 1.5582].

***o*-(1-Cyclodecenyl)chlorobenzene (11b).** The mixture of cyclodecanone (0.15 mole, prepared[27] conveniently and in good yield from cyclooctanone) and Grignard reagent (0.17 mole) was heated at the reflux temperature for 6 hr and processed as described above. *o*-(1-Cyclodecenyl)chlorobenzene (**11b**) [10.7 g, 29% yield, bp 80–87° (0.02 mm), n^{25} D 1.5618] was obtained as a colorless oil together with considerable quantities of cyclodecanone [bp 58–60° (1 mm), up to 70% recovery]. A sample of **11b**, rechromatographed (alumina) and redistilled for analysis, had bp 103–103.5° (0.10 mm); $n^{25}D$ 1.5608; ultraviolet $\lambda_{max}^{95\%\ alcohol}$ 236 mμ (log ϵ 3.83), 255 mμ (sh) (log ϵ 3.54), λ_{max} 299 mμ (log ϵ 2.67).

Anal. Calcd for $C_{16}H_{21}Cl$: C, 77.24; H, 8.51; Cl, 14.25. Found: C, 77.22; H, 8.39; Cl, 14.32.

The Barbier–Grignard procedure[28] gave **11b** in 24% yield.

***o*-(1-Cyclododecenyl)chlorobenzene (11c).** The mixture obtained from cyclododecanone (0.1 mole) and Grignard reagent (0.2 mole) was heated for 24 hr. The mixture was processed essentially as described above for **11a**. The dehydrated product was chromatographed on alumina (600 g), using petroleum ether (bp 60–68°). The oil (23 g, 83% yield) eluted from the column solidified (mp 96–108°). The olefin **11c** was recrystallized for analysis from ethanol and melted at 114.5–116.5°.

Anal. Calcd for $C_{18}H_{25}Cl$: C, 78.09; H, 9.10; Cl, 12.80. Found: C, 78.37; H, 8.81; Cl, 12.47.

Synthesis of 12. *o*-(1-Cyclohexenyl)benzonitrile (12a). A stirred mixture of **11a** (19.3 g, 0.1 mole), cuprous cyanide (16.4 g, 0.18 mole), and N-methyl-2-pyrrolidone (100 ml) was heated[29] at the reflux temperature for 8 hr under nitrogen. Method A described by Friedman and Schechter[30] was used in processing the reaction mixture. The brown product was poured into a solution of hydrated ferric chloride (40 g), concentrated hydrochloric acid (10 ml), and water (60 ml). Residues were transferred with hot N-methyl-2-pyrrolidone. The resulting mixture was maintained at 60–70° for 20 min, and the layers were separated. The separation of the dark layers was facilitated by reflecting light off the separatory funnel. The hot aqueous (bottom) layer was extracted with two 25-ml portions of toluene. The combined organic layers were washed with dilute (1:1) hydrochloric acid (40 ml), two 50-ml portions of water, two 50-ml portions of 10% aqueous sodium hydroxide and were then filtered. The organic layer was washed with two additional 50-ml portions of water, dried (Na_2SO_4), and concentrated. The residue was distilled (14-in. spiral wire column) to give recovered **11a** (4.5 g, 23%) and **12a** [10.5 g, 75% yield, bp 88–90° (0.05 mm), $n^{26}D$ 1.5648; lit.[15] 60% yield, bp 92–94° (0.05 mm), $n^{25.5}D$ 1.5648].

***o*-(1-Cyclodecenyl)benzonitrile (12b).** The procedure described above for **12a** gave a low yield (5% of **12b**, 84% recovered **11b**) of **12b**. The following modification gave high yields of **12b**.

A mixture of **11b** (7.5 g, 0.03 mole), cuprous cyanide (4.5 g, 0.05 mole), and cuprous chloride (0.5 g) was heated[31] in N-methyl-2-pyrrolidone (20 ml) for 28 hr. Method C of Friedman and Schechter[30] was used to process the mixture. The hot reaction mixture was poured into a warm solution of potassium cyanide (20 g) in water (60 ml), and the mixture was shaken vigorously in a separatory funnel. The layers were separated, and the aqueous layer was extracted with benzene (150 ml). The combined organic layers were washed with 10% aqueous potassium cyanide (30 ml), filtered, dried ($MgSO_4$), and concentrated. The product was chromatographed (130 g of alumina), and the products were eluted with petroleum ether (bp 60–68°). There was obtained recovered

---

(27) K. C. Brannock, R. D. Burpitt, V. W. Goodlett, and J. G. Thweat, *J. Org. Chem.*, **29**, 818 (1964).

(28) M. P. Dreyfuss, *ibid.*, **28**, 3269 (1963).

(29) M. S. Newman and H Boden, *ibid.*, **26**, 2525 (1961).

(30) L. Friedman and H. Shechter, *ibid.*, **26**, 2522 (1961).

(31) C. F. Koelsch and A. G. Whitney, *ibid.*, **6**, 795 (1941).

11b (0.5 g, 6.5%) and **12b** (yellow oil, 4.63 g, 65% yield). The yellow oil solidified and melted at 46–47.5° (from ethanol).

Anal. Calcd for $C_{17}H_{21}N$: C, 85.30; H, 8.84; N, 5.85. Found C, 85.10; H, 8.87; N, 5.57.

***o*-(1-Cyclododecenyl)benzonitrile (12c).** The mixture containing chloride **11c** (21.3 g, 0.077 mole) was heated for 41 hr as described above for the preparation of **12b**. Method A[30] (see preparation of **12a**) was used to process the mixture. The crude product was chromatographed on alumina (500 g), and there was obtained recovered **11c** (2.87 g, 13.5%) and (with 40% benzene–petroleum ether) nitrile **12c** (13.61 g, 66% yield, yellow oil). The oil crystallized (mp 125–127°), and pure **12c** (white crystals) melted at 127–128° from ethanol.

Anal. Calcd for $C_{19}H_{25}N$: C, 85.34; H, 9.42; N, 5.24. Found: C, 85.62; H, 9.14; N, 5.04.

Conversion of 12 to 13. The procedures used were essentially identical with that previously described[15] for **13a**.

***o*-(1-Cyclohexenyl)benzylamine hydrochloride (13a)** was obtained as a white solid, mp 206–210° dec, 70% yield (lit.[15] 84% yield, mp 210–213° dec).

***o*-(1-Cyclodecenyl)benzylamine hydrochloride (13b),** after 5 hr reflux, was obtained in 80.4% yield, mp 195–203°, 198.5–199° from dry ethanol–ether.

Anal. Calcd for $C_{17}H_{26}ClN$: C, 72.96; H, 9.37; N, 5.01. Found: C, 72.99; H, 9.41; N, 4.73.

***o*-(1-Cyclododecenyl)benzylamine hydrochloride (13c),** after 5 hr reflux, was obtained in 53% yield, mp 176–180°, 196–197.5° from absolute ethanol.

Anal. Calcd for $C_{19}H_{30}ClN$: C, 74.11; H, 9.82; N, 4.55. Found: C, 73.77; H, 9.84; N, 4.74.

Conversion of 13 to 1. The procedure used is a modification of that previously described[15] for **1a** and **1** (n = 5) and is described in detail for **1a**.

1,2,3,4-Tetrahydrofluorene[32] (1a). A mixture of **13a** (7.0 g, 0.031 mole), sodium nitrite (2.55 g, 0.037 mole), and water (100 ml) was heated on a steam bath for 2 hr. The cooled mixture was extracted with ether (250 ml), and the ether extract was washed with three 100-ml portions of 10% aqueous hydrochloric acid, two 75-ml portions of 10% aqueous sodium hydroxide, and four 100-ml portions of water. The red oil obtained by removal of ether was dissolved in 88% formic acid (50 ml) and heated on a steam bath for 1.5 hr. The mixture was cooled and made just neutral with aqueous sodium hydroxide; the crude product (3.97 g, 75% yield, mp 46–51°) was collected and chromatographed on alumina (100 g) using petroleum ether (bp 60–68°) as eluent. There was obtained 3.09 g, 59%, of **1a** as colorless plates (mp 49–51°; lit.[15] mp 53.5–55°). The indene **1a** showed: infrared spectrum $\nu_{C=C}$ 1635 cm^{-1}; ultraviolet spectrum $\lambda_{max}^{95\%\ alcohol}$ 259 mμ (log ϵ 4.12), lit.[33] 260 mμ (log ϵ 4.185); nmr spectrum[16c] (25% in $DCCl_3$) C_6H_4 (complex, τ 2.59–3.18, wt 4), benzylic CH_2 (broad singlet, τ 6.86, wt 2), $C{=}CCH_2$ (complex, τ 7.50–7.83, wt 4), and CH_2 (complex, τ 8.15–8.42, wt 4.)

Octahydrocyclodec[*b*]indene (1b). The product from **13b** (3.20 g) was an oil which was extracted with ether and petroleum ether, washed with water, dried ($MgSO_4$), and concentrated. The oil obtained by removal of solvent was chromatographed (twice) on alumina (35 g), and the column was eluted with petroleum ether (bp 60–68°). Octahydrocyclodec[*b*]indene (**1b**) was obtained as a colorless oil [1.78 g, 69% yield, bp 109° (0.1 mm); $n^{25}\text{D}$ 1.5767 (distilled material)]. The indene **1b** showed: infrared spectrum (neat) $\nu_{C=C}$ 1620 cm^{-1}; ultraviolet spectrum $\lambda_{max}^{95\%\ alcohol}$ 219 (sh)[21] (4.12), 226 (sh) (3.39), 260 (4.13), 269 (sh) (4.02), and 282 mμ (inf)[21] (log ϵ 3.25); nmr spectrum (4% in $DCCl_3$) C_6H_4 (complex, τ 2.50–3.00, wt 3.9), benzylic CH_2 (broad singlet, τ 6.75, wt 2), $C{=}CCH_2$ (complex, τ 7.13–7.48, wt 3.9), and CH_2 (complex, τ 7.98–9.03, wt 11.6).

Anal. Calcd for $C_{17}H_{22}$: C, 90.20; H, 9.80. Found: C, 89.93; H, 9.82.

Decahydrocyclododec[*b*]indene (1c). The product from **13c** (7.28 g), subsequent to reaction with formic acid, was diluted with water and extracted with ether (two 100-ml portions). The extract was washed with 10% hydrochloric acid (100 ml) and saturated sodium bicarbonate (100 ml), dried ($MgSO_4$), and concentrated. The residue (6.0 g) was chromatographed on alumina (150 g). There was obtained 2.81 g (47% yield) of **1c** as a mushy solid. Recrystallization of the product from pentane gave pure **1c** as white crystals, mp 53.5–55°; infrared (Nujol) $\nu_{C=C}$ 1617 cm^{-1}; ultraviolet spectrum $\lambda_{max}^{95\%\ alcohol}$ 219 (sh) (4.10), 226 (3.91), 259 (4.13), 268 (inf) (4.03), and 282 mμ (inf) (log ϵ 3.18); nmr spectrum (2% in $DCCl_3$) C_6H_4 (complex, τ 2.53–2.94, wt 3.8), benzylic CH_2 (broad singlet, τ 6.75, wt 2), $C{=}CCH_2$ (complex, τ 7.28–7.66, wt 4), and CH_2 (complex, τ 8.12–8.83, wt 15.8).

Anal. Calcd for $C_{19}H_{26}$: C, 89.70; H, 10.30. Found: C, 89.93; H, 10.68.

Preparation of 12,13-Benzo-16-chloro[10]metacyclophane (3c). The indene **1c** (1.00 g, 3.94 mmoles) and phenyl(trichloromethyl)-mercury (3.12 g, 7.86 mmoles) were allowed to react in hot benzene for 36 hr, and the mixture was processed as described for the preparation of **6**. The crude oil was chromatographed on alumina (100 g, petroleum ether as eluent, 1 l.), and the product (1.10 g, 100% yield), which contained no unreacted **1c** (by infrared), solidified after standing several days to a mushy solid. Recrystallization of this product from ethanol gave 12,13-benzo-16-chloro[10]-metacyclophane (**1c**) as a white solid, mp 55–57°, 0.86 g, 73% yield. The melting point of **1c** was raised to 58–59.5° by further recrystallization of the product from ethanol. The product **1c** showed: ultraviolet spectrum $\lambda_{max}^{95\%\ alcohol}$ 230 (sh) (4.91), 235 (5.06), 259 (diffuse inf) (3.35), 269 (sh) (3.58), 278 (3.72), 288 (3.76), 298 (sh) (3.60), 312 (diffuse inf) (2.79), and 322 (inf) mμ (log ϵ 2.39); nmr spectrum (30% in $DCCl_3$) aromatic H (complex, τ 1.95–2.73, wt 5) and CH_2 (very complex, τ 6.08–6.96, wt 3, and very complex, τ 7.08–10.0, wt 17).

Anal. Calcd for $C_{20}H_{25}Cl$: C, 79.85; H, 8.38; Cl, 11.79. Found: C, 79.68; H, 8.13; Cl, 11.91.

In a second experiment the yield of **3c** (mp 53–54°) was 90%.

Reactions of 12,13-Benzo-16-chloro[10]metacyclophane (3c). Reaction with Magnesium. Reaction of **3c** with magnesium in ether in the presence of ethylene bromide (as described for **6**), and with magnesium in tetrahydrofuran, gave high recovery (92–100%) of starting material.

Bromination with N-Bromosuccinimide. A sample of **3c** (0.84 g, 2.79 moles) was treated with N-bromosuccinimide (0.99 g, 5.58 mmoles) as described for **6**. The concentrate, obtained subsequent to removal of succinimide, was chromatographed (75 g of alumina using petroleum ether, 1 l., as eluent) to give a colorless oil (0.80 g) which solidified upon standing to a solid, mp ~75°. One recrystallization of this material from petroleum ether (bp 60–68°) gave colorless crystals (mp 135–170°) composed (thin layer chromatography) of one major and two minor components. The nmr spectrum (20% in $DCCl_3$) of this material was consistent with that expected for the benzylic monobrominated product and showed aromatic H (complex, τ 1.79–2.64, wt 5), benzylic H (quartet, τ 3.95, 4.03, 4.13, 4.21, wt 1), benzylic H (complex, τ 6.31–6.67, wt 2), and CH_2 (complex, τ 7.12–10.00). This material was not examined further.

Conversion of 10. The cyclophane **3c** (0.25 g, 0.83 mmole) was oxidized by the procedure of Bamford and Simonsen,[34] as described in detail for oxidation of **6**. There was obtained 0.190 g of mixed methyl esters, and glpc (see conversion of **6** → **10**) showed the same major and minor product mixtures that were obtained from the oxidation of **6** but in different amounts (first major peak, ~21%; second major peak, ~40%; third peak, ~30%. The same minor peaks were present. These compare to 14, 26, and 31%, respectively, for the three major peaks obtained from **6**. Preparative glc was carried out as described for **6**, with essentially the same results. From the third major peak there was obtained **10** (mp and mmp 80–83°) identical (infrared, nmr) with that obtained from **6**.

Preparation of 10,11-Benzo-14-chloro[8]metacyclophane (3b). The reaction of **1b** (1.4 g, 6.2 mmoles) with phenyl(trichloromethyl)-mercury (3.00 g, 7.5 mmoles) in hot benzene (50 ml) was carried out for 67 hr as described for **3c** and **6**. The yellow oil (2.40 g) was chromatographed twice on alumina (40 g) using petroleum ether (bp 60–68°) as eluent. There was obtained 1.50 g (89% yield) of mushy yellow solid. Recrystallization of this product from ethanol gave **3b** as white crystals melting at 65–67°. The cyclophane **3b** showed: ultraviolet $\lambda_{max}^{95\%\ alcohol}$ 232 (sh) (4.74), 238 (4.91), 272 (inf) (3.60), 281 (3.69), 288 (3.72), 298 (diffuse inf) (3.57), and 319 (diffuse inf) mμ (log ϵ 2.40); nmr spectrum (19% in CCl_4) aromatic H (complex, τ 2.08–2.81, wt 5), CH_2 (complex, τ 6.15–6.93, wt ~3; complex τ 7.18–9.57, wt ~12; complex τ 9.77–10.48, wt ~2).

---

(32) The olefin **1a** is more conveniently prepared (~65% yield) by reduction of fluorene; *cf.* R. A. Benkeser, R. E. Robinson, D. M. Sauve, and O. H. Thomas, *J. Am. Chem. Soc.*, **77**, 3230 (1955).

(33) H. Christol, R. Jacquier, and M. Mousseron, *Bull. Soc. Chim. France*, 248 (1958).

(34) H. Bamford and J. L. Simonsen, *J. Chem. Soc.*, **97**, 1904 (1910).

Anal. Calcd for $C_{18}H_{21}Cl$: C, 79.24; H, 7.76. Found: C, 78.87; H, 7.74.

Preparation of 1,2,3,4-Tetrahydro(4a,9a-dichloromethano)fluorene (2a). A. Chloroform–Potassium *t*-Butoxide. Chloroform (11.94 g, 0.10 mole) in anhydrous benzene (50 ml) was added over a 35-min period under nitrogen to a cold, stirred mixture of **1a** (8.51 g, 0.05 mole) and potassium *t*-butoxide[9] (0.11 mole) in anhydrous benzene (100 ml). The mixture was processed as described for the conversion of **4** to **6**. The yellow oil (11.86 g, 94% yield) obtained by chromatography (alumina, 250 g) solidified. Recrystallization of this product from ethanol gave **2a** as a pale yellow solid, mp 86.5–87° (mixed up with that described below, 86–87.5°).

B. Phenyl(trichloromethyl)mercury. The reaction of **1a** (8.5 g, 0.05 mole) with phenyl(trichloromethyl)mercury (19.8 g, 0.05 mole) in hot benzene (100 ml) was carried out for 65 hr as described for reaction with **4**. The yellow solid (10.21 g, 81% yield, mp 84–86°), obtained subsequent to removal of phenylmercuric chloride (14.0 g, 90%), was recrystallized from ethanol to give **2a** as a white solid (mp 86.5–87.5°). The cyclopropane **2a** showed: nmr spectrum (25% in $DCCl_3$) C_6H_4 (complex, τ 2.67–2.98, wt 4), benzylic CH_2 (AB quartet, τ 6.35, 6.64, 6.80, and 7.09; $J_{AB} = 17.5$ cps, wt 2), CH_2 (complex, τ 7.56–8.18, wt 4), and CH_2 (complex, and τ 8.32–8.86, wt 4).

Anal. Calcd for $C_{14}H_{14}Cl$: C, 66.42; H, 5.57; Cl, 28.01. Found: C, 66.41; H, 5.59; Cl, 27.58.

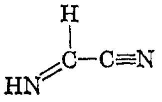
Hydrogen Cyanide Dimer. Aminocyanocarbene

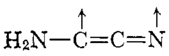
R. E. Moser, J. M. Fritsch, T. L. Westman, R. M. Kliss, and C. N. Matthews

Contribution from the Central Research Department, Monsanto Company, St. Louis, Missouri 63166. *Received May 31, 1967*

Abstract: The synthesis and properties of aminocyanocarbene are described. Thermal and photolytic decomposition of the sodium (Vb) and lithium (Vc) salts of 1-cyanoformamide *p*-toluenesulfonylhydrazone gives diaminomaleonitrile, a tetramer of hydrogen cyanide, as the major product. Irradiation of Vc at −196° in 2-methyltetrahydrofuran glass forms a yellow product, identified as aminocyanocarbene, absorbing in the range 332–450 mμ with the principal maximum at 391 mμ. No epr signals characteristic of a triplet methylene were observed. These results indicate that aminocyanocarbene is a singlet ground-state compound possessing considerable dipolar character. Aminocyanocarbene may be a key intermediate in hydrogen cyanide polymerization and in prebiological organic synthesis.

Base-catalyzed polymerization of hydrogen cyanide yields a mixture of products which includes a tetramer (diaminomaleonitrile),[1,2] a pentamer (adenine),[2] polymeric amino acid precursors,[3] and black, intractable solids believed to have fused tetrahydropyridine structures.[1] Whatever the reactions leading to these products, it is reasonable to suppose that a key step would be dimerization of hydrogen cyanide. In the absence of experimental evidence it has been widely assumed that HCN dimer is iminoacetonitrile (I).[1] An alternative structure has been proposed by Kliss and Matthews[4] who have argued that I would spontaneously tautomerize to aminocyanocarbene.


I


$H_2N{-}\overset{\uparrow}{C}{=}C{=}\overset{\uparrow}{N}$

III

The prediction that aminocyanocarbene is of lower energy than I has been supported by LCAO–MO calculations of Serre and Schneider[5] who suggest that its stability results from electron delocalization in a triplet ground state. Electron paramagnetic resonance (epr) experiments have established the existence of triplet ground states for two related compounds, cyanomethylene[6,7] and dicyanomethylene.[8] In the parent compound, cyanomethylene, the triplet state with delocalization of unpaired electrons in mutually orthogonal orbitals extending over the C–C–N system is evidently preferred to a 1,3-dipolar singlet state with paired electrons residing primarily on the more electronegative terminal nitrogen atom. For aminocyanocarbene, however, the effect of the amino group on this electron distribution may be significant. Delocalization of the unshared pair of amino electrons[9,10] into an unoccupied p orbital of the carbene center followed by further delocalization over the nitrile group could be sufficiently stabilizing to cause the ground state to be singlet (II), with considerable dipolar character. Two ground-state structures for aminocyanocarbene must therefore be considered, the singlet II and the triplet III. In this paper we describe the synthesis and properties of aminocyanocarbene and the determination of its ground spin state.

Results

1. Synthesis and Reactions of Aminocyanocarbene. A synthetic route was devised for generating aminocyanocarbene *via* aminocyanodiazomethane (IV) since polymerization of hydrogen cyanide proceeds too

---

[1] T. Völker, *Angew. Chem.*, **72**, 379 (1960), and references cited therein.

[2] R. Sanchez, J. Ferris, and L. E. Orgel, *Science*, **153**, 72 (1966), and references cited therein.

[3] (a) C. N. Matthews and R. E. Moser, *Nature*, **215**, 1230 (1967); (b) C. N. Matthews and R. E. Moser, *Proc. Natl. Acad. Sci. U. S.*, **56**, 1087 (1966), and references cited therein.

[4] R. M. Kliss and C. N. Matthews, *ibid.*, **48**, 1300 (1962).

[5] J. Serre and F. Schneider, *J. Chim. Phys.*, **61**, 1655 (1964).

[6] R. A. Bernheim, R. J. Kempf, P. W. Humer, and P. S. Skell, *J. Chem. Phys.*, **41**, 1156 (1964).

[7] R. A. Bernheim, R. J. Kempf, J. V. Gramas, and P. S. Skell, *ibid.*, **43**, 196 (1965).

[8] E. Wasserman, L. Barash, and W. A. Yager, *J. Am. Chem. Soc.*, **87**, 2075 (1965).

[9] J. Hine, "Divalent Carbon," The Ronald Press Co., New York, N. Y., 1964, pp 168, 172.

[10] W. Kirmse, "Carbene Chemistry," Academic Press Inc., New York, N. Y., 1964, p 204.