

SYNTHESIS AND SOME REACTIONS OF 3-AMINO-*o*-CARBORANES

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SUMMARY

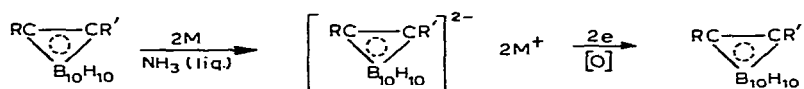
1. 3-Aminocarboranes have been prepared using the dicarbadodecaborane(14) dianions—the products obtained by the addition of two electrons to the carborane molecule in liquid ammonia.

2. 3-Aminocarboranes exhibit the properties characteristic of aliphatic and aromatic amines: they form salts with acids, and may be alkylated, acylated and diazotized.

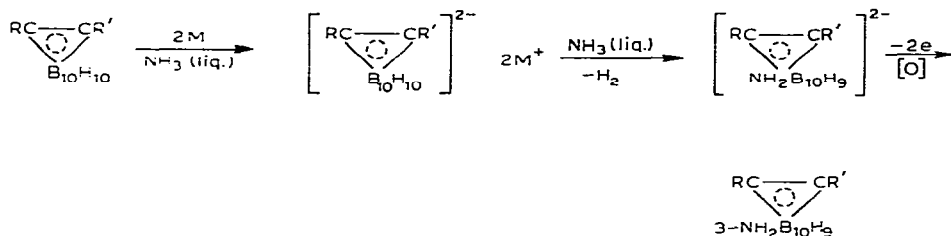
3. 3-Halocarboranes, including 3-fluorocarboranes, have been prepared via the diazonium salts of 3-aminocarboranes.

Information on the functional derivatives of *o*-carboranes where a functional group is bonded to the boron atom of the carborane nucleus has so far been very scanty. Only the preparation of the 9-hydroxycarboranes and their nitrates from nitric acid and carboranes¹, the synthesis of 3-carborane aldehyde and 3-carborane carboxylic acid from 3-vinylcarborane², and the synthesis of 3-(*N*-diethylamino)-carborane from disodium(1)-2,3-dicarbollide and *N*-diethylaminoboron dichloride³ have been described.

In the present paper we propose a simple method for the synthesis of the previously unknown 3-aminocarboranes, and discuss some of their properties. Recently, the reaction of the alkali metals with carboranes in liquid ammonia has been shown⁴ to produce dianions of dicarbadodecaboranes(14) after two electrons add to the carborane system. This addition is reversible, and in the presence of oxidants these dianions transform into the initial carboranes:

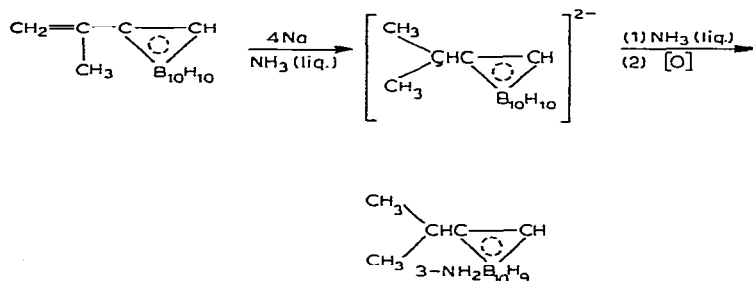


We have found that the dianions of dicarbadodecaboranes(14) react with liquid ammonia at low temperature with hydrogen evolution to give *B*-amino derivatives, which subsequently oxidize in liquid ammonia with the appropriate oxidant (*e.g.*, potassium permanganate or cupric halides) to give a high yield of 3-aminocarboranes:



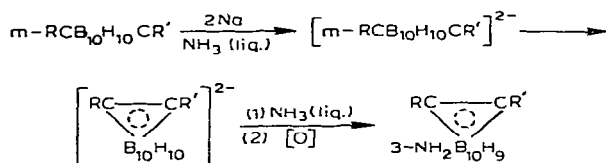
In this reaction only one amino group combines with the carborane nucleus to give a single isomer—a 3-amino-substituted carborane. The reaction rate of the dianion with ammonia is affected by the substituents in the 1- and 2-positions of the carborane nucleus. The effect of the substituents is associated with their electronic and steric characteristics. The introduction of electron-releasing substituents into the 1- and 2-positions speeds up the reaction whereas the bulk groups hinder the reaction. We have therefore failed to react 1,2-diphenylcarborane with ammonia, for the two phenyl groups in the dianion of diphenyldicarbododecaborane(14) seem to exhibit a strong steric hindrance to the neighbouring reaction center. This method has been used to prepare 3-aminocarboranes (Table 1) from carborane, 1-methylcarborane, 1-ethylcarborane, 1-isopropylcarborane, 1-phenylcarborane and 1,2-dimethylcarborane.

Earlier it was shown⁵ that four equivalents of alkali metal should react with 1-isopropenyl carborane in liquid ammonia. We have found that in this case the reaction product is the dianion of isopropyldicarbododecaborane(14) which further gives 1-isopropyl-3-aminocarborane. In the case of 1-vinylcarborane, the reaction product was 1-ethyl-3-aminocarborane. Thus, 3-aminocarboranes prepared by means of this method have been completely identical with those obtained from 1-isopropyl- and 1-ethylcarboranes.



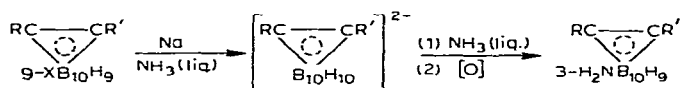
The mechanism of the reaction described here may be explained as follows. The addition of two electrons to the carborane molecule should undoubtedly proceed into the regions of lowest electron density in the carborane nucleus, *i.e.*, within the area of the 3rd and 6th boron atoms. This substantially increases the electron density on the latter and the hydride lability of hydrogens bonded to them. This lability seems to be quite essential to the reaction with ammonia, splitting a hydrogen molecule and generating the B–N bonding. The introduction of one NH₂-group into the 3-position should decrease the electron density in the 6-position, and the lowered hydrogen lability is then insufficient to provide a reaction with another ammonia molecule. The mechanism suggested is in a good agreement with experimental data (formation

of hydrogen in the reaction, high selectivity of the process, influence of steric effects, rate increase after introduction of electron-releasing substituents into the 1- and 2-positions of the carborane nucleus). In such reactions *m*-carboranes do not give *B*-aminocarboranes, but the corresponding 3-amino-*o*-carborane, since under the reaction conditions the *m*-dicarbadodecaborane(14) dianions rearrange into those of *o*-dicarbadodecaboranes(14)⁶:



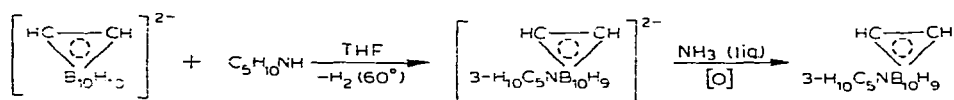
Thus, *m*-carborane, 1-methyl-*m*-carborane, 1-phenyl-*m*-carborane and 1,7-dimethyl-*m*-carborane gave the relevant 3-amino-*o*-carboranes which are completely identical with 3-aminocarboranes prepared from the corresponding *o*-carboranes.

We have attempted to prepare from 9-halocarboranes, 3-aminocarboranes containing a halide atom in the carborane nucleus, but more than two (about three) equivalents of alkali metal react with 9-halocarboranes in liquid ammonia, and the subsequent oxidation leads to 3-aminocarboranes free of halogen:



(X = Br or I)

Thus, the reaction of alkali metals with 9-halocarboranes involves dehalogenation with substitution of the halogen by a hydrogen atom and, finally, the generation of dicarbadodecaborane(14) dianion. In some cases 3-aminocarborane derivatives may be prepared from the dicarbadodecaborane(14) dianions and primary and secondary amines. For example, on heating dicarbadodecaborane(14) anion and piperidine in THF solution at 60° and oxidizing further with potassium permanganate in liquid ammonia, *N*-3-piperidinocarborane is obtained.



3-Aminocarboranes are colourless, easily crystallized compounds, stable to water and air oxygen. In the infrared spectra of all 3-aminocarboranes two absorption bands characteristic of the NH₂-group have been found in the region of 3300–3500 cm⁻¹. 3-Aminocarboranes have been shown to participate in reactions characteristic of aliphatic and aromatic primary amines. They also form stable salts with acids. Thus, we have prepared hydrochlorides and picrates of 3-aminocarborane, 1-methyl-3-aminocarborane and 1-ethyl-3-aminocarborane. The basicity of the amino series have been determined in 50% alcohol solution (Table 2).

It can be seen that the acid dissociation constants of carborane-3-ammonium salts are nearly equal to the acid dissociation constants of anilinium salts.

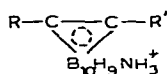
TABLE I
 3-AMINOCARBORANES

Amine	M.p. (°C)	Found (%)			Formula	Calcd. (%)			Yield (%)		
		C	H	N		C	H	N			
3-Aminocarborane	218-219	15.36	8.33	67.44	8.32	$C_2H_{13}B_{10}N$	15.08	8.22	67.91	8.79	85-90
1-Methyl-3-aminocarborane	231-232	21.00	8.76	62.50	8.20	$C_3H_{13}B_{10}N$	20.80	8.66	62.40	8.08	85-90
1-Ethyl-3-aminocarborane	91-93	25.73	9.10	57.74	7.70	$C_{14}H_{17}B_{10}N$	25.64	9.14	57.74	7.48	85-90
1-Isopropyl-3-aminocarborane	"				7.02	$C_5H_{19}B_{10}N$	31.40	9.95	56.70	6.96	70-75
1-Phenyl-3-aminocarborane	81-82	40.90	7.63	46.18	6.12	$C_8H_{17}B_{10}N$	40.81	7.28	45.96	5.95	50-60
1,2-Dimethyl-3-aminocarborane	319-320	25.63	9.30	57.70	7.35	$C_4H_{17}B_{10}N$	25.64	9.14	57.74	7.48	80-85

" B.p. 116° (2 mm).

TABLE 2

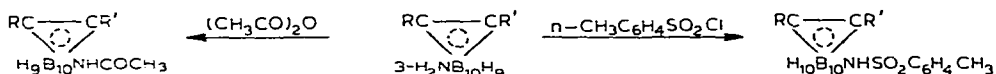
ACID DISSOCIATION CONSTANTS OF CARBORANE-3-AMMONIUM SALTS



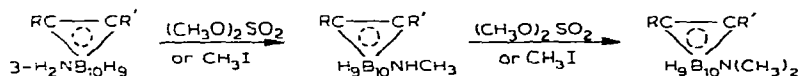
Amines	pK_a
3-Aminocarborane	3.17
1-Methyl-3-aminocarborane	3.00
1-Ethyl-3-aminocarborane	2.93
1-Isopropyl-3-aminocarborane	2.78
1-Phenyl-3-aminocarborane	2.70
1,2-Dimethyl-3-aminocarborane	2.53
Aniline	4.04
<i>p</i> -Chloroaniline ^a	3.98 ^b
<i>p</i> -Nitroaniline ^a	1.02 ^b

^a In water. ^b Ref. 7.

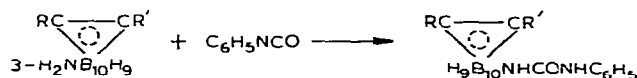
3-Aminocarboranes are readily acylated with acetic anhydride benzoyl chloride and *p*-toluenesulfonyl chloride into the corresponding acid amides:



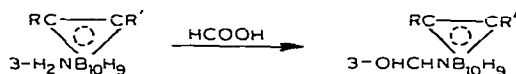
They are alkylated by dialkyl sulfates and alkyl halides into *N*-dialkyl-3-aminocarboranes:



The reaction of 3-aminocarboranes with phenylisocyanate gives the corresponding urea derivatives:



Formic acid reacts with 3-aminocarborane to give the *N*-formyl derivatives:



The *N*-substituted 3-aminocarboranes that have been prepared are shown in Table 3.

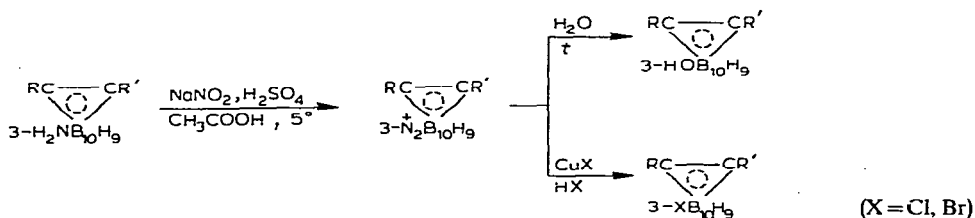
An interesting property of the amino-group in 3-aminocarboranes is its ability to participate in diazotization (nitrosylsulfuric acid reacting with 3-aminocarborane solution in acetic acid). The resulting diazonium salts are of relatively low stability, slowly decomposing in solution at 0–5° into the corresponding 3-hydroxycarboranes. However, the rapid addition of the diazonium salt solution to that of a cuprous salt in the appropriate acid easily gives the respective 3-halocarboranes. In this way, for example, we have obtained the previously unreported 3-chloro- and 3-bromocarboranes.

TABLE 3

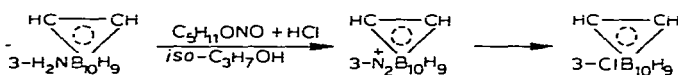
N-SUBSTITUTED-3-AMINOCARBORANES

Compound	M.p. (°C)	Found (%)	Formula	Calc. (%)
		N		N
Hydrochloride of 3-aminocarborane ^a	290–291	7.07	C ₂ H ₁₄ B ₁₀ NCl	7.15
Hydrochloride of 1-methyl-3-aminocarborane ^b	250–252	6.64	C ₃ H ₁₆ B ₁₀ NCl	6.68
Hydrochloride of 1-ethyl-3-aminocarborane	220–222	6.66	C ₄ H ₁₈ B ₁₀ NCl	6.38
Hydrochloride of 1-isopropyl-3-aminocarborane ^c	215–218	6.31	C ₅ H ₂₀ B ₁₀ NCl	5.90
Picrate of 3-aminocarborane	217–219	14.03	C ₈ H ₁₆ B ₁₀ N ₃ O ₇	14.41
3-N-Acetylamino-carborane ^d	129–130	6.50	C ₄ H ₁₅ B ₁₀ NO	6.96
1-Methyl-3-N-acetylamino-carborane	150–151	6.63	C ₅ H ₁₇ B ₁₀ NO	6.52
3-N-Benzoylamino-carborane	179–180	5.40	C ₉ H ₁₇ B ₁₀ NO	5.31
1-Methyl-3-N-benzoylamino-carborane	170–171	5.39	C ₁₀ H ₁₉ B ₁₀ NO	5.07
N-(3-Carboranyl)-p-toluenesulfamide	189–190	4.26	C ₉ H ₁₉ B ₁₀ NO ₂ S	4.47
N-(3-Methylcarboranyl)-p-toluenesulfamide	186–187	4.10	C ₁₀ H ₂₁ B ₁₀ NO ₂ S	4.28
3-N-Dimethylaminocarborane ^e	71.5–72	6.88	C ₄ H ₁₈ B ₁₀ N	7.50
1-Methyl-3-N-dimethylaminocarborane	61–63	6.75	C ₅ H ₂₀ B ₁₀ N	6.96
3-N-Diethylaminocarborane	84–85	6.05	C ₈ H ₂₂ B ₁₀ N	6.52
N-Phenyl-N'-3-carboranyl urea	151–153	10.30	C ₉ H ₁₈ B ₁₀ N ₂ O	10.08
N-Phenyl-N'-3-(methylcarboranyl)urea	160–162	9.63	C ₁₀ H ₂₀ B ₁₀ N ₂ O	9.58

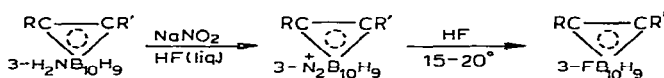
^a Found: Cl, 18.22. Calcd.: Cl, 18.11%. ^b Found: Cl, 17.37. Calcd.: Cl, 16.94%. ^c Found: Cl, 15.57. Calcd.: Cl, 15.00%. ^d Found: C, 23.69; H, 7.24; B, 53.07. Calcd.: C, 23.86; H, 7.51; B, 53.73%. ^e Found: C, 25.92; H, 9.14; B, 57.64. Calcd.: C, 25.65; H, 9.09; B, 57.70%.



3-Aminocarboranes may be diazotized similarly by amyl nitrite in isopropanol solution saturated with hydrogen chloride. On heating 3-chlorocarborane is produced.



3-Aminocarboranes may be readily diazotized by sodium nitrate in a solution of liquid hydrogen fluoride. By raising the temperature of the reaction mixture to 15–20° we have prepared the B-fluorocarborane derivatives, the 3-fluorocarboranes:

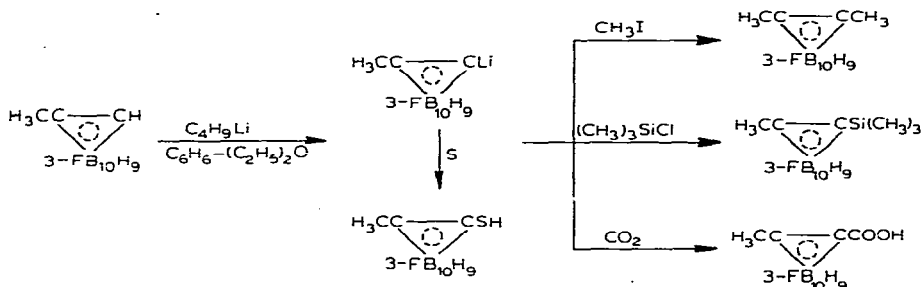


The 3-halo- and 3-hydroxycarboranes obtained in the present study are shown in Table 4. 3-Fluorocarboranes are crystalline compounds, stable to moisture, and

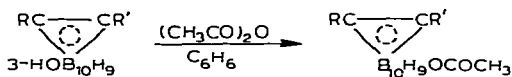
TABLE 4
3-HALO- AND 3-HYDROXY-CARBORANES

Compound	M.p. (°C)	Found (%)			Calcd. (%)		
		C	H	Hal	C	H	Hal
3-Hydroxycarborane	356-358	15.27	7.47	67.09	14.98	7.54	67.49
1-Methyl-3-hydroxycarborane	259-261	20.24	7.63		20.67	8.09	
3-Acetyloxycarborane	76-76.5	23.38	6.96	53.76	23.74	6.97	53.47
1-Methyl-3-acetyloxycarborane	74-75	27.84	7.65	49.92	27.75	7.46	50.00
3-Chlorocarborane	169.5-170	13.55	6.33	60.55	13.44	6.20	60.53
3-Bromocarborane	118.5-119	11.33	5.12	48.92	10.76	4.97	48.47
1-Methyl-3-chlorocarborane	184-185	19.03	6.85	56.64	17.98	6.90	56.12
3-Fluorocarborane	242			66.04			66.60
1-Methyl-3-fluorocarborane	207-208			61.09			61.40
1,2-Dimethyl-3-fluorocarborane	234-235	26.09	8.09	56.25	25.23	7.95	56.88
1-Methyl-2-carboxy-3-fluorocarborane	240			48.58			49.08
1-Methyl-2-mercapto-3-fluorocarborane	241			51.35			52.03
1-Methyl-2-trimethylsilyl-3-fluorocarborane	98			43.69			43.50

have properties analogous to those of other 3-halocarboranes. It is of interest to note that they are more volatile than the relevant carboranes. They are smoothly metalated in ether-benzene medium by butyllithium along the C-H bonding of the carborane nucleus. Reactions with methyl iodide, carbon dioxide, trimethylchlorosilane and sulfur lead to the corresponding C-derivatives of 3-fluorocarboranes.



3-Hydroxycarboranes are easily acylated by acetic anhydride to give the respective 3-acetoxycarboranes.



EXPERIMENTAL

General procedure for preparation of 3-aminocarboranes

To 0.1 mole of the corresponding carborane in 400 ml of liquid NH_3 , was added 0.2 g-equiv. of alkali metal (Li, Na, K) at -50° and the mixture stirred at -40° to -50° for 1-2 h. Then at -60° 0.2 mole of KMnO_4 (CuCl_2 or CuBr_2) (finely dispersed) was slowly added to the reaction mixture. The major part of the ammonia was evaporated and to the residue at -60° was added 200 ml of water and then 200 ml of toluene with caution. The mixture was heated to room temperature and the organic layer separated, washed with water and dried over MgSO_4 . After evaporation of the solvent, the residue was crystallized from a $\text{C}_6\text{H}_{12}/\text{CHCl}_3$ mixture.

N-(3-Carboranyl)piperidine

To a solution of dicarbadodecaborane(14) dianion (from 1.44 g of carborane, 0.1 g of naphthalene and 0.5 g of sodium in 20 ml of THF) was added 1 g of piperidine. The mixture refluxed for 12 h; 205 ml of H_2 evolved during the reaction. The solution was poured into 100 ml of liquid NH_3 , after which 3 g of KMnO_4 was added at -60° . The excess NH_3 was evaporated and 100 ml of water and 50 ml of toluene were added to the residue. The organic layer was separated, washed with water and dried over MgSO_4 . After evaporation of the solvent, the product was crystallized from hexane. 1.1 g (49%) of *N*-(3-piperidino)carborane was obtained, m.p. 62° . (Found: C, 36.58; H, 9.51; N, 6.21. $\text{C}_7\text{H}_{21}\text{B}_{10}\text{N}$ calcd.: C, 36.98; H, 9.28; N, 6.16%.)

General procedure for preparation of 3-hydroxycarboranes

A solution of 0.82 g of NaNO_2 in 12 ml of conc. H_2SO_4 was added slowly to 0.01 mole of the corresponding 3-aminocarborane in 24 ml of CH_3COOH at $0-10^\circ$.

After 10 min the solution was poured into 100 ml of an ice-water mixture and the latter was stirred at 20° for 1 h. The solid precipitated was dissolved in ether, and the ethereal layer dried over MgSO₄. After evaporation of the solvent, the residue was crystallized from a C₆H₁₂/CHCl₃ mixture.

3-Chlorocarborane

The diazonium solution from the last experiment was added quickly to 2 g of CuCl in 50 ml of conc. HCl and heated to 60° for 1 h. The reaction mixture was extracted with ether and the ethereal layer dried over CaCl₂. After evaporation of the solvent, the residue, dissolved in hexane, was passed through a column of Al₂O₃; 0.85 g (47.5%) of 3-chlorocarborane was obtained.

General procedure for preparation of 3-fluorocarboranes

To 0.05 mole of the corresponding 3-aminocarborane in 150 ml of anhydrous HF, was added 0.052 mole of NaNO₂ in small portions at -10°. The HF was evaporated and 100 ml of water added to the residue. The mixture was neutralized with Na₂CO₃, and extracted with benzene. The benzene solution was dried over CaCl₂. After evaporation of the solvent the residue was sublimed *in vacuo*.

The determination of acid dissociation constants of carborane-3-ammonium salts

The acid dissociation constants of carborane-3-ammonium chloride were determined in 50% (v/v) ethanol/water mixture by potentiometric titration using an LPU-01 pH-meter in conjunction with glass and silver chloride electrodes at 25°. The calculation of acid dissociation constants is described in ref. 7.

The corresponding 3-aminocarborane (0.01 mole) was dissolved in 100 ml 50% (v/v) ethanol/water mixture and titrated against 0.104 N HCl to the equivalence point. The measurement of pK_a was accurate to ±0.02.

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