Alkenylboranes

Characterization of Methylvinylboranes

C. D. GOOD and D. M. RITTER

Department of Chemistry, University of Washington, Seattle 5, Wash.

METHYLVINYLBORANES and trivinylborane were characterized as the result of an improved preparative method (4) through observation of their infrared, ultraviolet, nuclear magnetic resonance (NMR), and mass spectra vapor pressures, and by vapor density. The ultraviolet and NMR spectra are published elsewhere (4). The gas-liquid chromatographic (GLC) properties were determined, and with suitable calibration they can be used henceforth for identification.

METHODS AND RESULTS

The GLC method previously described (10, 12) was modified by abandoning the recirculation of helium. Instead, the gas (Airco high purity helium) was passed into the apparatus through a column packed with Molecular Sieves (Type 5A, 1/16-inch pellets from Linde Air Products Co. Division, Union Carbide Corp.). The pressure was maintained constant by a glass-mercury regulator (6), and the flow rate was observed by means of a rotometer (F and P Co. precision bore Flowrator 08 - $\frac{1}{16}$ - 08 - $\frac{4}{32}$ with the sapphire sphere). For accurate measurements a moving soap film flowmeter (8) was installed at the exit. The flow rates were corrected for barometric pressure and the vapor pressure of the soap solution. The collecting system consisted of a parallel-series arrangement of cold traps packed with stainless steel wool and glass wool connected by flat-ground stopcocks (Kern-Exelo Brand distributed by Kern Laboratory Supply Co., Los Angeles 34, Calif.). The chromatographic columns were packed with Johns-Manville firebrick of 32-65 Taylor mesh impregnated with standard white oil No. 9 in a weight ratio of 0.38 to 1 applied from *n*-pentane and vacuum-dried at 80° C. for 1 hour before and after application of the oil. One column used in the purification of difluorovinylborane was constructed from 10-mm. I.D. borosilicate glass tubing filled with 50.0 grams of packing in 100-cm. length. Before use the column was conditioned by treatment with boron trifluoride at nearly 1-atm. pressure for 24 hours. Another column was constructed from 6.5-mm. I.D. borosilicate glass tubing filled with 9.85 grams of the same packing over a length of 45 cm. conditioned by a treatment with boron trichloride for 2 hours. Pertinent data are collected in Table I (1, 7).

Trimethylborane, the methylvinylboranes, trivinylborane, and triethylborane have specific retention volumes, V_{e} , which vary linearly with the molecular weight. Trivinylborane and the chlorovinylboranes form a similar linear set, but boron trichloride is slightly off the line.

The mass spectra were determined on a Consolidated Model 21-103 mass spectrometer operating at 70 volts with a rhenium filament. The measurements were made at two different pressures (about 30 and 100 microns) to assist in identification of trace impurities. These and few small background peaks were subtracted from each spectrum and by using a boron isotope ratio (13), 0.2500, and carbon isotope ratio, 0.01204, the results were reduced to the monoisotopic spectra recorded in Table II. The closeness of fit for a monoisotopic spectrum was judged from the residual $R = \Sigma N_i^2 / \Sigma I_i$ where N_i is the residue and I_i the intensity, respectively, for the *i* th peak. The polyisotopic spectra and a catalog of the impurities are recorded

	Table I.	GLC Prop	oerties ^a		
Compound	${V_{{\scriptscriptstyle R}}}^{\circ}$	H	V_s	n	8
$(CH_3)_3B$	67	16	17.5	100	558
$(CH_3)_2BC_2H_3$	201	60	63	117	517
$CH_{3}B(C_{2}H_{3})_{2}$	697	219	232	182	418
$(C_2H_3)_3B$	2250	718	761	340	425
$(C_2H_3)_2BCl$	1377	438	464	97	383
$C_2H_3BCl_2$	551	172	182		
BCl ₃	243	73	77		•••
$(C_2H_5)_3B$	4000	1280	1360		
$(C_2H_3)BF_2$	154	4.4	5.1	87	

n = column efficiency as number of theoretical plates.

s = detector sensitivity, ml. mv./mg.

^a At 22° C., atm. pressure, except $(C_2H_3)BF_2$ which was determined at 0°. V_{R° = corrected retention volume in cc. H = partition coefficient. V_{ε} = specific retention volume in cc.

(5). The polyisotopic spectra of the chlorovinylboranes are listed in Table III.

Infrared measurements were made on a Perkin-Elmer Model 21 spectrometer with sodium chloride and calcium fluoride optics. All measurements were made on gas phases, and atmospheric absorption peaks were used for calibration. The wave numbers reported are believed accurate to ± 5 cm.⁻¹. Previously unpublished infrared spectra are listed for dimethylvinylborane and methyldivinylborane in Table IV. The spectrum measured for trivinylborane was identical (within the experimental error) with that published elsewhere (3).

For further characterization, the standard method of static vapor pressure measurement was applied as developed by Stock (15) and Schlesinger and coworkers (14). The results are recorded in Table V, and the constants in Table VI are collected for the Antoine equation calculated from the data.

In Table VII are given the molecular weights of the methylvinylboranes and some other alkenylboranes examined by the measurements reported in this paper.

DISCUSSION

The original separation of trivinylborane by fractional condensation (10) gave a small amount of that product with an identity based upon complete ultimate analysis. In a later separation by the GLC method trivinylborane became confused with another substance of nearly the same GLC properties and vapor density. There seems now no doubt concerning the identity of trivinylborane as demonstrated by analyses based on instrumental measurements.

Trivinylborane and the methylvinylboranes had molecular weights corresponding to the calculated values (Table VII).

Each substance contained the assigned number of boron, carbon, and hydrogen atoms as shown by the mass spectra, because the residue from the conversion to the monoisotopic spectrum for a wrong empirical formula could not be as small as 7.7×10^{-5} found for trivinylborane, with comparable fit for the others.

$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$				Table	ll. Par	tial Mond	oisotopic	Mass Spectra	of Vinylbo	oranes				
$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$		R	elative I	ntensities					F	lelative I	ntensities			
$ \begin{array}{llllllllllllllllllllllllllllllllllll$		Trivinylborane		Methyl- vinylborane		Dimethyl- vinylborane			Trivinylborane		Methyl- vinylborane		Dimethyl- vinylborane	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Ion Species	+	2+	+	2+	+	2+.	Ion Species	+	2+	+	2+	+	2+
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC ₆ H ₉	0.76	0.06					$\mathbf{BC}_{2}\mathbf{H}_{4}$	87.2ª		48.0^{a}		11.4°	0.03
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC ₆ H ₈	100.0	0.25					BC ₂ H ₃	12.0	0.09	4.64		1.85	0.01
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC _e H ₇	17.2	0.55					BC ₂ H ₂	90.5	0.01	44.5			0.01
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BCeHe	13.5	0.13					BC	4.44		3.83			0.01
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC _e H _e	14.9	0.16					BC	1 10	0.02	0.75	•••	•••	• • •
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC.H.	0.97	0.10	• • •	•••			B02	1.10	0.02	0.10	• • •	•••	• • •
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC.H.	0.01	0.01	•••	•••		•••							
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		0.11	0.70	• • •	• • •	• • •	• • •	D:4			01.1			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		0.03	0.24	• • •	•••	• • •	•••	Dinuoro	ovinyiboran	e	Chlor	ometnylt	omyibora.	ne
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC6H	0.35	0.40	• • •	•••	• • •	• • •		Re	lative			Rela	ative
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC ₆	0.51	• • •		• • •	• • •	• • •	Ion Species	Inte	nsities	Ion Spe	cies	Inter	sities
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC ⁵ H ⁹	0.71	• • •	41.8	• • •	• • •	• • •			+				+
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC₅H₀	1.32	• • •	3.98	• • •	• • •	• • •							
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC_5H_7	11.6		7.43		• • •	• • •	$\mathbf{BC}_{2}\mathbf{H}_{3}\mathbf{F}_{2}$	10	0.0	$BC_{3}H$	sCl	51	1.1
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC_5H_6	31.1		4.31				$\mathbf{BC}_{2}\mathbf{H}_{2}\mathbf{F}_{2}$	1	.8.0	BC₃H	₅ Cl	().2
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC₅H₅	7.18		1.84				$\mathbf{BC}_{2}\mathbf{HF}_{2}$	1	5.9				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC_5H_4	0.56		0.43		• • •		$\mathbf{BC}_{2}\mathbf{F}_{2}$		0.79				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC_5H_3	1.23		1.17				BCHF ₂		1.37				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC ₅ H ₂	0.92		1.49				BF ₂	7	8.1				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC ₅ H	0.20		0.36				BC.H.F	2	1 0'	BC.H	Cl	100	0.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC.	0.20		0.11				BCaHaF		21.0 21.8	BC.H	.CI	100	20
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BCH.	• • •		0.11	•••	10.5	•••	BCUF	2	36	BC U		4	2.0
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC H.	0.69	• • •	•••	• • •	10.0	•••	BC.F	4	7.00	DC_2H		2	7.1
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		11 44	• • •	• • •	• • •	0.23	• • •			1.92	DOLL	01		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		11.4	• • •	100.0		• • •	• • •	BCH3F		1.34	BCH ₃		4(5.7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		54.0		100.0	0.03	• • •	•••	BCH ₂ F		0.67	BCH ₂	UI	38	3.5
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC ₄ H ₅	33.0	0.06	26.3	0.02	• • •	• • •	BCHF		2.25	BCHC		4	1.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC ⁴ H ⁴	22.4	0.08	5.06	0.13	• • •	• • •	BCF		1.18				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC₄H₃	2.20	0.57	0.78	0.53	• • •	• • •	BHF	1	4.9	BHCl		28	5.4
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC_4H_2	14.8	0.18	5.06	0.18		• • •	BF	1	1.5	BCl		1.	6
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC₄H	3.08	0.06	1.50	0.17	• • •	• • •				BC₃H	6	65.	0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	\mathbf{BC}_{4}	0.14	0.03			• • •					BC ₃ H	5	2.	2
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$BC_{3}H_{6}$	9.22°		73.3		100.0	?				BC ₃ H	4	12.	8
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	BC_3H_5	7.36°		22.5		0.70	?				BC ₃ H	- 1	12.	1
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	BC_3H_4	22.8	0.03	34.7	0.07	6.85	0.35				BC ₂ H	- -	11	.3
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC ₃ H ₃	9.67	?	21.3	?	5.47	?				BC	2	2	8.0
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC ₃ H ₃	3 77	0.03	11 6	0.04	3 52	0.08				BC.H		ر 1	5.8
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC	0.95	2.00	2 36	9 9	0.77	0.00					4	i. /	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	BC	0.55	0.11	2.00	0.00	0.77	• • •	DC II		1 00		3).Z
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		0.17	0.11	0.15	0.09		• • •			1.02	$\mathbf{D}\mathbf{U}_{2}\mathbf{H}_{2}$	2	10).1
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		1 554	• • •		• • •	3.40	• • •	. BC₂H		1,17	Da			
$\mathbf{B}\mathbf{C}_{2}\mathbf{H}_{5}$ 16.5 ⁻ 8.80 ⁻ 7.50 ⁻ HCl 47.9		1.77*	• • •	24.0	• • •	20.8	•••	BC_2		0.96	BC_2		1	1
	BC_2H_5	16.5	•••	8.80"	•••	7.50°	• • •				HCl		47	7.9

 $^{\circ}$ Species generated by elimination or migration. $^{\circ}$ 2+, 1.36.

Table III. Polyisotopic Spectra

m/eª	Intensity	m/e	Intensity	m/e	Intensity	m/e^{a}	Intensity	m/e	Intensity	m/e	Intensity
	(Dichloroviny	lborane	Ionizing poter	ntial of 8.0	volts ^b)		(Chlorodiviny	lborane	Ionizing pote	ntial of 70	volts')
$\begin{array}{c} 28\\ 29\\ 30\\ 31\\ 35\\ 36\\ 37\\ 38\\ 39\\ 40\\ 41\\ 42\\ 43\\ 44\\ 45\\ 46\\ 47\\ 48\end{array}$	$(Dichloroviny 28.0 \\ 14.4 \\ 2.9 \\ 5.1 \\ 1.0 \\ 485. \\ 125.3 \\ 139.6 \\ 41.0 \\ 1.3 \\ 17.3 \\ 11.1 \\ 5.9 \\ 1.8 \\ 0.8 \\ 2.6 \\ 7.2 \\ 0.5 $	/lborane 57 58 59 60 61 62 63 64 65 67 68 69 70 71 72 73 74 75	101121ng poten 16.4 1.3 0.7 13.5 44.8 4.6 13.8 2.5 0.8 8.9 3.0 10.7 4.9 4.7 41.3 100. 18.5 33.9	ntial of 8.0 83 84 85 88 90 91 92 93 94 99 100 101 102 107 108 109 110	2.4 9.3 0.8 1.4 2.2 7.8 2.0 6.8 0.8 1.6 0.8 1.6 0.8 2.2 0.5 0.8 11.4 43.0 8.1 26.0	$\begin{array}{c} 28\\ 29\\ 30\\ 31\\ 35\\ 36\\ 37\\ 38\\ 39\\ 40\\ 41\\ 42\\ 43\\ 44\\ 45\\ 46\\ 47\end{array}$	$\begin{array}{c} \text{(Chlorodiviny}\\ 28.7\\ 23.3\\ 10.2\\ 14.9\\ 0.76\\ 64.6\\ 208.1\\ 108.4\\ 64.5\\ 72.8\\ 3.06\\ 19.9\\ 4.43\\ 5.27\\ 4.82\\ 7.68\\ 0.69\\ 1.06\end{array}$	lborane 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70	Ionizing potes 13.4 19.0 37.5 28.6 31.2 3.57 0.99 2.34 5.64 3.47 9.65 28.5 100.0 5.56 14.4 1.90 3.13 0.89	ntial of 70 75 76 77 78 79 80 81 82 83 84 85 86 85 86 87 89 90 91 92 93	$\begin{array}{c} \text{volts}^{\circ})\\ 0.83\\ 1.36\\ 1.97\\ 1.99\\ 2.39\\ 2.49\\ 6.79\\ 17.1\\ 15.5\\ 15.8\\ 1.04\\ 0.08\\ 0.03\\ 0.02\\ 4.60\\ 7.01\\ 10.36\\ 1.60 \end{array}$
49 52 53 54	$2.1 \\ 0.7 \\ 3.2 \\ 11.3 \\ 7$	76 77 80 81	5.7 2.0 0.9 3.6	$111 \\ 112 \\ 113$	1.9 4.4 0.8	48 49 50	$ 1.31 \\ 2.51 \\ 4.14 \\ \dots $	71 72 73 74	3.27 1.01 1.58 0.71	99 100 101 102	0.27 0.64 0.20 0.64
оо 56	33.7 19.7	82	1.4								(Continued

Table III. Polyisotopic Spectra (Continued)

$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	m/eª	Intensity	m/e	Intensity	m/e	Intensity	m/e^{a}	Intensity	m/e	Intensity	m/e	Intensity
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	(Tri	vinylborane S (adjusted to	Sensitivit butane s	y at 70 volts sensitivity of	20.8 div./µ 50 for m/e 4	for <i>m/e</i>) 13)	(Dimet)	nylvinylbora (53 adjusted	ne Sensi to buta	tivity at 70 vo ne sensitivity o	lts 49.31 div of 50 for <i>m</i> /	v./µ for m/e) e 43)
13 10.5 46 0.004 99 2.10 13 4.68 39 5.00 83 0.13 14 0.12 49 0.12 82 2.24 16 0.48 39 13.3 65 0.19 15 0.05 52 2.0 3 85 0.67 19 0.004 42 2.17 86 68 0.639 15 0.05 52 2.0 3 85 0.67 19 0.004 44 2.17 86 68 0.639 12 0.44 5 3.74 85 0.43 20 0.004 42 2.17 0.02 14 6.02 17 0.02 14 60 0.33 12 0.44 5 3.74 85 0.43 20 0.004 12 0.004 44 2.17 86 68 0.639 12 0.44 5 3.74 85 0.43 20 0.004 42 0.13 44 0.02 17 0.02 0.44 12 0.44 5 3.74 85 0.42 17 0.02 14 0.03 72 0.04 40 0.33 72 0.04 42 12 0.44 5 3.74 85 0.75 0.22 90 422 2 2 10 0.14 40 0.03 72 0.04 40 0.35 72 0.04 42 0.21 13.3 0.050 12 0.44 5 3.74 86 0.64 93 0.35 27 15.7 85 0.02 44 0.03 72 0.04 42 0.21 13.3 0.050 12 0.64 64 0.57 0.22 90 422 2 24 0.71 47 0.24 13.3 0.050 12 25 0.04 95 0.05 93 1.00 40 25 1.07 45 0.24 13.3 0.050 25 0.12 56 0.664 93 0.35 27 15.7 85 0 1.29 23.6 0.084 25 0.13 46 0.06 82 0.22 10 0.5 93 1.05 46 43 13.3 0.050 25 1.20 61 15.7 94 0.065 22 0.074 55 0.98 0.035 27 15.7 85 0 0.98 0.034 25 0.064 66 75.5 98 0.1.3 22 0.074 55 0.98 0.035 27 15.7 85 0.044 15.7 90.5 0.034 25 0.064 66 75.5 98 0.1.4 33 0.054 44 0.048 15.7 90.5 0.034 25 0.064 66 75.5 98 0.1.4 33 0.054 44 0.048 55 0.044 45 0.056 1.57 0.054 0.054 3.0 0.44 45 0.056 2.21 8 0.044 45 0.013 32 0.074 55 0.98 0.013 32.4 0.064 55 0.049 0.07 13 32.4 0.044 57 0.054 54 0.98 0.31.3 0.344 150 0.044 57 0.056 0.05 0.057 100 0.05 0.004 15.7 0.056 0.053 0.050 100 0.05 0.004 15.0 0.044 157 0.056 0.057 0.050 0.050 0.050 0.050 0.075 0.050 0.076 0.050 0.075 0.050 0.076 0.050 0.075 0.078 0.078 0.078 0.078 0.078 0.077 0.053 0.050 0.078	12	3.94	45	0.56d	78	13.4	12	1.94	35	0.73	61	1.04
	13	10.5	$\frac{46}{47}$	0.06d 0.40	79 80	$2.11 \\ 0.90$	13	$\frac{4.68}{2.75}$	36 37	5.01 14.2	62 63	$0.17 \\ 0.34$
	15	3.23	48	1.87	81	1.08	15	14.9	38	4.99	64	0.17
	16	0.12	49	6.12	82	2.34	16	0.48	39	13.3	65	0.19
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	17	•••	50 51	15.2 24.6	83 84	0.60	17	0.01 0.01d	40 41	12.9 21.1	60 67	2.83
20 53 9.88 86 0.99 20 43 3.46 69 0.53 22 0.04 54 5.524 86 1.30 22 43 3.46 69 0.53 71 0.03 22 0.04 54 5.524 87 19 17.6 23 0.13 46 0.03 72 0.04 73 0.04 73	19	0.05	52^{-1}	10.3	85	0.67	19	0.03d	$\tilde{42}$	1.78	68	10.53p
	20		53	9.88	86 87	0.39	20 21		43	3.43	69 70	0.53
	$\frac{21}{22}$	0.40	54 55	5.24	88	4.80	$\frac{21}{22}$	0.02	44	0.18	70	0.08
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\overline{23}$	0.12	56	0.87	89	17.6	23	0.13	46	0.03	72	0.04
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	24 25	0.76	57 58	0.22	90 91	42.2	$\frac{24}{25}$	$0.71 \\ 3.07$	47 48	0.24	13.8	0.15m 0.02d
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	26	14.2	59	0.99	92	7.40p	$\frac{1}{26}$	16.8	49	4.88	19.5	0.03d
230 1.20 6.3 30.3 96 0 30 0.064 53 100.0 26.5 $^{-0}$ 25.0 0.32 13 0.064 64 46.7 97 31 0.574 64 3.57 30.5 0.534 33 0.064 65 75.5 98 32 0.074 65 0.98 31.5 0.344 33 0.04 66 13.8 17.5 0.024 33 0.014 56 4.3.5 32.5 0.064 33 0.24 57 30.5 0.534 33 0.24 57 30.5 0.534 33 0.24 57 30.5 0.534 33 0.24 57 30.5 0.34 13.5 0.014 34 0.094 57 10.3 23.5 0.064 35 25.5 0.075 35.2 0.075	27	25.9	60	6.64	93	0.35	27	37.8	50	7.29	23.6	0.08d
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	28 29	1.20	61 62	15.3	94 95	0.08	28 29	$\frac{2.82}{1.74}$	$51 \\ 52$	25.7	$\frac{24.5}{25.5}$	0.08d 0.35d
31 0.59d 64 467 97 31 0.57d 54 0.35 30.5 0.53d 32 0.06d 65 57.5 98 0.04 33 0.014 55 0.34 33.5 0.05d 33 0.04 66 13.8 17.5 0.014 33 0.014 55 0.34 58 0.42 33.5 0.05d 36 26.6 69 0.15 24.5 0.04d 59 0.22 37 92.3 70 0.13 25.5 0.03d 59 0.22 37 92.3 70 0.13 25.5 0.03d 59 0.22 37 92.3 70 0.13 25.5 0.03d 59 0.22 38 35.1 71 0.11 30.5 0.20d 40 18.2 74 1.21 42.5 0.26d 76 0.31 64 0.31 64 0.17 42 2.56d 75 1.233 44.5 0.19d 29 3.93 47 0.30 65 0.18 44 0.30d 77 33.9 22.7 0.03m 31 44.8 49 77.8 67 0.03 44 0.30d 77 33.9 22.7 0.03m 31 44.8 49 77.8 67 0.03 30 0.024 51 0.016 69 0.06 (65 adjusted to butane sensitivity of 50 for m/e 43) 12 3.38 39 49.7 66 4.85 12 3.38 39 49.7 66 4.85 35 1.138 38 0.12 56 30.3 74 20.4 14 4.46 42 4.2 0.60 71 0.25 14 7.032 44 0.60 71 0.25 14 7.032 44 0.60 71 0.25 15 1.48 38 0.12 56 30.3 74 20.4 15 0.04 77 3 0.75 16 10.54 43 4.58 70 1.44 16 0.54 43 4.58 70 1.44 17 0.52 44 0.60 71 0.25 18 1.03 45 0.49 77.8 67 19 0.05 46 0.07 73 0.75 18 1.03 45 0.49 77.8 0.75 19 0.04 49 15.3 76 2.89 10 0.04 49 0.54 77 10.25 18 1.03 45 0.49 77.8 0.77 2.39 17 0.32 44.4 0.60 71 0.25 41 0.17 58 0.84 775 10 0.42 285 1.34 63 0.19 41.4 0.31m 21 0.2 44 0.62 77 3 0.75 44 1.03 62 1.40 40.4 0.7m (m/r 23 a)2.0 50 30.0 77 6.17 (m/r 23 a)2.0 50 30.0 77 6.17 (m/r 23 a)2.0 50 30.0 77 6.17 32 0.04 49 15.8 76 2.89 13 0.04 49 0.53 76 2.89 14 0.43 0.77 7 0.75 33 0.05 60 2.84 2.70 0.03m 34 0.24 67 76.2 76 0.74 34 0.62 76 0.74 35 0.64 7.62 76 0.74 36 0.64 7.62 76 0.74 37 0.06 13 0.10 40 20.93 777 38 0.66 0.28 59 0.53 30 0.04 2.60 4.22 90 16.0 31 0.20 46 7.62 76 0.74 33 0.06 60 2.84 2.77 0.75 33 0.06 60 2.84 2.77 0.75 34 0.24 67 6.27 76 0.74 34 0.60 77 0.57 1.37 35 0.64 88 0.50 7.5 36 0.64	30	0.20d	63	30.3	96	• • •	30	0.09d	53	100.0	26.5	*d
as 0.044 e6 12.8 17.5 0.024 33 0.014 56 4.35 22.5 0.064 35 2.6 66 09 0.15 24.5 0.044 58 0.42 37 92.3 70 0.13 25.5 0.034 60 0.75 38 35.1 71 0.11 30.5 0.044 59 0.22 37 92.3 70 0.13 25.5 0.034 60 0.75 38 35.1 71 0.11 30.5 0.044 60 0.75 41 2.2 0.74 1.44 43.5 0.104 29 3.39 47 0.93 65 0.18 41 0.20 74 1.44 43.5 0.104 29 3.39 47 0.93 65 0.18 44 0.30d 76 12.8 44.5 0.254 30 15.1 48 19.8 66 0.05 44 0.30d 77 33.9 22.7 0.03m 31 24.8 40 0.31 69 0.05 44 0.30d 77 33.9 22.7 0.03m 31 24.8 40 0.31 69 0.05 13 7.38 39 41.7 66 4.85 30 14.4 64 1.87 7.8 66 0.03 (Methyldivinylborane Sensitivity at 70 volts 20.41 div/µ for m/e 13 12 3.38 39 41.7 66 4.85 30 14.4 54 18.7 7.2 0.25 13 7.30 40 40 15.7 66 4.85 30 1.44 54 18.7 7.2 0.25 13 7.30 40 40 7.7 1.41 4.4 4.86 41 24.2 66 0.18 39 0.27 57 31.3 75 2.31 14 4.86 41 24.2 66 0.18 39 0.27 57 31.3 75 2.31 15 10.4 42 3.10 69 0.44 40 0.27 57 31.3 75 2.31 15 10.4 42 3.10 69 0.24 40 0.27 57 31.3 75 2.31 16 0.58 43 4.58 70 1 1.41 41 1.39 59 0.28 77 2.28 16 0.59 46 0.07 73 0.76 43 2.42 60 0.11 78 0.13 16 0.58 43 4.58 70 1 1.41 41 1.39 59 0.28 77 2.38 16 0.59 46 0.07 73 0.76 43 2.42 60 0.11 78 0.13 17 0.23 46 0.09 72 0.71 42 1.75 60 0.11 78 0.13 18 0.02 46 0.07 73 0.76 43 2.42 60 0.11 78 0.13 19 0.05 46 0.07 73 0.76 43 2.42 60 0.11 78 0.33 19 0.05 46 0.07 73 0.76 443 2.42 61 0.42 2.85 1.364 10 0.17 74 1.36 44 1.03 68 40.7 3 100.0 7 12 0.20 439 16.8 77 2.28 12.39 14 10.4 40 4 0.17m (m c7.8 adjusted to butten esnativity of 50 tor m (e43) 25 7 67.4 54 19.2 81 2.39 16 8.62 1.44 94 12.00 74 102.4 17.5 div/µ for m (e43) 26 1.70 55 0.28 85 0.06 119 0.10 49 2.09 79 30 0.05 60 2.85 22.7 0.03m 22 15 0.22 46 72 0.7 6 31 0.00 14 88 0.29 77 32 0.04 49 16.8 77 2.28 12.39 14 0.42 2.00 74 102.4 17.5 div/µ for m (e43) 34 0.22 61 5.79 2.35 0.009 13 0.16 49 0.22 77 0 35 1.26 60 0.21 90 0.41 6.9 1.44 4.42 1.76 60 0.11 78 0.33 35 0.056 60 2.85 22.7 0.03m 22 15 0.30 58 1.44 0.44 1.03 17m 12.4 1.76 60 0.11 78 0.33 78 0.26 77 0 35 0.064 58 0.059 35 0.030 0.77 6 6	31	0.59d	64 65	46.7	97	•••	$\frac{31}{32}$	0.57d 0.07d	54 55	3.57	30.5	0.53d 0.24d
34 0.24 67 1.21 18.5 0.01d 34 0.99d 57 16.5 33.5 0.06d 35 0.42 36 27.6 69 0.15 23.5 0.12d 38 90.22 60 0.7 10.13 23.5 0.04d 69 0.7 15.5 div./ μ for m/e 0.13 23.5 0.04d 69 0.7 15.5 div./ μ for m/e 0.14 2.5 0.36d 69 0.7 12 0.14 23.5 0.04d 69 0.7 12 0.15 1.57 div./ μ for m/e 0.14 2.5 0.36d 69 0.7 12 0.36 0.19d 29 3.93 47 0.93 65 0.18 43 0.80d 76 14.6 45.5 0.25d 30 15.1 48 19.8 66 0.05 144 0.30d 77 33.9 22.7 0.3m 31 14.8 49 77.8 66 0.06 1.4 44 0.30d 77 33.9 22.7 0.3m 31 14.8 49 77.8 66 0.06 1.4 44 0.30d 77 33.9 22.7 0.3m 31 14.8 49 77.8 66 0.06 1.4 44 0.30d 77 33.9 22.7 0.3m 31 14.4 54 18.7 72 0.35 10.8 0.06 1.4 1.4 54 18.7 72 0.35 10.8 0.06 1.4 1.4 54 18.7 72 0.35 10.8 0.06 1.4 1.4 54 18.7 72 0.35 11.2 5 33 0.2 1.7 1 0.03 16 0.06 1.4 1.4 54 1.8 7 72 0.35 11.2 5.5 30.2 7 1.2 0.33 10 0.6 7 0.07 1.4 1.4 1.4 1.3 9 59 0.03.7 7 4.20.4 1.5 1.4 4.6 14 2.4 2.6 10.16 33 0.12 56 30.3 7.4 2.0 4.1 1.5 10.4 42 3.10 69 0.64 30 0.27 56 30.3 7.4 2.0 4.1 1.5 10.4 42 3.10 69 0.64 30 0.27 56 30.3 7.4 2.0 4.1 1.5 10.4 42 3.10 69 0.64 30 0.27 56 30.3 7.4 2.0 4.1 1.5 10.4 4.5 1.5 7 3.0 0.7 1.4 0.25 14 1.3 3.6 0.03 7.7 0.25 14 1.4 1.3 39 59 0.33 7.7 1.20.5 11.5 10.4 1.4 1.24 0.66 7.1 2.5 14 1.5 10.4 4.2 3.10 69 0.64 30 0.27 56 30.3 7.4 2.04 1.5 1.4 2.4 1.03 62 1.40 4.0 4.0 1.7 1.20.1 1.5 1.0.4 4.2 3.10 69 0.64 30 0.27 5.8 30.3 7.7 1.20.5 11.2 1.24 43 0.60 7.7 2.3 0.44 40.6 0.7 1.4 1.4 1.3 9 59 0.33 7.7 1.20.5 11.5 1.3.7 1.20.5 1.20.1 1.5 2.5 1.20.1 1.5 2.5 1.3.7 1.20.5 1.30.7 1.20.5 1.20.1 1.5 2.5 1.3.7 1.20.5 1.30.7 1.20.5 1.30.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.5 1.20.7 1.20.5 1.20.5 1.20.7 1.20.5 1.20.5 1.20.7 1.20.5 1.20.5 1.20.7 1.20.5 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.5 1.20.7 1.20.5 1.20.5 1.20.7 1.20.5 1.20.5 1.20.7 1.20.5 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.20.7 1.20.5 1.2	32 33	0.000	66	13.8	17.5	0.02d	33	0.01d	56	4.35	32.5	0.05d
33 2.15 68 0.15 2.3. 0.124 38 0.124 39 0.124 36 0.125 31 60 0.15 2.3. 0.034 69 0.75 61 0.15 2.3. 0.034 69 0.75 61 0.15 2.3. 0.034 69 0.75 61 0.15 2.3. 0.034 69 0.75 61 0.15 2.3. 0.034 69 0.75 61 0.15 2.3. 0.3. 0.3. 0.3. 0.3. 0.44 10 2.20 74 1.44 43.5 0.104 29 3.9. 3.4 7 0.9. 0.3 65 0.18 41 0.3. 0.3. 0.3. 0.44 0.3. 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.3. 0.44 0.44	34	0.24	67	1.21	18.5	0.01d	34	0.09d	57	16.5	33.5	0.06d
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	35 36	2.18 26.6	68 69	$0.15 \\ 0.15$	$23.5 \\ 24.5$	0.12d 0.04d			58 59	0.42		
38 35.1 71 0.11 30.5 0.204 39 90.2 72 0.42 31.5 0.08d 40 18.2 73 1.21 42.5 0.26d 41 2.2 0.7 74 1.44 43.5 0.104 42 0.50d 75 1.38 44.5 0.03d 44 0.30d 77 33.9 22.7 0.33 (Methyldivinylborane Sensitivity at 70 volts 11.57 div./µ for <i>n</i> /e 43) (Methyldivinylborane Sensitivity at 70 volts 20.41 div./µ for <i>m</i> /e) 6 adjusted to butane sensitivity at 70 volts 20.41 div./µ for <i>m</i> /e) (6 adjusted to butane sensitivity at 70 volts 20.41 div./µ for <i>m</i> /e) 13 7.30 40 15.7 67 1.83 14 4.86 41 24.2 68 0.18 15 10.4 42 3.10 69 0.64 16 0.38 43 4.58 70 1.41 41 1.39 50 0.27 58 0.84 76 100.0 p 16 0.38 43 4.58 70 1.41 41 1.39 59 0.23 77 2.38 17 0.32 44 0.60 71 0.05 14.1 75 0.95 18 1.33 60 0.66 68 0.03 19 0.32 55 4.90 74 4.74 14 4.86 41 24.2 68 0.18 38 0.027 58 0.84 76 100.0 p 16 0.38 43 4.58 70 1.41 41 1.39 59 0.23 77 2.38 19 0.22 44 0.60 71 0.25 44 2.12 56 0.011 78 0.13 19 0.5 47 0.07 76 1.74 1.36 44 1.03 62 1.40 40.4 0.17m 21 0.12 48 5.17 75 0.95 45 1.34 63 0.19 44.4 2.01 69 0.45 10 0.5 47 0.07 76 1.77 23 0.20 50 30.0 77 6.17 24 1.19 51 40.6 78 8.56 13 4.40 42 2.42 61 0.42 2.25 5 1.36d 13 0.30 50 50.0 77 6.17 24 1.19 51 40.6 78 8.56 13 4.40 42 0.19 71 0.25 45 7.99 52 41.4 79 14.5 13 0.30 67 76.17 24 1.19 51 40.6 78 8.56 13 4.40 42 0.19 71 0.02 175 44 0.01 73 10.02 24 1.19 51 40.6 78 8.56 13 4.40 42 0.19 71 0.02 175 44 0.02 75 88 0.18 75 0.50 for <i>m</i> /e 43) 25 7.99 52 41.4 79 14.5 13 0.30 56 70.98 50 0.01 77 6.17 24 1.19 51 40.6 78 8.56 13 4.40 42 0.19 71 0.02 8 44 0.23 50 1.69 85 0.01 20 0.04 45 0.19 9 0.10 49 2.09 79 21 0.02 48 51 0.02 84 0.00 18 0.16 48 5.33 78 0.50 31 0.33 0.56 60 2.85 22.7 0.33m 32 0.024 59 0.53 33 0.05 60 2.85 22.7 0.33m 34 0.23 61 5.79 2.35 0.094 35 1.26 65 2.94 95 1.16 85 1.00 36 1.47 63 11.5 2.55 0.071 37 0.42 44 57 5.58 87 1.16 85 1.00 38 17.4 65 100.0 31.5 0.134 39 14.6 9 50 50 1.10 86 0.25 30 0.42 20 1.44 8 4.45 30 0.42 20 1.45 1.5 3.50 1.45 31 0.42 64 1.47 9 1.55 1.45 31 0.42 64 1.49 9 1.55 1.45 31 0.42 64 1.49 9 1.55 1.45 31 0.42 64 1.49 9 1.5	37	92.3	70	0.13	25.5	0.03d			60	0.75		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	38	35.1	$71 \\ 72$	0.11	30.5	0.20d	(Difluc	orovinylborar	ne Sensit	ivity at 70 vol	ts 11.57 div	$v./\mu$ for m/e)
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	39 40	90.2 18.2	73	$0.42 \\ 1.21$	$\frac{31.5}{42.5}$	0.08d 0.26d		(76 adjusted	to buta	ne sensitivity a	at 50 for $m/$	e 43)
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	41	2.20	74	1.44	43.5	0.10d	28	6.72	46	0.31	64	0.17
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	42	0.59d	75 76	2.38	44.5	0.19d 0.25d	29 30	3.93 15.1	47 48	0.93	65 66	$0.18 \\ 0.05$
	43	0.30 d	77	33.9	22.7	0.03m	31	14.8	49	77.8	67	0.03
$ \begin{array}{c} (\mathrm{Methyldivinylborane Sensitivity at 70 volts 20.41 div/a for m/e 43) & 33 & 0.42 & 31 & 0.31 & 03 & 0.07 \\ \hline (65 adjusted to butane sensitivity of 50 for m/e 43) & 31 & 125 & 63 & 0.21 & 71 & 0.03 \\ 12 & 3.38 & 39 & 49.7 & 66 & 4.85 & 36 & 1.44 & 55 & 167 & 72 & 4.74 \\ 13 & 7.30 & 40 & 15.7 & 67 & 1.63 & 37 & 0.12 & 56 & 30.3 & 74 & 20.4 \\ 14 & 4.86 & 41 & 24.2 & 68 & 0.18 & 39 & 0.27 & 57 & 31.3 & 75 & 43.1 \\ 15 & 10.4 & 42 & 3.10 & 69 & 0.54 & 40 & 0.27 & 58 & 0.84 & 76 & 100.0 \\ 16 & 0.58 & 43 & 4.58 & 70 & 1.41 & 41 & 139 & 59 & 0.23 & 77 & 2.38 \\ 16 & 0.58 & 43 & 4.58 & 70 & 1.41 & 41 & 139 & 59 & 0.23 & 77 & 2.38 \\ 19 & 0.05 & 46 & 0.07 & 73 & 0.76 & 44 & 1.03 & 62 & 1.40 & 40.4 & 0.17m \\ 20 & \dots & 47 & 0.71 & 74 & 1.36 & 45 & 1.34 & 63 & 0.19 & 41.4 & 0.31m \\ 21 & 0.12 & 48 & 5.17 & 75 & 0.95 \\ 23 & 0.20 & 50 & 30.0 & 77 & 6.17 & (m/e^{73} adjusted to butane sensitivity at 70 volts 17.5 div/a for) \\ 23 & 0.20 & 50 & 30.0 & 77 & 6.17 & (m/e^{73} adjusted to butane sensitivity of 50 for m/e 43) \\ 25 & 7.09 & 52 & 41.4 & 79 & 14.5 & 13 & 4.40 & 44 & 2.01 & 74 & 10.2 \\ 26 & 42.3 & 53 & 76.9 & 80 & 41.6 & p & 15 & 8.62 & 45 & 2.62 & 75 & 31.4 \\ 27 & 97.4 & 54 & 19.2 & 81 & 2.39 & 16 & 0.22 & 46 & 7.62 & 76 & 0.74 \\ 28 & 1.08 & 55 & 9.68 & 82 & 0.15 & 17 & \dots & 47 & 25.2 & 77 & \dots \\ 30 & 0.17d & 57 & 0.28 & 84 & 0.06 & 19 & 0.10 & 49 & 20.9 & 79 & \dots \\ 31 & 0.33d & 56 & 0.074 & 83 & 0.09 & 18 & 0.16 & 48 & 8.33 & 78 & 0.50 \\ 33 & 0.36 & 60 & 2.85 & 2.27 & 0.37 & 21 & \dots & 51 & 13.2 & 81 & 0.20 \\ 34 & 0.36 & 60 & 2.85 & 2.24 & 24.5 & 0.094 & 22 & 0.11 & 52 & 18.0 & 82 & 0.73 \\ 35 & 1.28 & 61 & 2.39 & 1.6 & 0.25 & 55 & 51 & 1.16 & 85 & 1.00 \\ 37 & 4.2 & 64 & 5.05 & 5.0 & 0.13 & 27 & 41.4 & 57 & 5.58 & 87 & 12.6 \\ 38 & 1.74 & 65 & 100.0 & 31.5 & 0.13d & 27 & 41.4 & 57 & 5.58 & 87 & 12.6 \\ 39 & 0.42 & 60 & 42.2 & 90 & 16.0 \\ 31 & 1.20 & 61 & 43.0 & 92 & 0.22 \\ 32 & 0.17 & 51 & 50 & 51 & 1.6 & 85 & 1.07 \\ 39 & 5.61 & 69 & 0.83 & 18.5 & 0.44 \\ 37 & 31 & 53 & 61 & 0.00 & 31.5 & 0.13d & 27 & 41.4 & 57 & 5.58 & 87$							32	0.33	50	0.06	68 69	0.03
$ \begin{array}{c} (66) adjusted to butane sensitivity of 30 1 or m/e 43) & 36 & 1.26 & 53 & 2.21 & 71 & 0.03 \\ 12 & 3.38 & 39 & 49.7 & 66 & 4.85 & 37 & 1.03 & 55 & 49.0 & 73 & 4.74 \\ 14 & 4.86 & 41 & 24.2 & 68 & 0.16 & 39 & 0.27 & 57 & 31.3 & 75 & 43.1 \\ 15 & 10.4 & 42 & 3.10 & 69 & 0.54 & 40 & 0.27 & 58 & 0.84 & 76 & 100.0 & p \\ 16 & 0.58 & 43 & 4.58 & 70 & 1.41 & 41 & 1.39 & 59 & 0.23 & 77 & 2.38 \\ 17 & 0.32 & 44 & 0.60 & 71 & 0.25 & 42 & 1.75 & 60 & 0.11 & 78 & 0.13 \\ 18 & 1.03 & 45 & 0.09 & 72 & 0.71 & 43 & 2.42 & 61 & 0.42 & 28.5 & 1.36d \\ 19 & 0.05 & 46 & 0.07 & 73 & 0.76 & 44 & 1.03 & 62 & 1.40 & 40.4 & 0.17m \\ 20 & \dots & 47 & 0.71 & 74 & 1.36 & 45 & 1.34 & 63 & 0.19 & 41.4 & 0.31m \\ 22 & 0.04 & 49 & 16.8 & 76 & 2.89 & (Choromethylvinjborane Sensitivity at 70 volts 17.5 div./\mu (for) \\ (m/e 73 adjusted to butane sensitivity of 30 for m/e 43) & 10.2 \\ 26 & 42.3 & 53 & 76.9 & 80 & 41.6 & p & 15 & 8.62 & 45 & 2.62 & 75 & 31.4 \\ 28 & 1.08 & 55 & 9.68 & 82 & 0.15 & 17 & 0.16 & 48 & 8.33 & 78 & 0.50 \\ 30 & 0.17d & 57 & 0.28 & 84 & 0.09 & 18 & 0.49 & 42 & 201 & 74 & 10.2 \\ 26 & 42.3 & 55 & 9.68 & 82 & 0.15 & 17 & 0.16 & 48 & 8.33 & 78 & 0.50 \\ 31 & 0.53d & 55 & 0.674 & 83 & 0.09 & 17 & 0.16 & 48 & 8.33 & 78 & 0.50 \\ 32 & 0.02d & 59 & 0.53 & 2.27 & 0.03m & 21 & 0.16 & 48 & 8.33 & 78 & 0.50 \\ 33 & 0.05 & 60 & 2.85 & 2.27 & 0.03m & 21 & 0.16 & 48 & 8.33 & 78 & 0.50 \\ 34 & 0.23 & 61 & 5.79 & 23.5 & 0.01 & 20 & 0.04 & 49 & 20.9 & 79 & \\ 35 & 1.68 & 62 & 2.24 & 24.5 & 0.044 & 22 & 30 & 54 & 3.17 & 84 & 1.76 \\ 36 & 14.7 & 63 & 11.5 & 22.5 & 0.07 & 21 & 5.6 & 55 & 55 & 1.16 & 85 & 0.02 \\ 38 & 17.4 & 65 & 100.0 & 31.5 & 0.18d & 26 & 655 & 55 & 1.16 & 85 & 0.07 \\ 38 & 17.4 & 65 & 100.0 & 31.5 & 0.18d & 27 & 41.4 & 57 & 5.58 & 87 & 12.6 \\ 38 & 17.4 & 65 & 100.0 & 31.5 & 0.18d & 27 & 41.4 & 57 & 5.58 & 87 & 12.6 \\ 39 & 0.42 & 60 & 42.2 & 90 & 16.0 \\ 31 & 1.20 & 61 & 43.0 & 91 & 0.85 \\ 30 & 0.42 & 60 & 42.2 & 90 & 16.0 \\ 31 & 1.20 & 61 & 43.0 & 91 & 0.85 \\ 32 & 0.19 & 62 & 14.0 & 92 & 0.22 \\ 33 & 0.35 & 60 & 2.55 & 0.31 & 2.5 & 0.28$	(Methy	ldivinylboran	ie Sensiti	vity at 70 vo	lts 20.41 div	r/μ for m/e)	33 34	$0.24 \\ 0.25$	$51 \\ 52$	0.31	69 70	0.08
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		(65 adjusted t	to butane	e sensitivity of	of 50 for m/ϵ	2 43)	35	1.25	53	2.21	71	0.03
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	12	3.38	39	49.7	66	4.85	$\frac{36}{37}$	$1.44 \\ 1.03$	54 55	18.7	72 73	0.25 4 74
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	13	7.30	40	15.7	67 68	1.63	38	0.12	56	30.3	$\frac{10}{74}$	20.4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$14 \\ 15$	$\frac{4.86}{10.4}$	41	3.10	69	0.54	39	0.27	57	31.3	75	43.1
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	16	0.58	43	4.58	70	1.41	40 41	1.39	58 59	0.84	76	2.38
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	17	$0.32 \\ 1.03$	44 45	0.60	$\frac{71}{72}$	0.25	42	1.75	60	0.11	78	0.13
20 47 0.71 74 1.36 75 1.34 63 1.10 10.71 75 0.31 m 21 0.12 48 5.17 75 0.95 (Chlormethylvinylborane Sensitivity at 70 volts 17.5 div./ μ for) 23 0.20 50 30.0 77 6.17 (m/e 73 adjusted to butane sensitivity of 50 for m/e 43) 24 1.19 51 40.6 78 8.56 13 3.89 43 7.00 73 100.0 26 42.3 53 76.9 80 41.6 p 15 8.62 45 2.62 75 31.4 27 97.4 54 19.2 81 2.39 16 8.62 45 2.62 76 31.4 29 3.05 56 0.74 83 0.09 17 47 25.2 77 30 0.17d 57 0.28 84 0.06 18 0.16 48 8.33 78 0.50 31 0.53d 58 0.09 85 0.01 19 0.10 49 20.9 79 32 0.02d 59 0.53 21 51 13.2 81 0.23 33 0.05 60 2.86 22.7 0.3m 21 51 13.2 81 0.23 34 0.23 61 5.79 23.5 0.09d 23 0.69 53 62.5 83 1.94 35 1.68 62 2.24 2.45 0.04d 23 0.69 53 62.5 83 1.94 36 14.7 63 11.5 25.5 0.074 25 0.09d 23 0.69 53 62.5 83 1.94 36 14.7 63 11.5 25.5 0.074 25 0.18d 23 0.69 53 62.5 83 1.94 36 14.7 63 11.5 25.5 0.074 25 6.55 55 1.16 85 1.00 38 17.4 65 100.0 31.5 0.18d 26 21.5 56 1.40 86 0.67 39 0.42 60 42.2 90 16.0 31 0.28 41.6 9 0.85 9 0.53 94 0.93 31 0.536 62 2.24 2.45 0.044 23 0.69 53 62.5 83 1.94 32 0.02 64 50.6 30.5 0.18d 25 6.55 55 1.16 85 1.00 33 0.042 60 42.2 90 16.0 34 1.20 61 43.0 91 0.85 32 0.19 62 14.0 92 0.22 33 0.042 60 42.2 90 16.0 31 1.20 61 43.0 91 0.85 32 0.19 62 14.0 92 0.22 33 0.042 60 42.2 90 16.0 31 1.20 61 43.0 91 0.85 32 0.19 62 14.0 92 0.22 33 0.042 60 42.2 90 16.0 31 1.20 61 43.0 91 0.85 32 0.19 62 14.0 92 0.22 33 63 13.5 93 0.22 34 0.28 64 94 0.93 35 12.6 65 2.94 95 1.87 36 40.8 66 0.21 96 0.14 37 13.5 67 0.08 38 16.6 68 0.25 17.5 1.37 39 5.61 69 0.83 18.5 0.44 30 0.42 60 42.2 90 16.0 31 1.20 61 43.0 91 0.85 32 0.19 62 14.0 92 0.22 33 63 13.5 93 0.22 34 0.28 64 94 0.93 35 12.6 65 2.94 95 1.87 36 40.8 66 0.21 96 0.14 37 13.5 67 0.08 38 16.6 68 0.25 17.5 1.37 39 5.61 69 0.83 18.5 0.44 39 5.61 69 0.83 18.5 0.44 30 0.66 70 3.31 24.5 0.15 30 0.61 69 0.83 18.5 0.44 33 0.61 69 0.83 18.5 0.44 33 0.61 69 0.83 18.5 0.44 34 0.28 64 94 0.93 35 0.61 69 0.83 18.5 0.44 36 0.66 0.21 96 0.14	19	0.05	46	0.07	$\overline{73}$	0.76	43	2.42	61 62	$0.42 \\ 1.40$	28.5	1.36d 0.17m
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	20		47	0.71	$\frac{74}{75}$	1.36	45	1.34	63	0.19	40.4	0.31m
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$\frac{21}{22}$	0.12	48 49	16.8	75 76	2.89	(Chloron	nethvlvinvlbo	orane Se	nsitivity at 7	0 volts 17.	.5 div./ μ for)
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	23	0.20	50	30.0	77	6.17	(m	ı∕e 73 adjust	ed to bu	tane sensitivit	y of 50 for <i>i</i>	n/e 43)
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$\frac{24}{25}$	1.19	51 52	40.6 41.4	78 79	8.56 14.5	13	3.89	43	7.00	73	100.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\frac{25}{26}$	42.3	53	76.9	80	41.6 p	14	4.40	44	2.01	74 75	10.2 31.4
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	27	97.4	54	19.2	81	2.39	16	0.02	46	7.62	76	0.74
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	28 29	3.05	56	0.74	83	0.09	17		47	25.2	77	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	30	0.17d	57	0.28	84	0.06	18 19	0.16	$\frac{48}{49}$	8.33 20.9	78 79	0.50
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$\frac{31}{32}$	0.53d 0.02d	58 59	0.09	85	0.01	20	0.04	50	15.0	80	0.25
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	33	0.05	60	2.85	22.7	0.03m	21 22	0.11	51 52	13.2	81 82	0.20 0.73
d = doubly charged ion m = metastable peak m =	34	0.23	61 62	5.79	23.5	0.09d	23	0.69	53	62.5	83	1.94
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	35 36	1.68 14.7	62 63	$11.5^{2.24}$	$24.5 \\ 25.5$	0.040	24	2.30	54	3.17	84	1.76
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	37	45.2	64	50.6	30.5	0.18d	25 26	21.5	56 56	1.10	86	0.67
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	38	17.4	65	100.0	31.5	0.13 d	$\bar{27}$	41.4	57	5.58	87	12.6
$d = doubly charged ion p = parent peak m = metastable peak r = rearrangement peak * Mass per unit of electronic charge. * Spectrum adjusted to 100 for m/e 73 rather than m/e 36 as this peak is due to HCl * Spectrum 41 3.33 71 9.73 25.5 0.28 \frac{30}{31} 0.42 60 42.2 90 16.0 16.0 16.0 100 1$							28 29	$5.12 \\ 1.28$	58 59	0.14 11.9	88 89	49.5 5.68
d = doubly charged ion p = parent peak m = metastable peak r = rearrangement peak 31 1.20 61 43.0 91 0.85 32 0.19 62 14.0 92 0.22 33 63 13.5 93 0.22 34 0.28 64 94 0.93 35 12.6 65 2.94 95 1.87 36 49.8 66 0.21 96 0.14 37 13.5 67 0.08 38 16.6 68 0.25 17.5 1.37 39 5.61 69 0.83 18.5 0.44 39 5.61 69 0.83 18.5 0.44 39 5.61 69 0.83 18.5 0.44 39 3.61 69 0.83 18.5 0.44 30 41 3.33 71 9.73 25.5 0.28 41 3.33 71 9.73 25.5 0.28 42 2.00 72 27.9 31 1.20 61 43.0 91 0.85 32 0.19 62 14.0 92 0.22 33 0.22 0.22 34 0.28 64 94 0.93 35 12.6 65 2.94 95 1.87 36 49.8 66 0.21 96 0.14 37 13.5 67 0.08 41 3.33 71 9.73 25.5 0.28 42 2.00 72 27.9 41 3.33 71 9.73 25.5 0.28 42 2.00 72 27.9 41 3.33 71 9.73 25.5 0.28 42 2.00 72 27.9 43 3.0 28 64 94 0.93 44 0.93 0.22 45 0.28 64 94 0.93 45 0.28 64 94 0.93 46 0.25 17.5 1.37 41 0.25 0.28 42 2.00 72 27.9 41 3.33 71 9.73 25.5 0.28 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.25 17.5 1.37 45 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.25 0.28 64 94 0.93 45 0.26 0.28 64 94 0.93 45 0.26 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.93 45 0.28 64 94 0.94 0.93 45 0.28 64 94 0.94 0.94 0.94 0.94 0.94 0.94 0							30	0.42	60	42.2	90	16.0
d = doubly charged ion p = parent peak m = metastable peak r = rearrangement peak 32 0.15 62 14.0 52 0.22 33 0.22 34 0.28 64 94 0.93 35 12.6 65 2.94 95 1.87 36 49.8 66 0.21 96 0.14 37 13.5 67 0.08 38 16.6 68 0.25 17.5 1.37 39 5.61 69 0.83 18.5 0.44 39 5.61 69 0.83 18.5 0.44 39 5.61 69 0.83 18.5 0.44 39 3.61 69 0.83 18.5 0.44 39 3.61 69 0.83 18.5 0.44 30 41 3.33 71 9.73 25.5 0.28 41 3.33 71 9.73 25.5 0.28 42 2.00 72 27.9 31 3.5 0.15 0.22 32 0.22 0.22 33 0.22 0.22 0.22 0.22 0.22 0.22 0.22 0.2							31	1.20	61 62	43.0 14 0	91 92	0.85 0.22
$d = aoubly charged 10n$ $p = parent peak$ 34 0.28 64 $$ 94 0.93 $m = metastable peak$ $r = rearrangement peak$ 35 12.6 65 2.94 95 1.87 36 49.8 66 0.21 96 0.14 37 13.5 67 0.08 38 16.6 68 0.25 17.5 1.37 $^{\circ}$ Mass per unit of electronic charge. $^{\circ}$ Spectrum adjusted to 100 for 40 0.65 70 3.31 24.5 0.15 m/e 73 rather than m/e 36 as this peak is due to HCl ⁻ . $^{\circ}$ Spectrum 41 3.33 71 9.73 25.5 0.28		1 11 1				. 1.	32		63	13.5	93	0.22
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	d = m -	doubly char	ged ion	p = r -	rearrange	an ment peak	34	0.28	64	0.04	94 05	0.93
* Mass per unit of electronic charge. * Spectrum adjusted to 100 for m/e 73 rather than m/e 36 as this peak is due to HCl ⁻ . * Spectrum 41 3.33 71 9.73 25.5 0.28 42 2.00 72 27.9	=	metastable	Pean	1 -	i carrange	mente peak	35 36	49.8	66 66	$2.94 \\ 0.21$	90 96	0.14
³⁸ 16.6 68 0.25 17.5 1.37 ³⁹ 5.61 69 0.83 18.5 0.44 ⁶ Mass per unit of electronic charge. ^b Spectrum adjusted to 100 for 40 0.65 70 3.31 24.5 0.15 m/e 73 rather than m/e 36 as this peak is due to HCl ⁻ . ^c Spectrum 41 3.33 71 9.73 25.5 0.28 adjusted to 100 for m/e 65 rather than m/e 36. 42 2.00 72 27.9							37	13.5	67	0.08	1	1.05
⁶ Mass per unit of electronic charge. ⁶ Spectrum adjusted to 100 for 40 0.65 70 3.31 24.5 0.15 m/e 73 rather than m/e 36 as this peak is due to HCl ⁻ . ⁶ Spectrum 41 3.33 71 9.73 25.5 0.28 adjusted to 100 for m/e 65 rather than m/e 36. 42 2.00 72 27.9							38 30	$16.6 \\ 5.61$	68 69	0.25	17.5 18.5	1.37 0.44
m/e 73 rather than m/e 36 as this peak is due to HCI ^T . Spectrum 41 3.33 71 9.73 25.5 0.28 adjusted to 100 for m/e 65 rather than m/e 36. 42 2.00 72 27.9	° Mass pe	r unit of elec	tronic ch	arge. ' Spec	trum adjust	ed to 100 for	40	0.65	70	3.31	24.5	0.15
	m/e 73 ra	to 100 for m/c	/e 36 as ' e 65 rath	this peak is (er than m /e ?	due to HCl	. Spectrum	41 42	$3.33 \\ 2.00$	$\frac{71}{72}$	9.73 27.9	25.5	0.28

Table IV. Infrared Spectra

$(Cm.^{-1})$

Dimethylvinylborane: 3058 (m. sh.), 2959 (m.s.), 2899 (m.), 1949
(w.), 1603 (m.s.), 1414 (v.s.), 1290 (v.s.), 1206 (m.), 1170 (v.s.),
$1120\ (v.s.),\ 1015\ (m.),\ 988\ (m),\ 973\ (s),\ 917\ (m.),\ 847\ (b.m.w.)$
Methyldivinylborane: 3067 (m.), 3040 (m.), 2967 (m.s.), 2874
(m.w.), 1949 (m.w.), 1605 (s.), 1420 (v.s.), 1299 (s.), 1196 (m.),
$1176~(s.),\ 1127~(m.),\ 1094~(s.),\ 1016~(s.),\ 972~(v.s.),\ 855~(b.m.)$
Trivinylborane: 3078 (m.s.), 3048 (m. sh.), 2999 (m.s.), 2973 (m.s.),
1942 (m.w.), 1613 (s. sh.), 1605 (s.), 1462 (s. sh.), 1422 (v.s.),
1302 (m.w.), 1183 (m. sh.), 1153 (s.), 1119 (m. sh.), 1093 (s.),
1018 (s. sh.), 972 (v.s.), 907 (m.s. sh.), 821 (b.v.w.), 705 (b.m.)
w - work $v - vorv$

w	=	weak	v	=	very
m	=	medium	sh.	=	shoulder
s	=	strong	b	=	broad

	Table V. Vapor Pressures	
<i>t</i> , ° C.	$P_{\rm mm}$, Obsd.	$P_{\rm mm}$, Calcd.
	(Difluorovinylborane)	
$-81.5 \\ -70.5 \\ -64.2 \\ -54.1 \\ -51.8 \\ -45.5 \\ -40.8$	62.7 134.4 202.7 360.8 407.2 562 703	$\begin{array}{c} 62.7\\ 135.6\\ 202.0\\ 360.8\\ 407.9\\ 562\\ 703 \end{array}$
	(Dichlorovinylborane)	
-40.1 -23.5 -7.4 -4.0 0.0	13.7 38.0 83.0 100.5 121.8	$13.7 \\ 36.8 \\ 85.5 \\ 100.8 \\ 121.8$
	(Chlorodivinylborane)	
$\begin{array}{r} -6.0 \\ 0.0 \\ 5.5 \\ 12.2 \\ 13.8 \\ 19.8 \\ 23.7 \end{array}$	26.8 37.9 50.3 71.0 75.9 102.2 120.2	$27.1 \\ 37.9 \\ 50.6 \\ 70.8 \\ 76.5 \\ 101.2 \\ 120.4$
	(Dimethylvinylborane)	
$-81.9 \\ -64.1 \\ -45.5 \\ -23.0 \\ 0.0 \\ 6.1$	$\begin{array}{r} 3.2 \\ 12.7 \\ 42.9 \\ 145.3 \\ 411.5 \\ 524.6 \end{array}$	$\begin{array}{c} 3.1 \\ 12.7 \\ 42.9 \\ 146.1 \\ 411.5 \\ 525.4 \end{array}$
	(Methyldivinylborane)	
-45.5 -22.9 0.0 10.1 14.4 21.9	$\begin{array}{c} 6.9\\ 27.9\\ 95.6\\ 153.3\\ 184.4\\ 253.4\end{array}$	$\begin{array}{c} 6.7 \\ 28.5 \\ 95.8 \\ 153.1 \\ 184.0 \\ 253.4 \end{array}$
	(Trivinylborane)	
$\begin{array}{r} -22.9 \\ 0.0 \\ 6.2 \\ 9.9 \\ 14.3 \\ 20.0 \end{array}$	6.8 24.4 33.5 40.0 49.9 65.6	$\begin{array}{c} 6.3\\ 24.3\\ 33.6\\ 40.4\\ 50.1\\ 65.6\end{array}$
	(Methylchlorovinylborane)	
-64.0 -45.4 -38.2 -23.0 0.0 6.2	3.5 12.9 19.7 51.3 161.7 211.9	$\begin{array}{c} 3.4 \\ 13.2 \\ 19.7 \\ 51.0 \\ 160.8 \\ 211.9 \end{array}$

Each substance gave a strong infrared band in the carbon double bond region (2).

For trivinylborane, only the H^1 NMR multiplet (4) was found with chemical shift downfield to the extent charac-

Table VI. Constants from Vapor Pressure Data

			•			
Compound	A°	B^a	C^a	ΔH^{\flat}	ΔS°	B.P.ª
$C_2H_3BF_2$	10.4642	1430.0	0.006300	4.96	21.2	-39.1
$C_2H_3BCl_2$	7.6053	1508.0		6.90	21.6	46.0
$(C_2H_3)_2BCl$	11.4619	2230.0	0.006300	7.21	20.6	76.4
$(C_2H_3)_3B$	8.2833	1810.0	0.001000	7.69	21.4	85.7
$(C_2H_3)_2BCH_3$	8.4126	1660.0	0.001300	6.97	21.5	51.7
$(CH_3)_2BC_2H_3$	11.9166	1890.0	0.008700	5.29	18.2	17.1
$(CH_3)(C_2H_3)BCl$	8.1529	1550.0	0.001000	6.64	21.2	39.3
	• • • • • • • • •	1	D	_ 4	D / T	07

Constant for Antoine equation $\log_{10} P$ mm. Hg = A - B/T - CT.

^b Heat of vaporization kcal./mole at b.p.

^c Entropy of vaporization at b.p., Trouton's constant,

^d Extrapolated from vapor pressure curve.

Table VII. Molecular Weight Data

	Molecu	ights	
Compound	a	b	с
C ₂ H ₃ BF ₂			
$C_2H_3BCl_2$	76.3		75.9
$(C_2H_3)_2BCl$	109.9		108.7
$(C_2H_3)_3B$	101.0		100.4
$(C_2H_3)_2BCH_3$	93.8	92	92.0
$(CH_3)_2 B(C_2H_3)$	80.6	80	79.9
	68.7	68	67.9
From: a vapor density culated.	b monoisotopic	mass	spectrum c cal-

teristic of vinyl groups (11) and comparable to tetravinyltin (9). In addition, a single band in the methyl proton range of chemical shift was found for methyldivinylborane with an area ratio indicating vinyl to methyl proton ratio of 2 to 1. The corresponding area ratio for dimethylvinylborane was the expected 1 to 2.

LITERATURE CITED

- Ambrose, D., Keulemans, A.I.M., Purnell, J.H., Anal. Chem. (1)30, 1582 (1958).
- Bellamy, L.J., "Infrared Spectra of Complex Molecules," p. 34 ff, Wiley, New York, 1958. (2)
- Brinckman, F.E., Stone, F.G.A., J. Am. Chem. Soc. 82, (3)6218 (1960)
- Good, C.D., Ritter, D.M., Ibid., 84, 1162 (1962). (4)
- Good, C.D., Ph.D. thesis, Univ. of Washington, 1961. (5)
- James, D.H., Phillips, C.S.J. J. Sci. Instr. 29, 362 (1952). (6)
- (7)
- Johnson, H.S., Stross, F.H., Anal. Chem. 30, 1586 (1958). Keulemans, A.M.I., "Gas Chromatography," p. 56, Reinhold, (8)New York, 1957.
- Moore, D.W., Hoppe, J.A., J. Phys. Chem. 65, 224 (1961). (9)
- Parsons, T.D., Silverman, M.B., Ritter, D.M., J. Am. Chem. (10)Soc. 79, 5091 (1957).
- (11)Pople, J.A., Schneider, W.G., Berstein, H.J., "High Resolution Nuclear Magnetic Resonance," McGraw-Hill p. 238 ff, New York, 1959.
- Seely, G.R., Oliver, J.P., Ritter, D.M., Anal. Chem. 31, (12)1993 (1959).
- (13)Shapiro, I., Ditter, J.F., J. Chem. Phys. 26, 799 (1957).
- Sanderson, R.T., "Vacuum Manipulation of Volatile Com-(14)pounds," Wiley, New York, 1948. Stock, Alfred, "Hydrides of Boron and Silicon," Cornell
- (15)Univ. Press, Ithaca, N. Y., 1933.

RECEIVED for review October 18, 1961. Accepted January 15, 1962. Work supported by the United States Air Force, Air Force Office of Scientific Research of the Air Research and Development Command under contracts No. AF18(600)-1541 and AF49(638)-937. Reproduction in whole or in part is permitted for any purpose of the United States Government. This article is third in a series on alkenylboranes by these authors.