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The Vibrational Spectra and Rotational Isomerism of 3-Butenylsilane

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The infrared and Raman spectra of 3-butenylsilane, $CH_2=CHCH_2CH_2SiH_3$ (and $-SiD_3$), were measured for the gaseous, liquid, and solid states. The fundamental vibrations were assigned, and the normal vibrations were calculated in relation to the rotational isomerism. The calculations indicated that the *cis-trans* (CT), *skew-trans* (ST), and *skew-gauche* (SG and SG′) forms coexist in the gaseous and liquid states, while the CT form only persists in the solid state. From the temperature variation in the Raman intensities, the stability of the molecular conformations was found to be in this order: $CT \gtrsim ST > SG' > SG$ in the liquid state, indicating that an appreciable interaction between the silicon atom and the C=C bond, such as in the case of allylsilane, is not present for 3-butenylsilane.

The properties of the UV and IR spectra of unsaturated organosilanes have long been investigated and have been commonly cited as evidence of the interaction between vacant 3d-orbitals of the silicon atom and the C=C π electron system, *i.e.*, $(p\rightarrow d)$-π-bonding and long $(p\rightarrow d)\pi$-bonding.[1] Recently, however, the bathochromic effect of the UV spectra and the abnormal high reactivity to the C=C bond of β-unsaturated organosilanes have been interpreted in terms of the σ-π hyperconjugation between the C=C π and the Si–C σ bonds.[2] The magnitude of this hyperconjugation varies with the dihedral angle about the axis between the carbon atoms in the α- and β-positions, and it is maximal at 90°,[3] indicating that the *skew* conformation is preferable to the *cis* conformation. Actually, in a previous paper[4] the analysis of the vibrational spectra has confirmed that, for allylsilane, only the form near the *skew* form predominantly exists in the gaseous, liquid, and solid states, although, for methylvinylsilane, the *cis* and *skew* forms coexist in the gaseous and liquid states. The same conclusion as to the molecular conformation of allylsilane has also been drawn from the electron-diffraction study[5] and the microwave spectral analysis.[6]

In the present paper, we will, then, deal with the molecular vibrations and rotational isomerism of 3-butenylsilane in order to obtain information on the interaction between the C=C bond and the silicon atom of the γ-position.

Experimental

The samples of 3-butenylsilane, $CH_2=CHCH_2CH_2SiH_3$, and its deuterated species, $CH_2=CHCH_2CH_2SiD_3$, were prepared as follows. Allyl bromide was converted to 3-buten-1-ol using magnesium and paraform, and the 3-buten-1-ol was then converted to 3-bromo-1-butene using PBr_3, by the method of Linstead *et al.*[7] A Grignard reagent prepared from the 3-bromo-1-butene was added to silicon tetrachloride in dry ether to yield 3-butenyltrichlorosilane. The resulting 3-butenyltrichlorosilane was reduced to 3-butenylsilane with $LiAlH_4$ or $LiAlD_4$ in dry dibutyl ether. The purities of the 3-butenylsilane-d_0 and -d_3 were checked by NMR analysis.[8]

The infrared spectra in the 250—4000 cm^{-1} region and the Raman spectra in the 10—4000 cm^{-1} region were recorded on a Perkin-Elmer instrument (Model 621) and a JEOL Raman spectrometer (Model JRS-400D) with an argon-ion laser respectively. The infrared and Raman spectra were measured for the gaseous, liquid, and solid states and for the liquid and solid states respectively, using the technique described in a previous paper.[4]

Results

Normal Coordinate Treatment. A molecule of 3-butenylsilane has two C–C axes and five possible isomers : *cis-trans* (CT), *cis-gauche* (CG), *skew-trans* (ST), *skew-gauche* (SG: stretched), and *skew-gauche′* (SG′: bent). In order to confirm the molecular forms and the assignments of the observed spectra to rotational isomers, the normal vibrations were calculated using the modified Urey-Bradley force field. The structural parameters used were transferred from those of 1-butene[9] and ethylsilane[10] determined by microwave study. All the valence angles except for the $CH_2=CH$ group were assumed to be tetrahedral, and the dihedral angles were assumed to be 0° for the C form and 120° for the S form about the $(CH_2=)CH-CH_2(CH_2)$ axis, and 60° for the G form and 180° for the T form about the $(=CH)CH_2-CH_2(SiH_3)$ axis. The force constants used in the present calculation were transferred from those of propylsilane,[11] allylsilane,[4] and olefins,[12] and the torsional force constants[13] of $Y(C-C=)$ and $Y(C-Si)$ were assumed from the barrier heights of 1.7 kcal/mol for 1-butene[9] and 2.04 kcal/mol for ethylsilane[10] respectively. Tables 1 and 2 give the observed and calculated frequencies of 3-butenylsilane-d_0 (BS-d_0) and 3-butenylsilane-d_3 (BS-d_3), together with the assignments based on the predominant potential energy distributions.

Rotational Isomerism. The molecule of 3-butenylsilane has 15 atoms and has the molecular symmetry of C_s for the CT form and that of C_1 for the CG, ST, SG, and SG′ forms. In the C_s symmetry, the 39 normal vibrations are reduced to 24 of the A′ species and 15 of the A″, while in the C_1 symmetry all 39 are of A. All the normal vibrations are infrared and Raman active.

Figures 1 and 2 show that several Raman lines in the liquid state disappear in the solid state, indicating the existence of the rotational isomers in the liquid state. On the other hand, almost all the frequencies observed in the solid state are assigned to the fundamental vibrations for one isomer, as Tables 1 and 2 show.

For such *n*-alkylsilanes as propylsilane and butyl-

TABLE 1. OBSERVED AND CALCULATED FREQUENCIES (cm^{-1}) OF 3-BUTENYLSILANE-d_0[a)]

Gas	Liquid		ρ	Solid		Calculated				Assignment[c),d)]
IR	IR	R		IR	R	CT[b)]	ST	SG′	SG	
				2171 sh vs	2181 vvs	2174 A'	2174	2174	2174	ν_aSiH$_3$
2162 vs	2158 vs	2154 vvs	p	2158 vs 2148 vs	2154 vvs 2149sh vs	2174 A''	2174	2174	2174	ν_aSiH$_3$
					2127 vvs	2171 A'	2171	2171	2171	ν_sSiH$_3$
1646 m	1641 w	1640 vvs	p	1639 m	1639 vs	1645 A'	1642	1642	1642	νC=C
1445 w	1444 vw	1447 b vw	dp					1434	1432	sSiCH$_2$
1429 w	1432 b vw	1430 sh vw		1430 w	1432 sh w 1423 m	1430 A'	1427			s=CH$_2$
1416 w	1415 vw	1416 s	p	1416 vw	1415 w	1426 A'	1424	1422	1424	sSiCH$_2$ (CT, ST), s=CH$_2$ (SG′, SG)
	1405 vw	1406 sh w	dp?	1403 vw 1400 sh vw	1407 s	1404 A'	1406	1405	1405	sCCH$_2$
1348 vw	1342 vvw	1345 vvw		1344 vw	1345 vw	1347 A'		1353	1351	wCCH$_2$
1316 b vw	1314 vvw	1317 sh vw					1329			wCCH$_2$
		1300 sh s					1290			tCCH$_2$
	1294 vvw	1295 vs	p	1298 b vvw	1296 vs	1277 A''		1282	1283	tCCH$_2$
	1262 vvw	1277 m	p	1281 b vvw	1280 w	1269 A'	1255	1255	1256	δ=CH i.p.
		1193 w	p				1191			wSiCH$_2$
1178 b w	1181 vw	1184 w	p	1183 w	1181 m	1190 A'				wSiCH$_2$
	1162 vw	1173 w	p						1165	wSiCH$_2$
		1145 b vvw					1144	1154		ν=C–C
								1145		wSiCH$_2$
1089 sh w	1095 vw	1087 b vvw		1087 w	1095 vw	1104 A''			1100	tSiCH$_2$(CT), ν=C–C(SG)
						1093 A'			1092	ν=C–C(CT), tSiCH$_2$(SG)
1057 w	1053 vw	1057 b vvw					1070	1047		tSiCH$_2$
		1013 w					1008			νC–C
992 s	991 m	992 w	dp?	1000 m	1003 vw	998 A''	997	1004	1003	t=CH$_2$
				981 vw	985 m	984 A'		995	990	νC–C
		942 vs	dp	939 sh s	947 sh vs	950 A''	950	949	950	δ_aSiH$_3$
					943 vs	947 A'	947	948	948	δ_aSiH$_3$
936 vs	922 b vs	931 s	dp?	930 vs	937 m	925 A''	924	927	926	w=CH$_2$
				917 b vs	922 w	917 A'	917	917	917	δ_sSiH$_3$
	908 sh vs	912 m	dp?		909 w	903 A'	905	904	909	r=CH$_2$(CT, ST, SG′), rCCH$_2$(SG)
		898 w	p	904 vs	901 m	900 A''	896			rCCH$_2$
		878 vw						887	885	rCCH$_2$(SG′), r=CH$_2$(SG)
802 m	799 w	800 vw						801		rSiCH$_2$
	789 sh w	790 sh vw							787	rSiCH$_2$
753 m	757 b w	758 s	p	760 m	763 vs	763 A'	758			νC–Si
	749 b w	745 w	dp?	748 m	746 vw	731 A''	728			rSiCH$_2$
		699 sh w							696	νC–Si
697 w	692 w	693 m	p					692		νC–Si
		661 sh w						628	631	δ=CH o. p.
	643 vw	651 w	dp?				623			δ=CH o. p.
	604 vw	610 w	p	601 m	613 s 607 m	602 A'				r_sSiH$_3$
582 b w	578 w	584 vs	p				568	569	574	r_sSiH$_3$
	549 vw	555 b vw		552 w	554 w	563 A''				δ=CH o. p.
524 b m	522 b vw	525 w	dp?	528 w	538 w 528 w	538 A'' 525 A'	539	537	537	r_aSiH$_3$ δC=CC
		433 sh w						440		δC=CC
424 b vw	422 vvw	423 m	p				439		438	δC=CC

Table 1. (Continued)

Gas	Liquid		ρ	Solid		Calculated				Assign-ment[c),d)]
IR	IR	R		IR	R	CT[b)]	ST	SG′	SG	
		332 sh vw						369	371	δCCC=
		305 w	p				321			δCCC=
		261 w	p		264 m	243 A′				δCCSi
		224 b w	dp?					229	219	δCCSi
					208 w					106×2
		179 sh m	dp?		179 w	161 A′	188			δCCC=(CT), δCCSi(ST)
					158 w	162 A″				τC–Si
							156	140	139	τC–Si
		96 sh m	dp?		106 vs	131 A″	95	91	96	τ=C–C
					92 vs 88 vs	75 A″				τC–C
							78	69	69	τC–C
					79 sh m					Lattice vibrations
					59 s					
					52 vs					
					36 vvs					

a) Frequencies above 2200 cm^{-1} are not included, and infrared spectra below 250 cm^{-1} are not recorded. s: strong, m: medium, w: weak, v: very, sh: shoulder, b: broad, p: polarized, and dp: depolarized. b) A′, A″: A′ and A″ species in the C_s symmetry. c) When molecular symbols are not indicated in parentheses, the band is assigned to each of the existing forms (CT, ST, SG′, and SG). *ν*: stretching, *s*: scissoring, *w*: wagging, *t*: twisting, *r*: rocking, *δ*: deformation, i. p.: in-plane, o. p.: out-of-plane, a: asymmetric mode, and s: symmetric mode. d) A large mixing of the modes occurred. (*t*CCH$_2$, *t*SiCH$_2$), (*ν*=C–C, *r*=CH$_2$), and (δCCSi, δCCC=) for CT. (r_sSiH$_3$, δ=CH o. p.) for ST, SG′, and SG. (δ=CH i. p., *w*SiCH$_2$, *t*CCH$_2$) for SG′ and SG. (δ=CH o. p., *w*=CH$_2$, *t*=CH$_2$) and (*r*CCH$_2$, *r*SiCH$_2$, *w*=CH$_2$) for SG.

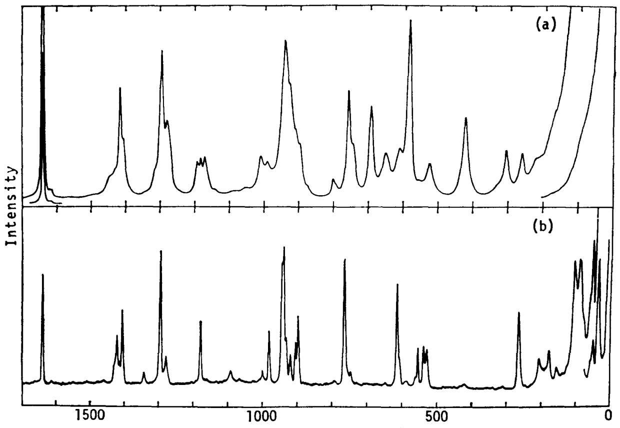

Fig. 1. Raman spectra of 3-butenylsilane-d_0 in the 10—1700 cm^{-1} region.

(a): Liquid state at room temperature, (b): solid state at liquid nitrogen temperature.

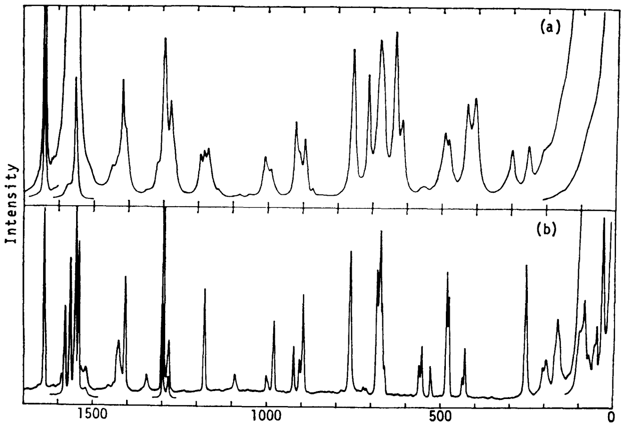

Fig. 2. Raman spectra of 3-butenylsilane-d_3 in the 10—1700 cm^{-1} region.

(a): Liquid state at room temperature, (b): solid state at liquid nitrogen temperature.

silane containing a $-CH_2CH_2SiH_3$ group, only the C–Si stretching and CH_2Si rocking vibrations have been observed in the 650—850 cm^{-1} region.[11)] By analogy with the case of the C–Cl stretching vibration in alkyl chlorides,[14)] the C–Si stretching vibration for the T form (P_C) has been assigned on a higher-frequency side than that for the G form (P_H), while the reverse is true for the CH_2Si rocking vibration,[15)] as is shown in Fig. 3. The CH_2Si rocking vibration, however, is, in general, weak in the Raman scattering and is of medium strength in the infrared absorption. Thus, from a comparison of the spectra of BS-d_0 with those of propylsilane and butylsilane, the stronger Raman lines at 758, 699 (shoulder), and 693 cm^{-1} are assigned to the C–Si stretching vibration, while the Raman lines at 800, 790 (shoulder), and 745 cm^{-1} are assigned to the CH_2Si rocking vibration. The Raman lines at 800, 790, 699, and 693 cm^{-1}, vanishing in the solid state, belong to the G form, and the Raman lines at 758 and 745 cm^{-1}, persisting in the solid state, to the T form.

On the other hand, for 1-butene[12)] and allyl chlo-

TABLE 2. OBSERVED AND CALCULATED FREQUENCIES (cm^{-1}) OF 3-BUTENYLSILANE-d_3[a]

Gas		Liquid				ρ	Solid				Calculated				Assignment[c),d)]
IR		IR		R			IR		R		CT[b)]	ST	SG′	SG	
1646	m	1641	m	1639	vvs	p	1641	s	1640	vs	1645 A′	1642	1642	1642	νC=C
1575	vs	1571	vs	1570	vvs	dp?	1580	vs	1589	vs	1572 A′	1572	1572	1572	ν_aSiD$_3$
							1565	vs	1564	vs	1572 A″	1572	1572	1572	ν_aSiD$_3$
1564	vs	1550	vs	1551	vvs	p	1552	vs	1549 1539	vvs vvs	1545 A′	1545	1545	1545	ν_sSiD$_3$
				1528 sh	w				1521	vw					755×2
1443	w	1445	w	1446	w	dp							1434	1432	*s*SiCH$_2$
1430	w	1431	w	1432 sh	w		1429	s	1425	w	1430 A′	1427			*s*=CH$_2$
1417	w	1415	w	1416	s	p	1418 sh	vw	1416 sh	vw	1426 A′	1424	1422	1424	*s*SiCH$_2$ (CT, ST), *s*=CH$_2$ (SG′, SG)
		1407	w	1407 sh	m	dp?	1406 1401 sh	m vw	1407	s	1404 A′	1406	1405	1405	*s*CCH$_2$
		1359 sh	vvw												677×2
1356 b	vvw	1345	vvw	1346	vvw		1343	vw	1344	vw	1347 A′		1353	1351	*w*CCH$_2$
1314 b	vw	1317	vvw	1314	w	p						1329			*w*CCH$_2$
				1299 sh	s							1290			*t*CCH$_2$
1299 sh	vw	1295	vvw	1295	vs	p	1299	vw	1296	vs	1277 A″		1282	1283	*t*CCH$_2$
1260	vvw	1263	vw	1278	m	p	1283	vvw	1280	w	1269 A′	1255	1255	1256	δ=CH i. p.
				1194	w	p						1190			*w*SiCH$_2$
1170 b	vw	1180	vw	1182	w	p	1180	m	1179	s	1188 A′				*w*SiCH$_2$
		1161	vw	1171	w	p								1164	*w*SiCH$_2$
				1142 b	vw							1143	1154		ν=C-C
													1144		*w*SiCH$_2$
1088 b	vw	1094	vw	1084	vvw		1090	m	1092	vw	1103 A″			1098	*t*SiCH$_2$(CT), ν=C-C(SG)
											1093 A′			1091	ν=C-C(CT), *t*SiCH$_2$(SG)
1054	w	1052	vw	1053	vvw							1068	1046		*t*SiCH$_2$
		1010	w	1007	w							1005	1003	1002	νC-C(ST), *t*=CH$_2$(SG′, SG)
999	m	992	m	994	w	dp?	997	m	1002	vw	997 A″	996	993	988	*t*=CH$_2$(CT, ST), νC-C (SG′, SG)
				986 sh	vw		983	w	981	m	980 A′				νC-C
918	s	918	s	921	m	p			925	w	924 A″	923	927	925	*w*=CH$_2$
912	s			912	w	dp?	903	vs	907	w	903 A′	903	900	905	*r*=CH$_2$(CT, ST, SG′), *r*CCH$_2$(SG)
		901	vs	896	w	p	895 sh	m	896	m	892 A″				*r*CCH$_2$
				871	vw							887	886	884	*r*CCH$_2$(ST, SG′), *r*=CH$_2$(SG)
760	vs	756	vs	755	vs	p	764	vs	761	s	770 A′	766	785	770	νC-Si(CT, ST), *r*SiCH$_2$ (SG′, SG)
716	vs	710	vs	713	s	p	727 723	m m	722 714	vvw vvw	718 A″	716	717	715	*r*SiCH$_2$(CT, ST), νC-Si (SG′, SG)
							688 sh	vw	684	s	681 A″	680	681	681	δ_aSiD$_3$
676	vs	677 b	vs	678 b	vs	dp?	674	vs	674	vs	680 A′	680	680	680	δ_aSiD$_3$
												662			δ_sSiD$_3$
							666	vs	668	m	664 A′				δ_sSiD$_3$
							662	vs	661	vw					
635	m	635	w	634	vs	p							638	644	δ_sSiD$_3$
		610 sh	vw	614	m	p						593	608	613	δ=CH o. p.
		547 b	vw	556	vw	dp?	552	w	562 559	vw w	563 A″				δ=CH o. p.

TABLE 2. (Continued)

Gas	Liquid		ρ	Solid		Calculated				Assignment$^{c),d)}$
IR	IR	R		IR	R	CT$^{b)}$	ST	SG′	SG	
		520 sh vw		521 vw	529 vw	537 A′				δC=CC
492 b w	489 b w	492 m					492	483	496	r_sSiD_3
	477 w	481 w		474 s	482 s	460 A′				r_sSiD_3
					476 m					
424 b w	437 w	428 m	p	434 m	438 vw		424	439	422	r_aSiD_3(ST), δC=CC(SG′, SG)
				427 sh w	430 w	419 A″		416	418	r_aSiD_3
		406 m	p				409			δC=CC
		319 sh vw						350	351	δCCC=
		300 vw	p				316			δCCC=
		253 w	p		255 s	230 A′				δCCSi
		211 w	dp?					215	207	δCCSi
					206 vw					102×2
					196 w					
		168 sh w	dp?		165 m	154 A′	175			δCCC=(CT), δCCSi(ST)
						149 A″	129	113	113	τC-Si
		100 sh s	dp?		102 vvs	112 A″	86	80	85	τ=C-C
					88 s	69 A″				τC-C
							76	66	67	τC-C
					73 s					Lattice vibrations
					52 vs					
					35 vs					

a), b), c) See a), b), and c) of Table 1. d) A large mixing of the modes occurred. (tCCH$_2$, tSiCH$_2$), (ν=C-C, r=CH$_2$), (δCCSi, δCCC=), and (τC-Si, τ=C-C) for CT. (r_aSiD$_3$, δC=CC) for ST. (wSiCH$_2$, tCCH$_2$, δ=CH i.p.) and (δ=CH o.p., t=CH$_2$, w=CH$_2$) for SG′ and SG. (rCCH$_2$, rSiCH$_2$, w=CH$_2$) for SG.

ride,[16] both containing the CH_2=CHCH$_2$– group, the C=CC skeletal bending vibration can be expected to be in the 400—550 cm^{-1} region; this vibration for the C form has been observed on a higher-frequency side than that for the S form, as is shown in Fig. 3. For BS-d_0, the Raman lines at 525 and 423 cm^{-1} are assigned to the C=CC skeletal bending vibration; the latter (the S form) disappears in the solid state, while the former (the C form) persists. Therefore, for 3-butenylsilane, it is indicated that the CT form persists in the solid state and that the CT and other forms coexist in both the gaseous and liquid states. The above results were confirmed from the normal coordinate treatment. The calculated frequencies of the CT form reproduced well the observed frequencies in the solid state. In the liquid state, the observed spectra were explained by the coexistence of the CT, ST, SG, and SG′ forms. Especially, the Raman lines at 305 cm^{-1} for BS-d_0 and at 300 cm^{-1} for BS-d_3 in the liquid state suggested the existence of the ST form, corresponding to the calculated frequencies of 321 cm^{-1} for BS-d_0 and 316 cm^{-1} for BS-d_3 given in Tables 1 and 2. The Raman lines at 800 and 693 cm^{-1} and the shoulder Raman lines at 790 and 699 cm^{-1} were assigned to the vibrations of the SG′ and SG forms respectively, as Fig. 4 shows. The existence of the CG form was not clear from the comparison of the observed frequencies with the calculated ones. However, this form is unlikely because of its large H···H nonbonded repulsion between the CH_2=CH and SiH_3 or SiD_3 groups.[12]

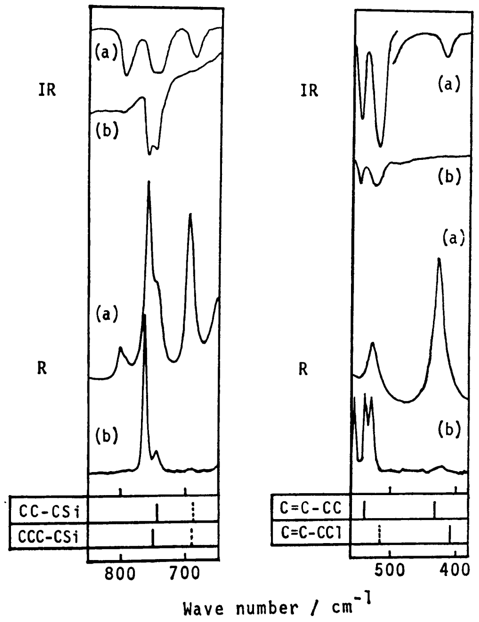

Fig. 3. Comparison of the spectra of 3-butenylsilane-d_0 with those of analogous molecules.
(a): Liquid state at room temperature, (b): solid state at liquid nitrogen temperature.

Stability of the Rotational Isomers. The enthalpy difference can be determined from the intensity ratios

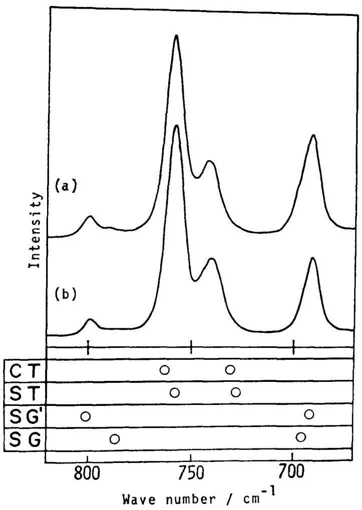

Fig. 4. Observed spectra in the 640—840 cm^{-1} region and calculated frequencies of each molecular form for 3-butenylsilane-d_0.
(a): Liquid state at −84 °C, (b): liquid state at −115 °C, ○: calculated frequency.

of the Raman lines belonging to different isomers.[17] However, only two pairs of the Raman lines were used for the determination because of the requirement that the pair of Raman lines be well separated from each other. The relative intensities were measured in the liquid state at different temperatures between −53 °C and −115 °C. The intensity ratios of the Raman lines at 758 (the CT and ST forms) and 693 cm^{-1} (the SG and SG′ forms) gave the apparent enthalpy difference, $\Delta H[(SG+SG')-(CT+ST)]=0.74\pm0.1$ kcal/mol, and those at 261 (the CT form) and 305 cm^{-1} (the ST form), $\Delta H(ST-CT)=0.22\pm0.2$ kcal/mol. On the other hand, Fig. 4 shows that the 800 and 693 cm^{-1} Raman lines assigned to the SG′ form increase in their relative intensities with a decrease in the temperature, as compared with those of the 790 and 699 cm^{-1} Raman lines assigned to the SG form. Therefore, for 3-butenylsilane, the stability of the rotational isomers is in this order: $CT \gtrsim ST > SG' > SG$ in the liquid state.

Discussion

For 3-butenylsilane, it was found that only the CT form persisted in the solid state and that the stability of the rotational isomers was in this order : $CT \gtrsim ST > SG' > SG$ in the liquid state. From the intensity ratios of the Raman lines belonging to the isomers, the enthalpy difference between the T and G conformations about the $(=CH)CH_2$–$CH_2(SiH_3)$ axis was estimated to be *ca.* 0.7 kcal/mol, and that the C and S conformations about the $(CH_2=)CH$–$CH_2(CH_2)$ axis, 0.22±0.2 kcal/mol. For propylsilane with the $(CH_3)CH_2$–$CH_2(SiH_3)$ axis, the T form has been found from the Raman spectral analysis[11] to be more stable than the G form by 0.60—0.65 kcal/mol. For 1-butene with the $(CH_2=)CH$–$CH_2(CH_3)$ axis, the enthalpy difference between the C and S forms has been reported to be $\Delta H(C\text{–}S)=0.15\pm0.15$ kcal/mol from the microwave analysis[9] and $\Delta H(C\text{–}S)=-0.10\pm0.05$ kcal/mol from the NMR analysis.[18] Therefore, 3-butenylsilane has a rough additivity of the enthalpy differences.

On the other hand, Harrah and Mayo[19] have reported, on the basis of their infrared spectral analysis of 1-alkenes, that the isomer with the S conformation persists in the solid state. The molecular form (the CT form) of 3-butenylsilane in the solid state differs from that of 1-pentene. This is, however, not peculiar, for the enthalpy difference about the $(CH_2=)CH$–$CH_2(CH_2)$ axis is quite small.

For 3-butenylsilane, the most and the least stable isomers in the liquid state were the CT and SG forms respectively. Therefore, the stability of the rotational isomers is mainly interpreted in terms of the steric repulsion between the nonbonded hydrogen atoms. The SG form has a considerable H···H nonbonded repulsion between the =CH– and CH_2Si groups. For the CT form, the silicon atom is more apart from the CH_2=CH group geometrically. Thus, there is no appreciable interaction between the C=C bond and the silicon atom of the γ-position for 3-butenylsilane.

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