Tetrahedron. Vol. 28, pp. 1097 to 1105. Pergamon Press 1972. Printed in Great Britain

NMR EXPERIMENTS ON ACETALS—XXXVII

NMR SPECTRAL STUDY OF *CIS*-, AND *TRANS*-6-METHYL-4-R-1,3-OXASELENANS

A. GEENS, M. ANTEUNIS, F. DE PESSEMIER, J. FRANSEN and G. VERHEGGHE

Department of Organic Chemistry, State University of Gent, Krijgslaan, 271 (S4) B-9000 Gent, Belgium.

(*Received in the UK* 29 *September* 1971: *Accepted for publication* 12 *October* 1971)

Abstract—The NMR spectral parameters are reported for *cis*-, and *trans*-6-Me-4-alkyl-1,3-oxaselenans with the aid of the INDOR- technique. Low temperature studies show the conformational equilibrium in the *trans* series to be pronouncedly one-sided and a value for the inversion barrier has been obtained.

RECENTLY we have described[1] the synthesis of 1,3-dihetero cyclohexanes containing selenium as one (or both) of the hetero atoms. We wish to describe now the NMR spectral behaviour of 4,6-disubstituted 1,3-oxaselenans and the results obtained from low temperature studies. Oxaselenans might show interesting features in connection with the possible ring distortion, a result of the pronounced differences in bond lengths met in the system; d(C—Se) = 1·98 Å and d(C—O) = 1·42 Å. Formerly distortions have been proposed for oxathians,[2, 3] for which compounds two models may be constructed, one with a puckered side, in the C—Se—C, resp. C—S—C region, and with a flattened C—O—C region, and one with the reversed situation. Although both conformers should in principle interconvert very easily it was concluded from NMR spectral data that there is no large energy barrier between them, and that probably the most abundant isomer[4] is the one with a flattened C—S—C moiety. Buys[3] however preferred to accept the other possibility, a situation which would parallel the puckering observed in 1,4-dithians, 1,4-diselenans, 1,3-thiacyclohexane and 1- selenacyclohexane.[5] No definitive conclusions may yet be drawn from the actual studied derivatives but we hope to be able to prepare model compounds (such as the parent C-2 substituted derivatives) to provide more information in the near future.

cis-6-*Methyl-4-alkyl-*1,3-*oxaselenans and* cis-4-*Methyl-*6-R-1,3-*oxaselenans* (**1**)

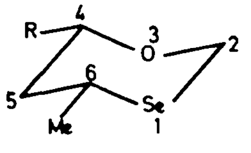
The NMR spectra of the *cis*-4-methyl-6-alkyl-1,3-oxaselenans were obtained in 10% solutions (CCl_4) on a Varian HA-100 MHz spectrometer, equipped with Muirhead Decade oscillators for multiple irradiation experiments and the necessary adaptation[6] for the INDOR-technique. As an example, the spectrum of the *cis*-4,6-dimethyl-derivative is displayed under Fig. 1 where atoms H5e, H5a, H4a and H6a forms an ABXY spin system, resulting in four subspectral quartets for H5e and H5a. Frequently a number of the H5a lines are hidden under the peaks belonging to the alkyl H-atoms, but peak location is easily obtained with the help of $^1H-\{^1H\}$-INDOR experiments, by monitoring the remaining resolved lines (mostly H5e). These experiments also allow the exact grouping of the four lines, belonging to each

TABLE I. COUPLING CONSTANTS IN Hz FOR *cis*-6-METHYL-4-ALKYL-1,3-OXASELENAN IN CCl_4

R—4	$-^2J$(5a,5e)	^3J(5a,6a)	^3J(5e,6a)	^3J(5a,4a)	^3J(5e,4a)	$\Sigma1^a$	$\Sigma2^b$	^3J(6a,Me)
Me	13·6	11·6	2·3	10·8	1·6	14·3	12·7	6·9[c]
Et	13·7	11·3	1·9	11·3	1·9	—	—	6·8
i-Pr	13·9	11·4	2·2	11·4	2·2	14·2	12·6	6·9[d]
i-Bu	13·8	10·9	1·9	10·9	1·9	14·4	—	6·9
neo-Pe	13·7	11·3	2·2	11·3	2·2	14·3	—	6·9[e]

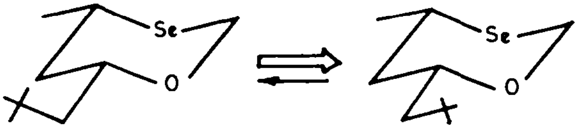
[a] $\Sigma1 = {}^3J(5a,6a) + {}^3J(5e,6a)$ by analysis of H6a.
[b] $\Sigma2 = {}^3J(5a,4a) = {}^3J(5e,4a)$ by analysis of H4a.
[c] $^3J(6a,Me) = 6{\cdot}4$ Hz.
[d] $^3J(4a,C\underline{H}Me_2) = 4{\cdot}9$ Hz.
[e] $^3J(A,4a) = 9{\cdot}9$ Hz; $^3J(B,4a) = 3{\cdot}4$ Hz; $^2J(A,B)[^2J(\underline{CH}_2,\text{-t-Bu})] = -14{\cdot}5$ Hz.

CHART 1

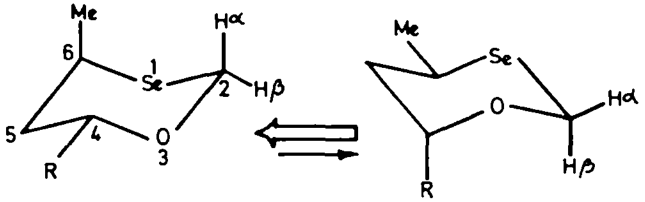


(1)

R= Me, Et, i.Pr, i.Bu, neo Pe



(2A) (2B)



(3A) (3B)

TABLE II. COMPARISON OF COUPLING CONSTANTS FOR 4,6Me-R-1,3-DIOXANS; 1,3-OXATHIANS; 1,3-OXASELENANS, 1,3-DITHIANS AND 1,3-DISELENANS[a]

Type	$-^2J$(5a,5e)	^3J(5a,6a)	^3J(5e,6a)	^3J(5a,4a)	^3J(5e,4a)
O-O	12·6	10·9	2·3	10·9	2·3
O-S	13·1	11·1	2·7	10·8	2·0
O-Se	13·7	11·6	2·3	10·8	1·6
S-S	13·6	11·3	2·3	11·3	2·3
Se-Se	14·3	11·3	2·0	11·3	2·0

[a] Numbering of the ring starts at the heteroatom with lowest mass number.

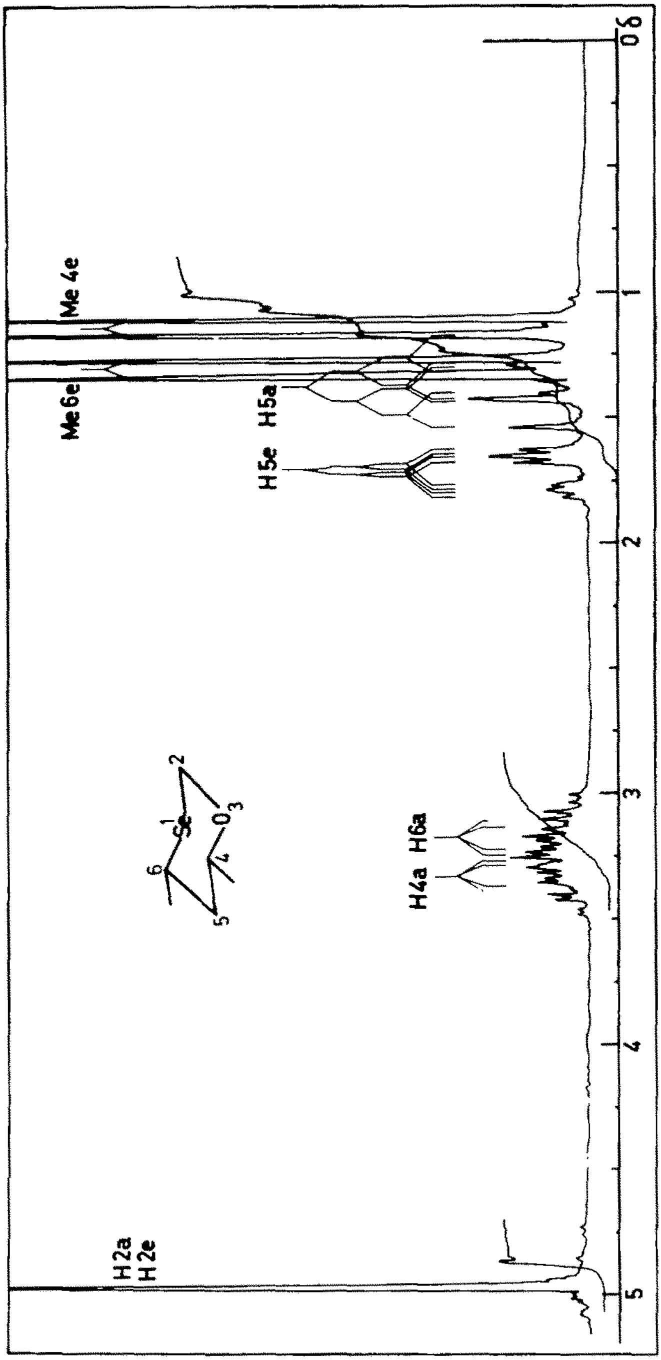


FIG 1. NMR Spectrum at 100 MHz (10 vol % in CCl_4, TMS internal) for *cis*-4,6-dimethyl-1,3-oxaselenan.

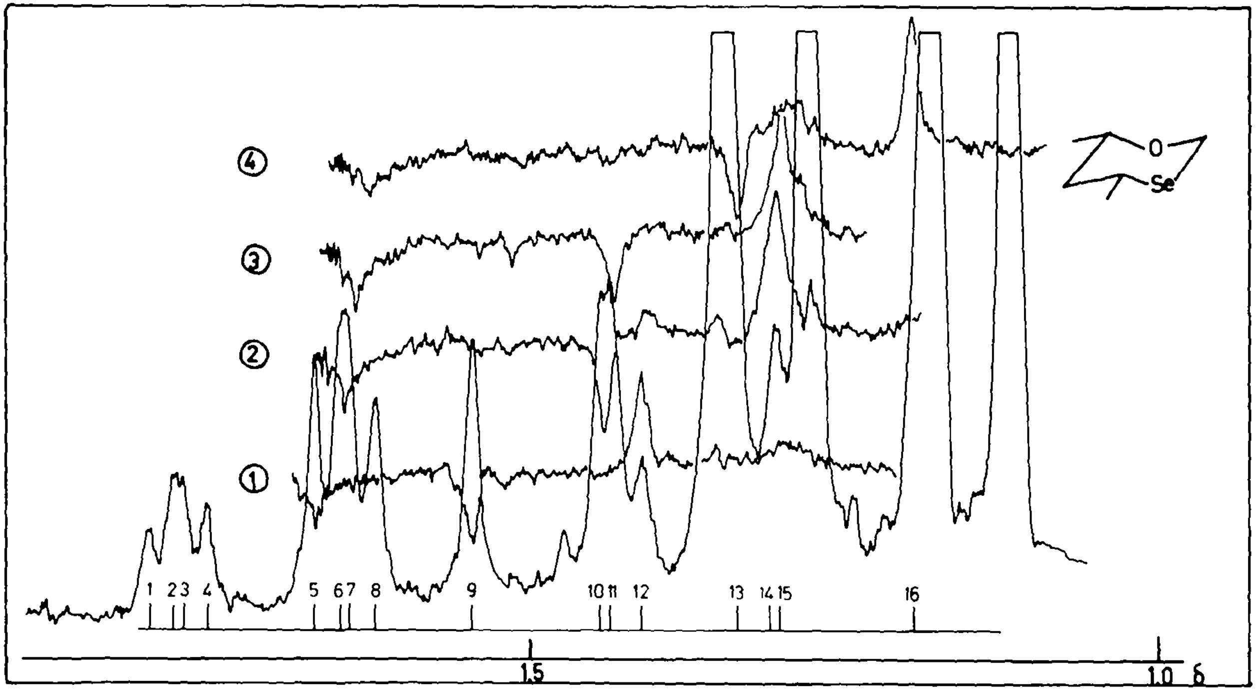


FIG 2. INDOR Spectra of the four subspectral ab systems for H5a and H5e in *cis*-4,6-dimethyl-1,3-oxaselenan, allowing the exact location of peaks. Numbers correspond to monitored peak as shown in the detailed spectrum.

of the four subspectral parts. Fig. 2 illustrates a typical example. From this the spectral parameters were obtained graphically by the subspectral procedure.[7] (Table I)

In most cases (except for the dimethyl-derivatives), lines 2, 6, 10 and 14 were very close to 3, 7, 11 and 15 and therefore were not resolved. Only an average value for both $^3J(5a, 4a)$, and $^3J(5a, 6a)$ and both $^3J(5e, 4a)$ and $^3J(5e, 6a)$ could be obtained. Furthermore the difference in chemical shift between H4a and H6a is rather small, giving rise to overlapping multiplets. The *exo*-couplings from these patterns could however easily be defined by INDOR, and from this also, Σ^3J4a and Σ^3J6a were easily obtained.

TABLE III. CHEMICAL SHIFTS (IN PPM FROM TMS INTERNAL) FOR *cis*-6-METHYL-4-ALKYL-1,3-OXASELENANS in CCl_4

R-4	$H_{2a} = H_{2e}$	H6a	H5a	H5e	H4a	Me6
Me	4·980	3·190	1·393	1·715	3·340	1·321[a]
Et	4·990	—	1·406	1·708	—	1·324
i-Pr	5·000	3·178	1·568	1·700	2·984	1·334
i-Bu	4·990	3·198	1·403	1·672	3·266	1·318
neoPe[b]	4·950	3·214	1·445	1·587	3·284	1·314

[a] δ(Me4) = 1·154.

[b] δ(CH₂-t-Bu)= 1·547 and 1·172.

Except for small changes, the inspection of Table I teaches us that coupling constants are insensitive to the nature of alkylsubstituents, except perhaps for the neopentyl and i-Pr substitution with respect to $^3J(5e,4a)$. An effect on $^3J(5a,4a)$ is still less visible because the coupling constant is near an extremum of the Karplus dependency with the corresponding torsion angle. Similar behaviour was found in *cis*-4,6-methyl,R-dioxans[8] and *cis*-4,6-methyl,R-oxathians,[9] and comparative data are gathered in Table II. Chemical shifts (Table III) were sensitive to substitution, only the value for δ(Me-6) being invariable 1·32 (±0·01 ppm).

We were also able to study in addition *cis*-6-ethyl-4-methyl-1,3-oxaselenan and *cis*-6-iso-butyl-4-methyl-1,3-oxaselenan which gives us some information about δ(Me-4) (1·150 ppm) and $^3J(\text{Me, H4a}) = 6{\cdot}4$ Hz.

Special attention may be paid to the neopentyl substituent, which also caused some deformation in the 1,3-dioxan moiety.[10] Typically the methylene protons of that group give an AB part of an ABX spin system (X being H4a). Values for geminal and vicinal coupling constants are denoted as $^2J(A,B)$ and $^3J(A,4a)$ and $^3J(B,4a)$ in Table I. The fact that $^3J(A,4a) - {}^3J(B,4a)$ is as large as 6·4 Hz indicates[10] the high preference in rotameric distribution of the neopentyl side chain (**2B**). Additionally Bayer-strain with the remaining ring will persist and a bending of the entire group results[10] in an enhanced value for $^2J(A,B) = -14{\cdot}6$ Hz, a value which is only partly explained by the possibility of the occurrence of an antiperiplanar C—O arrangement.

trans-6-*Methyl*,4-R-1,3-*oxaselenans* (**3A** ⇆ **3B**)

Only derivatives with the Me-group next to the selenium atom could be studied. *A priori* one might expect these compounds to occur as an equilibrated mixture of two

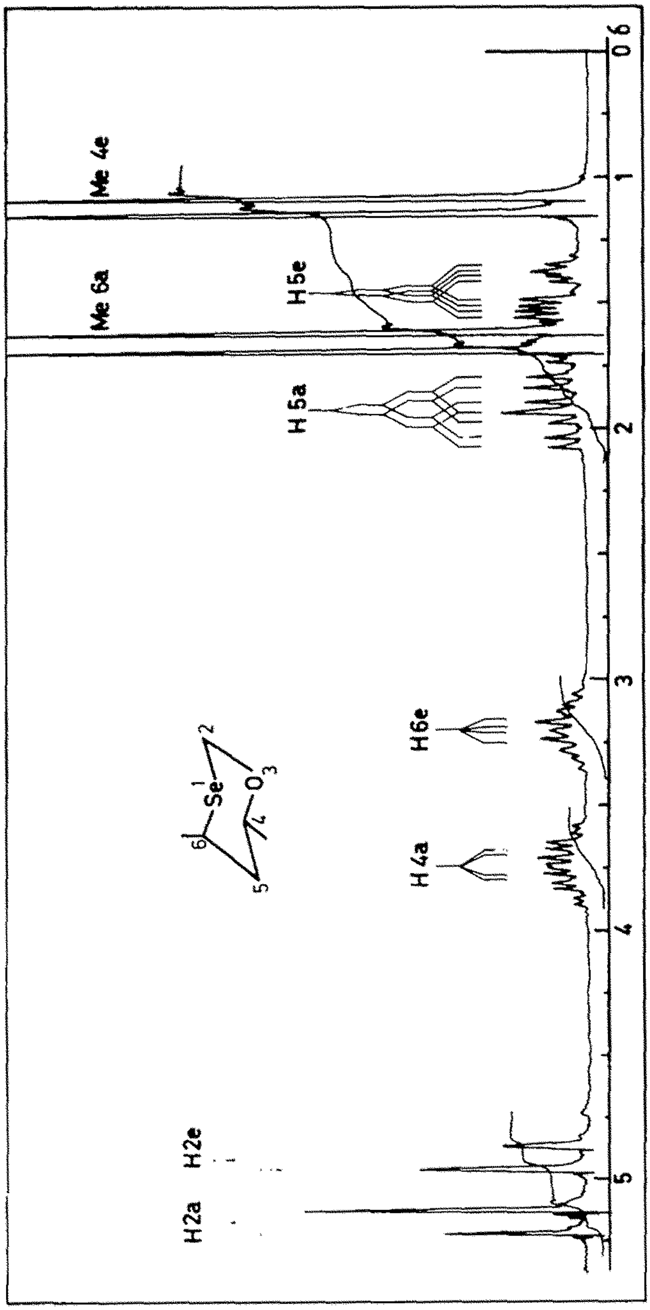


FIG 3. NMR Spectrum at 100 MHz (10 vol % in CCl_4, TMS internal) for *trans*-4,6-dimethyl-1,3-oxaselenan.

TABLE IV. COUPLING CONSTANTS IN Hz FOR *trans*-6-METHYL-4-ALKYL-1,3-OXASELENANS IN CCl_4

R-4	$-{}^2J$(5a,5e)	$-{}^2J$(2a,2e)	^3J(5a,6e)	^3J(5a,4a)	^3J(5e,6e)	^3J(5e,4a)	Σ1[a]	Σ2[b]	^3J(6e,Me6)
Me	14·1	9·6	4·4	10·0	4·1	2·3	8·4	12·2	7·1[c]
Et	13·9	9·3	4·2	9·9	4·5	2·1	—	—	7·3
i-Pr[d]	13·4	9·4	4·1	10·6	4·4	2·1	—	12·2	7·2
i-Bu	13·9	9·5	3·9	9·8	4·5	2·1	8·0	—	7·2
neoPe[e]	13·8	9·6	4·2	12·1	4·4	2·3	8·2	12·5	7·1

[a] Σ1 = J(5a,6e) + J(5e,6e) by analysis of H6e.
[b] Σ2 = J(5a,4a) + J(5e,4a) by analysis of H4a.
[c] ^3J(4a,Me4) = 6·4 Hz.
[d] ^3J(4a,C$\underline{H}$Me$_2$) = 5·3 Hz.
[e] ^3J(A,4a) = 8·4 Hz; ^3J(B,4a) = 2·6 Hz.
^2J(A,B)[= ^3J(C$\underline{H}_2$-t-Bu)] = 14·5 Hz.

conformers (3A and 3B). The values at room temperature indicate that conformer 3A certainly predominates, thus H6 occupies an essentially equatorial position [^3J(5e,6*e*) = 4·1 Hz; ^3J(5a,6e) = 4·4 Hz] but H4, on the contrary, an essentially axial position [^3J(5e,4a) = 2·3 Hz; ^3J(5a,4a) = 10 Hz]. The couplings ^3J(5a,4a) and ^3J(5e,4a) have values similar to those in the *cis*-isomers. The larger value for ^3J(6e,Me) = 7·1 Hz in the *trans* derivative in comparison to the value in the *cis*-isomer ^3J(6a,Me) = 6·9 Hz is remarkable. This corroborates the axial nature of the alkyl substituent in the *trans* derivative as illustrated in several heterocyclic systems.[11, 12]

If the difference in free energy ΔΔG° between both conformers has a reasonable value (< 1·5 Kcal/mole) we might expect by slowing down ring inversion, to be able to observe both forms at low temperature. Therefore a study down to – 100° was undertaken (in FREON 21). The behaviour of the H2a and H2e was closely followed. A spectral example is given in Fig. 3, where H2a and H2e form the AB spin system. The shift difference δ(2a → 2e) indeed suddenly changes in the region of 180–200° K.

Above 180° K, δ(2*a* → 2e) decreases more or less pronouncedly with increasing temperature, while below 180° K it remains almost constant or tends to increase with rise in temperature. The "jump" may be illustrated even better by following the individual shift values for both Hα and Hβ (Fig. 4a). Finally Fig. 4b shows the variation of bandwidth with temperature, from which one can unequivocally conclude that in the 180°–200° K region the conformational equilibrium 3A $\leftrightarrows$ 3B freezes out.

TABLE V. CHEMICAL SHIFTS (IN PPM FROM TMS INT.) FOR *trans*-4-METHYL-6-ALKYL-1,3-OXASELENANS IN CCl_4

R-4	H2a	H2e	H6e	H5a	H5e	H4a	Me6
Me	5·130	4·930	3·229	1·936	1·477	3·766	1·669[a]
Et	5·155	4·940	3·228	1·963	1·475	3·514	1·670
i-Pr	5·095	4·965	3·234	2·030	1·443	3·304	1·675
i-Bu	5·150	4·950	3·225	1·940	1·445	3·683	1·674
neoPe[b]	5·100	4·900	3·210	1·987	1·391	3·732	1·676

[a] δ(Me4) = 1·669.
[b] δ(C$\underline{H}_2$-t-Bu)= 1·555 and 1·015.

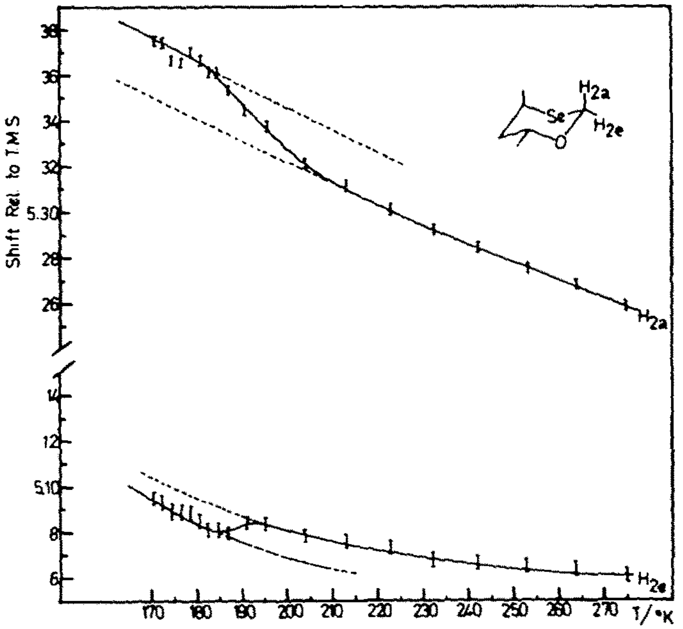


FIG 4a. Individual shift variation H2a and H2e as a function of temperature in *trans*-4,6-dimethyl-1,3-oxaselenan.

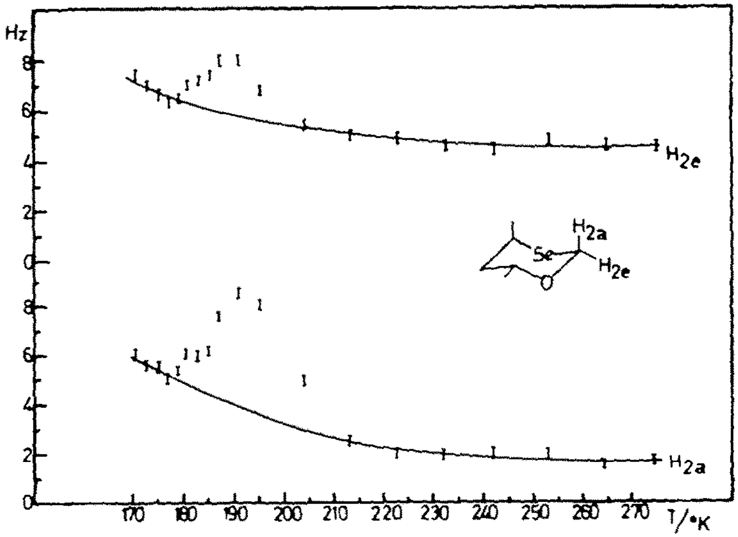


FIG 4b. Bandwidth variation for H2a and H2e as a function of temperature in *trans*-4,6-dimethyl-1,3-oxaselenan.

From the effects observed, the following conclusions may be drawn, (i) derivatives investigated (3) have their coalesce temperature at 187 ± 2·5°K. Hence *$\Delta G^{\neq}{}_{190}$ = 8·3 ± 0·1 Kcal/mole. Both shifts for the H2a and H2e show a different slope in their temperature dependence above T_c as compared with below T_c; (ii) Although a "freezing-out" is observed from bandwidths and shift behaviour, no separated peaks for two conformers may be noted. Thus **3B**, although roughly for 10% present is not distinguishable, and therefore coincidence with peaks from **3A** must occur. This behaviour parallels that for 1,3-oxathians; (iii) In order to define the pronounced effect on $\delta(2a \rightarrow 2e)$, *e.g.* whether it is due to a change in the structure of the solvent cage (acting differently on Ha and He as a function of temperature), measurements must be extended down to −130°, which for the moment could not be realized for instrumental reasons. We hope to clarify this problem in the future.

Acknowledgments—We are indebted to the "Nationaal Fonds voor Wetenschappelijk Onderzoek (Krediet aan Navorsers)" for their financial help in our research programmes.

REFERENCES

[1] A. Geens and M. Anteunis, *Bull. Soc. Chim. Belges* (in the press)
[2] J. Gelan, G. Swaelens and M. Anteunis; *Ibid.* **79**, 321, (1970)
[3] N. de Wolf and M. R. Buys, *Tetrahedron Letters* **8**, 551 (1970)
[4] J. Gelan and M. Anteunis, *Bull. Soc. Chim. Belges* **77**, 432 (1968); J. Gelan and M. Anteunis, *Ibid.* **79**, 313 (1970)
[5] M. R. Buys, *Rec. Trav. Chim. Pays-Bas* **88**, 1003 (1969)
[6] M. Scheidegger (Varian-Zug, Switzerland)
[7] P. Diehl, R. Harris and R. Jones, *Progress in NMR Spectroscopy*, vol 3, pp. 1–63. Ed. J. Emsley, J. Feeney and L. Sutcliffe, Pergamon Press (1967)
[8] D. Tavernier, *Ph.D. Thesis*, Gent (1971)
[9] J. Gelan and M. Anteunis, *Bull. Soc. Chim. Belges* **77**, 432, 1968); J. Gelan, *Ph.D. Thesis*, Gent (1971)
[10] D. Tavernier and M. Anteunis, *Bull. Soc. Chim. Belges* **80**, 219 (1971)
[11] M. Anteunis, *Ibid.* **80**, 3 (1971)
[12] D. Tavernier and M. Anteunis, *Tetrahedron* **27**, 1677 (1971)
[13] A. Geens, G. Swaelens and M. Anteunis, *Chem. Comm* 439 (1969)
[14] J. Gelan and M. Anteunis, *Bull. Soc. Chim. Belges* **78**, 559 (1969)
[15] E. Coene and M. Anteunis, *Ibid.* **79**, 37 (1970)
[16] H. Friebolin, H. Schmid, S. Kabuss and W. Faisst, *Org. Magn. Res.* **1**, 67 (1969)

---

* *cf.* $\Delta G^{\neq}$ in 1,3-diselenan[13] ≃8·2 ± 0·1 Kcal/mole; in 1,3-dithians:[14] 9·2 – 9·8 Kcal/mole; in 1,3-dioxans[15, 16] mostly 10·2 Kcal/mole.