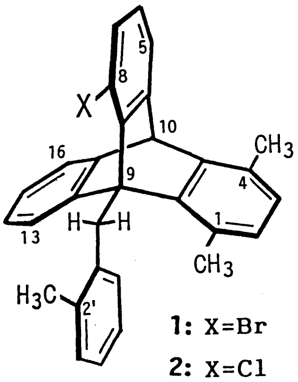
CHEMISTRY LETTERS, pp. 741-744, 1991.

Isomerization of Atropisomeric Triptycene Derivatives in Solid States

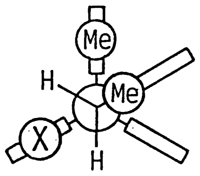
Gaku YAMAMOTO
Department of Chemistry, Faculty of Science,
The University of Tokyo, Bunkyo-ku, Tokyo 113

The sc*(9S*) rotamers of 8-bromo- and 8-chloro-1,4-dimethyl-9-(2-methylbenzyl)triptycenes irreversibly isomerize to the corresponding ap rotamers in solid states at the temperature range of 170 to 200 °C.

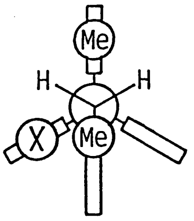
We recently reported the isolation of two rotational isomers, sc*(9S*) (hereafter referred to as sc1) and ap, of 8-bromo-1,4-dimethyl-9-(2-methylbenzyl)triptycene (**1**) as stable entities at room temperature.1) The sc1 isomer, mp 259-260 °C, was stereoselectively obtained by the reaction of 1-bromo-9-(2-methylbenzyl)anthracene with 3,6-dimethylbenzyne. Heating of a solution of sc1-**1** in toluene gave an equilibrium mixture of two isomers, ap and sc1, where K=[ap]/[sc1]=2.26 at 60 °C in toluene-d_8. The ap isomer, mp 260-261 °C, was isolated in a pure state by chromatographic separation of the equilibrium mixture. Kinetic studies gave the activation enthalpy of 26.3 kcal/mol for the sc1⟶ap conversion.



1: X=Br
2: X=Cl



ap



sc(9S*)*
scl

We noticed that both isomers had almost the same melting points (mps). Atropisomers should in principle have different mps and the observed fact may suggest that these isomers have accidentally quite similar mps. However, it may also be possible that a conformational change takes place in solid states during the course of heating up to the mp in either one or both of the isomers and that both solids exist in the same conformational state when they melt.

In order to investigate this point, we studied differential scanning calorimetry (DSC) for these isomers (Fig. 1). The ap-**1** shows an intense endothermic peak (ca. 8.9 kcal/mol) at 260.3 °C, which corresponds to the mp of ap-**1**,2) irrespective of the scan rate (20 and 60 °C/h). The sc1-**1**

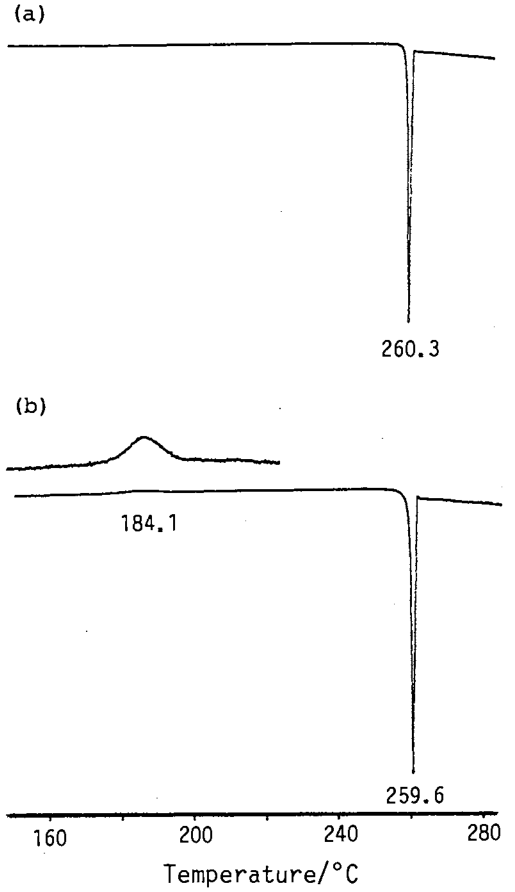


Fig. 1. DSC charts of (a) ap-**1**, 60 °C/h and (b) sc1-**1**, 60 °C/h.

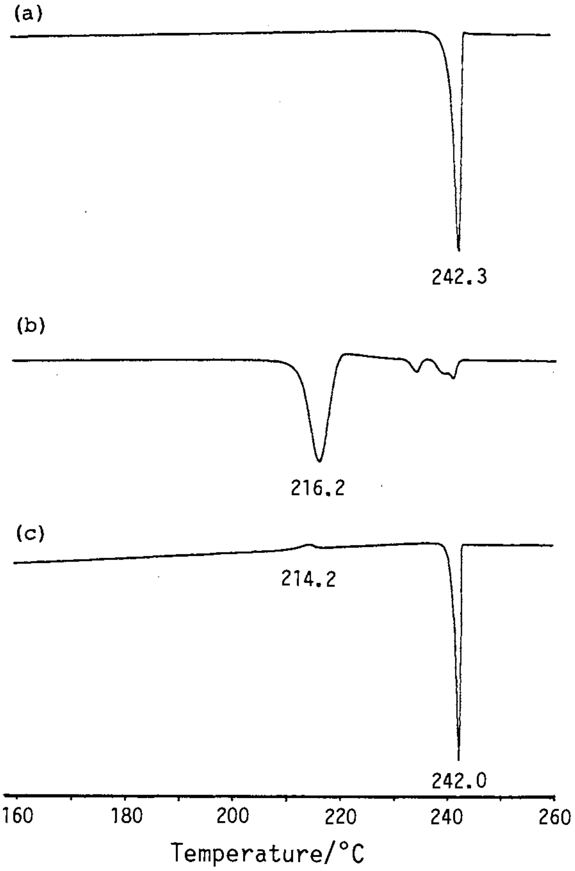


Fig. 2. DSC charts of (a) ap-**2**, 60 °C/h, (b) sc1-**2**, 180 °C/h, and (c) sc1-**2**, 20 °C/h.

shows an endothermic peak (ca. 8.3 kcal/mol) at 260 °C, and in addition a small broad exothermic peak (ca. 0.5 kcal/mol) at 180-190 °C region (20 to 180 °C/h).[3)]

These data evoke the following working hypothesis. The crystalline ap-**1** retains its identity until it melts at 260 °C, while the sc1 isomer entirely isomerizes to ap without melting at ca. 185 °C with an exothermic peak in DSC corresponding to a kind of phase transition and then melts at 260 °C, when the solid exits as the ap isomer.

To confirm this hypothesis, 1-2 mg portions of pure atropisomeric crystals were placed in capillary tubes and were heated in a metal heating block for the mp measurement under various conditions. The isomer composition of the samples was then determined by ^{1}H NMR spectra in $CDCl_3$.

The ap samples did not isomerize at all below 260 °C, the mp of ap-**1**. The sc1 isomer showed a complex behavior. In one experiment a sample of sc1-**1** was inserted into the heating block that had been preheated at 160 °C and was heated at a rate of ca. 0.5 °C/min to 250 °C and withdrawn from the heating block and cooled to room temperature. During this series of operations no change of the appearance of the solid was detected. The ^{1}H NMR spectrum of the sample gave the ap/sc1 ratio of 13.3 (7% sc1-**1**). When an sc1-**1** sample was inserted into the heating block preheated at 250 °C, it immediately melted to a clear liquid but in a few seconds it solidified to a waxy solid. Additional heating of the sample at 250 °C for 15 min showed no further change of the appearance. The ^{1}H NMR spectrum showed the ap/sc1 ratio of 6.30 (14% sc1-**1**). When inserted into the heating block at 210 °C, an sc1-1 sample partially melted and then solidified to give an ap/sc1 mixture with the isomer ratio of 5.0 after 30-min heating.

These findings as well as the DSC data indicate that the mp of 259-260 °C observed for sc1-**1** is really that of ap-**1** and the "intrinsic" mp of sc1-**1** might be around 185 °C and that rapid heating of sc1-**1** above ca. 190 °C results in melting but slow heating causes isomerization to ap-**1** without melting. In the melt an isomer equilibrium will be immediately attained.$^{4)}$ ap-**1** may selectively crystallize out, but a part of the melt may remain as glass and this may cause somewhat lower ratios when the sample is once melted.

When sc1-**1** crystals were placed in the block at 170 °C, slow isomerization took place without any change in the appearance. The ap/sc1 ratio was 0.18 and 0.70 after 40 and 150 min, respectively. Although the mechanistic details of the isomerization are yet unknown, if a first-order irreversible reaction is assumed, the rate constant is calculated to be $(6.5 \pm 0.5) \times 10^{-5}$ /s which corresponds to $\Delta G^{\ddagger}$ of ca. 35 kcal/mol. The ap/sc1 ratio reached 5.2 after 30 h.

In order to get further insights into these findings, we extended the study to a closely related compound to **1**, i.e., 8-chloro-1,4-dimethyl-9-(2-methylbenzyl)triptycene (**2**). Addition of 3,6-dimethylbenzyne to 1-chloro-9-(2-methylbenzyl)anthracene gave stereoselectively the sc1 isomer of **2**, mp 217-219 °C. Chromatographic separation of the equilibrated isomer mixture gave the ap isomer of 2 as a pure atropisomer, mp 244-245 °C.$^{5)}$

The DSC charts of the atropisomeric solids of **2** are shown in Fig. 2. ap-**2** behaves quite similarly as ap-**1** and shows an endothermic peak (ca. 8.5 kcal/mol) at 242 °C, mp of ap-**2** obtained by the conventional mp measurement,$^{2)}$ irrespective of the scan rate. In case of sc1-**2** the thermal behavior depends on the scan rate. When scanned rapidly (180 °C/h), an endothermic peak (ca. 7.6 kcal/mol) is observed at 216 °C, mp of sc1-**2**. When scanned slowly (20 °C/h), only a weak broad exothermic peak (ca. 0.5 kcal/mol) is observed at 214 °C and instead a strong endothermic peak (ca. 9.4 kcal/mol) appears at 242 °C. At an intermediate scan rate (60 °C/h), a chart like a superposition of these two extreme charts is obtained. The data clearly suggest that the sc1-**2** crystals melt upon rapid heating and isomerize to *ap*-**2** without melting upon slow heating.

This was again confirmed by the isomerization experiments in which the atropisomeric crystals of **2** were heated under various conditions. The *ap*-**2** crystals show no isomerization at all below 242 °C. The *sc1*-**2** crystals immediately melt and then re-solidify to afford an isomer mixture with the *ap*/*sc1* ratio of 7.6 when heated at 220 °C for 1 h, while they give a mixture with the ratio of 8.0 when the temperature is slowly raised from 185 °C to 220 °C by 6 °C/h. When inserted into the block at 200 °C, slow isomerization takes place. The isomer ratio is 0.14 after 5 min and 0.36 after 15 min, and finally reaches 13.1 after 4 h. The change at the early stage corresponds to $k=(4.0\pm0.5)\times10^{-4}$ /s and $\Delta G^{\ddagger}=35.5$ kcal/mol if the first-order rate law is assumed.

This study has revealed an intriguing phenomenon of isomerization of an atropisomer to another in solid state. The ease of the isomerization should be closely related to the similarity of the crystal lattices between the isomeric crystals. An X-ray crystallographic study will reveal this point and is under way.

As for the practical aspect, the present finding affords a simple way to isolate the *ap*-isomer of **1** or **2**. Instead of tedious chromatographic separation of the isomers from the equilibrated isomer mixture, heating a crystalline sample, either the pure *sc1* isomer or a mixture of isomers, at an appropriate temperature gives an *ap*-rich mixture, recrystallization of which gives a pure sample of the *ap* isomer.

The author is grateful to Mr. Katsuya Inoue, The University of Tokyo, for the DSC measurements. The present work was supported by a Grant-in-Aid for Scientific Research on Priority Areas (No. 02230108) from the Ministry of Education, Science and Culture.

References

1) G. Yamamoto, Chem. Lett., **1990**, 1373.
2) A small difference between mps obtained by conventional method and those by DSC may be due to the inaccuracy of the thermometer(s) used.
3) The peak position shifts to a higher temperature as the scan rate increases.
4) Either of *ap*-**1** and *sc1*-**1** gave an isomer mixture with the *ap*/*sc1* ratio of ca. 1.5 when heated above 260 °C.
5) Details of the synthesis and characterization of these atropisomers will be discussed in a full paper. Kinetic studies in toluene-d_8 solution in the temperature range of 50 and 90 °C gave the following parameters for the $sc1 \longrightarrow ap$ process: $\Delta H^{\ddagger}=25.4\pm0.6$ kcal/mol, $\Delta S^{\ddagger}=-2.7\pm1.8$ cal/(mol K), $\Delta G^{\ddagger}=26.3$ kcal/mol (60 °C), K(*ap*/*sc1*)=1.86 (60 °C).

(Received January 9, 1991)