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151. Yoshio Ueno, Shoji Takemura, Yoshiko Ando, and Hiromi Terauchi*2 : Reaction of N-Halosulfonamide. II.*1 Reaction of N,N-Dihalobenzenesulfonamide with Cyclohexene. (2).

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In order to examine the mode of reaction of N,N-dihalobenzenesulfonamide (I) with cyclohexene (II), the assumed intermediate, DL-*trans*-2,N-dibromo-1-benzenesulfonamidocyclohexane (X), was synthesized and the formation of it in the pathway of the reaction of the bromo analog of I with II was proved. Comparing the behavior of N-bromo-N-methylbenzenesulfonamide (XI) with that of X, the reaction of XI with II was examined, which afforded *trans*-1,2-dibromocyclohexane (V), 1,3-cyclohexadiene (VI), and 1-bromocyclohexene (XII). On the basis of these facts, the mechanism of the reaction of I with II was discussed.

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In the first work of this series,*1 attention was paid primarily to the reaction products. As indicated in Chart 1, the reaction products of N,N-dihalobenzenesulfonamide (I) with cyclohexene (II) were DL-*trans*-2-halo-1-benzenesulfonamidocyclohexane (III), its DL-*cis* isomer (IV), DL-*trans*-1,2-dihalocyclohexane (V), 1,3-cyclohexadiene (VI), benzenesulfonamide (VII) and 1-cyclohexen-3-one (VIII).

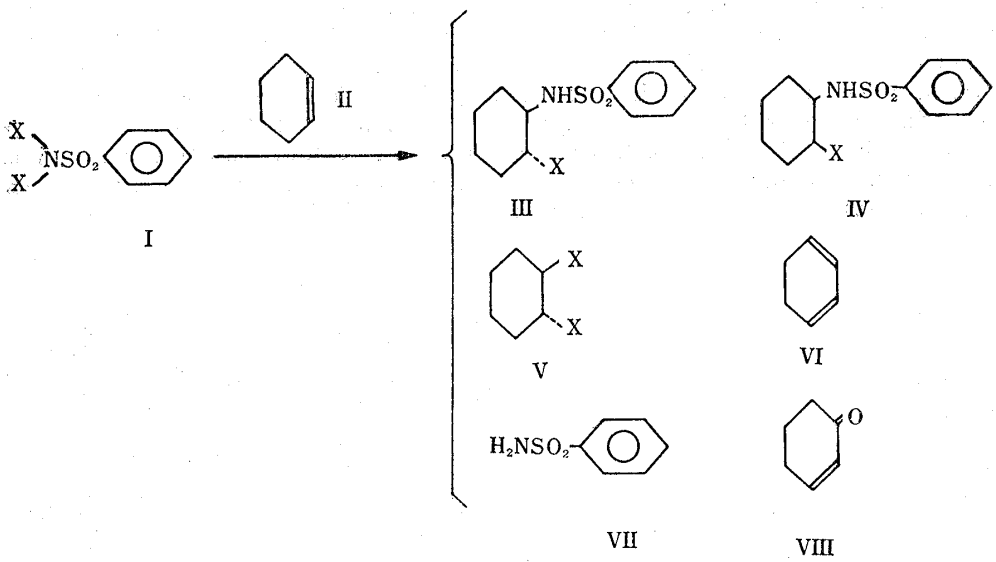

Chart 1.

The purpose of the present work is to throw some light on the mechanism of these types of reaction.

It was pointed out in the preceding paper*1 that a presumption might be drawn on this reaction where in the initial period of the reaction, a simple addition occurred between I and II in 1:1 molar ratio, forming some intermediates which subsequently induced the second reaction with II to give the final products. The brief observation was made on the reaction between I and II in various molar ratios to obtain evidence

*1 Part I : This Bulletin, **15**, 1193 (1967).

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for the above presumption. The results seems likely that the reaction involves two steps as shown in Chart 2, where the intermediate to the second step of the reaction is assumed as 2,N-dihalo-1-benzenesulfonamidocyclohexane (IX and X). When the intermediates undergo change to the final products (III and IV), it is questionable that from where did the hydrogen atoms linked to the nitrogen of final products come.

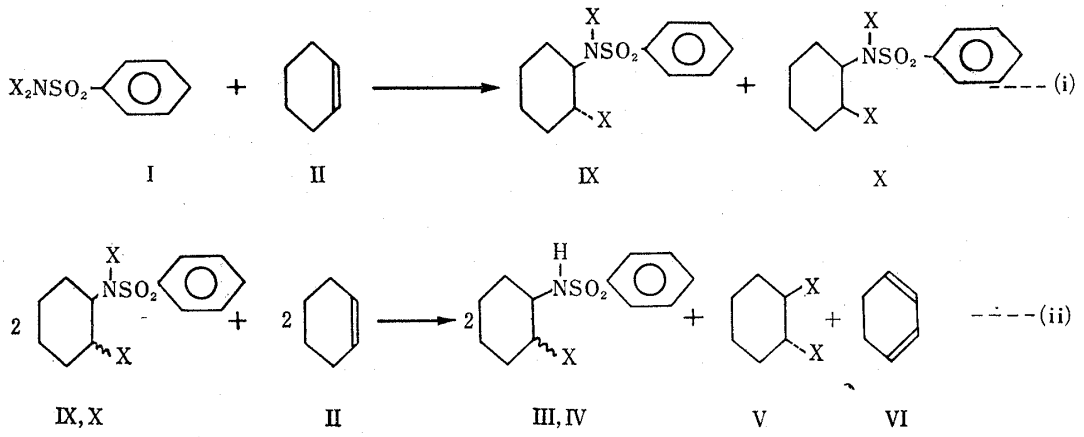


Chart 2.

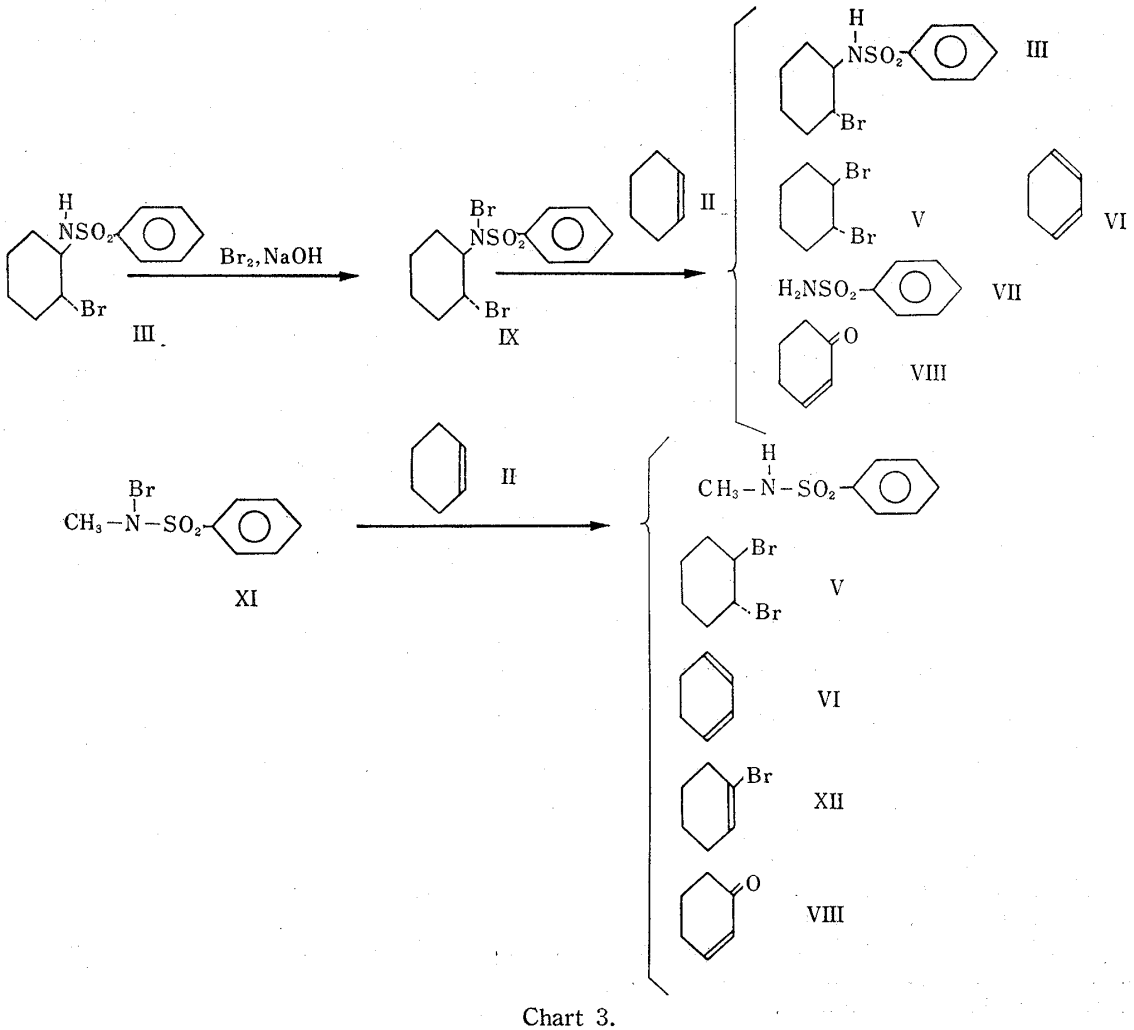


Chart 3.

It may be assumed that the source of hydrogens in the formation of the final products from the intermediates is an excess of cyclohexene and, in the course of the second step, abstraction of hydrogen atoms from a cyclohexene molecule by the intermediates (IX and X) giving cyclohexadiene (VI) and simultaneous addition of halogen atoms from nitrogen of the intermediates to another molecule of cyclohexene giving dihalocyclohexane (V) might occur.

On the basis of above presumption, synthesis of the probable intermediate, DL-*trans*-2,N-dibromo-1-benzenesulfonamidocyclohexane (IX, X=Br) as well as investigation of the chemical behavior of this compound were attempted.

Addition of bromine to the solution of DL-*trans*-2-bromo-1-benzenesulfonamidocyclohexane (III, X=Br) in aqueous alkali in the presence of $CHCl_3$ gave the expected compound (IX), m.p. 125~126°, $C_{12}H_{15}O_2NSBr_2$, whose Rf value was found to be identical with that of one spot detected on the thin-layer chromatogram of the initial reaction mixture of I (X=Br) and II. This compound was allowed to react with cyclohexene (II) and gave III (X=Br) in 96%,[*3] V (X=Br) in 13%,[*3] VI in 60%,[*3] and VIII in 13%[*3] yields.

The behavior of this intermediate (IX) suggests that the reaction of N-halo-N-alkyl derivatives of benzenesulfonamide with cyclohexene (II) is different from that of the N,N-dihalo derivatives. N-Bromo-N-methylbenzenesulfonamide[1] (XI) was therefore allowed to react with cyclohexene (II). As was expected, no addition of XI ocourred in this case and N-methylbenzenesulfonamide, $b.p_{30}$ 165~170° (86%[*4]), DL-*trans*-1,2-dibromocyclohexane (V) (15%[*4]), 1,3-cyclohexadiene (VI) (20%[*4]) and 1-bromocyclohexene (XII), b.p. 164~166° (11%[*4]) were obtained. The structure of XII was confirmed by showing complete agreement of infrared spectra with authentic 1-bromocyclohexene.[2]

Generally N,N-dihalobenzenesulfonamide reacts with cyclohexene to give 1:1 molar addition products, whereas N-halo-N-alkyl derivative of benzenesulfonamide causes abstraction of halogen atoms and simultaneous additions of their halogen atoms to cyclohexene.

Discussion

It is generally known that the reaction between N-halogenamides, such as N-bromosuccinimide and some N-bromo derivatives of amides as well as N-brominated aromatic sulfonamides, and ethylenic compounds appears to involve mainly two competing processes, leading to allylic substitution and halogen addition in 1,2-positions. Allylic bromination is often predominant and the mechanism for this process has been presented by many investigators, who presumably recognized it as a free radical type reaction as outlined in the following reaction scheme.[3,4]

$$>N\text{-}Br \longrightarrow >N\cdot + Br\cdot \quad (1)$$

$$-CH{=}CH{-}CH_2- + >N\cdot \longrightarrow -CH{=}CH{-}\dot{C}H- + >NH \quad (2)$$

$$-CH{=}CH{-}\dot{C}H- + Br\cdot \longrightarrow -CH{=}CH{-}CHBr- \quad (3)$$

$$-CH{=}CH{-}\dot{C}H- + >N\text{-}Br \longrightarrow -CH{=}CH{-}CHBr- + >N\cdot \quad (4)$$

*3 Yield calculated from IX (X=Br) used.
*4 Yield calculated from XI used.

1) Z. Fördi: Ber., **63**, 2257 (1930).
2) R. Willstätter, D. Hatt: Ber., **45**, 1468 (1912); N. Zelinsky, A. Gorski: Ber., **44**, 2314 (1911).
3) G. F. Bloomfield: J. Chem. Soc., **1944**, 114.
4) E. Müller: Angew. Chem., **64**, 243 (1952).

Goldfinger[5] proposed an alternative course in which the function of N-bromosuccinimide is to provide molecular bromine at a low concentration by reaction with hydrogen bromide.

Some structural features promote halogen addition as the main reaction. Buckles, *et al.*,[6] and Park, *et al.*[7] reported that N-bromoacetamide or some chlorinated N-bromoacetamides showed apparent tendency toward bromine addition in the reaction with cyclohexene and other olefins in comparison with the mode of N-bromosuccinimide. The presumable mechanism presented by Buckles[8] and his coworkers[6] is shown by equations (5) to (10).

$$\rangle N\text{-}Br \xrightarrow{h\nu} \rangle N\cdot + Br\cdot \quad (5)$$

$$\rangle C{=}C\langle + Br\cdot \longrightarrow \rangle CBr\text{-}\dot{C}\langle \quad (6)$$

$$\rangle CBr\text{-}\dot{C}\langle + \rangle N\text{-}Br \longrightarrow \rangle CBr\text{-}CBr\langle + \rangle N\cdot \quad (7)$$

$$Br\cdot + \rangle N\text{-}Br \longrightarrow Br_2 + \rangle N\cdot \quad (8)$$

$$Br_2 \xrightarrow{h\nu} 2Br\cdot \quad (9)$$

$$Br_2 + \rangle CBr\text{-}\dot{C}\langle \longrightarrow \rangle CBr\text{-}CBr\langle + Br\cdot \quad (10)$$

It seems to be necessary to consider the source of hydrogen atom but no hydrogen-donator has been mentioned by them. Addition of halogen can also be prompted by a certain catalyst; the action of N-bromosuccinimide on cyclohexene gives 1,2-dibromocyclohexane (V, X=Br) as the major product in the presence of alkylammonium salts.[9]

The less known process in the reaction of N-halogen amides with olefins is the formation of 1:1 adducts. Ziegler, *et al.*[10] reported that N-bromophthalimide and cyclohexene react to produce 1:1 adduct, *i.e.* 2-bromo-1-phthalylimidocyclohexane, in 21% yield accompanied by allylic bromine substitution giving 3-bromocyclohexene in 50% yield. Park, *et al.*[7] showed that trichloro- and trifluoro-N-bromoacetamides react with cyclohexene to give 1:1 adducts, *i.e.* 2-bromo-1-trichloro- and 2-bromo-1-trifluoro-acetamidocyclohexanes, respectively.

The tendency to give 1:1 adduct seems to predominate in the reaction of aromatic

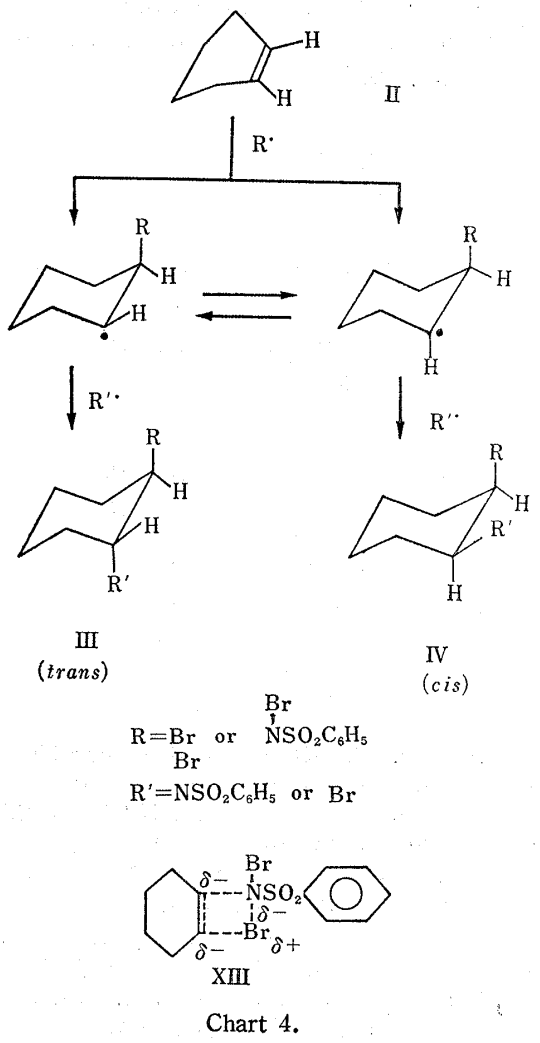
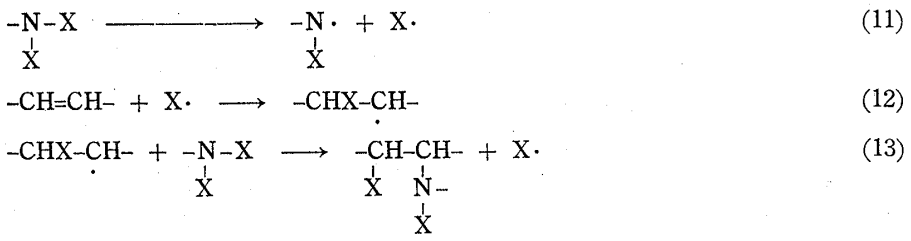


Chart 4.

5) J. Adam, P. A. Gosselain, P. Goldfinger: Bull. soc. chim. Belges, **65**, 523 (1956) (C. A., **51**, 248 (1957)).
6) R. E. Buckles, R. C. Johnson, W. J. Probst: J. Org. Chem., **22**, 55 (1957).
7) J. D. Park, *et al.*: J. Am. Chem. Soc., **74**, 2189 (1952).
8) R. E. Buckles: *Ibid.*, **71**, 1157 (1949).
9) E. A. Braude, E. S. Waight: J. Chem. Soc., **1952**, 1116.
10) K. Ziegler, *et al.*: Ann., **551**, 80 (1942).

N,N-dihalosulfonamides. They react with styrene to form 1-phenyl-1-arylsulfonamido-2-bromoethanes.[11,12]

If the above-mentioned free radical mechanism of bromine addition could be applied to the present case, the first step, *i.e.* the addition of N,N-dihalobenzenesulfonamide to cyclohexene to form the intermediates (IX and X), might be explained by equations (11) to (13), where 2-halocyclohexyl radical produced in the step (12) corresponding to (6) would react with N,N-dihalosulfonamide to give the intermediates in the step (13) equivalent to (7).



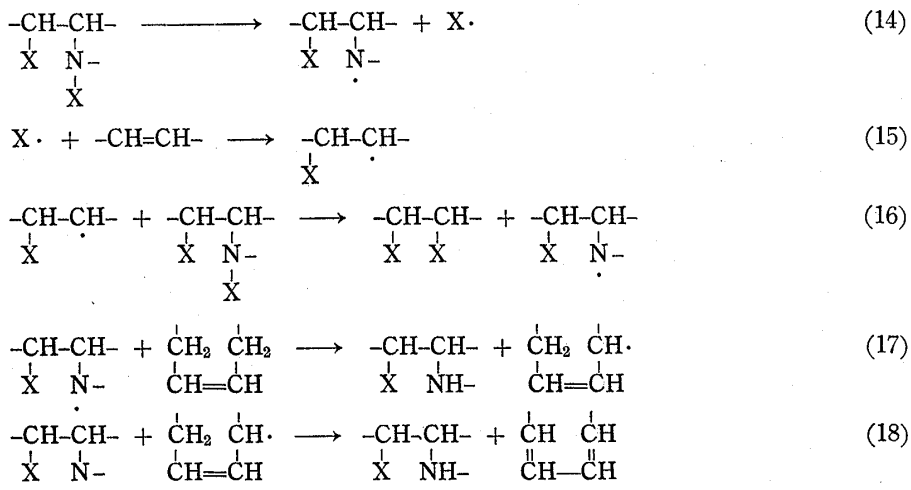
(11)

(12)

(13)

The formation of geometrical isomers, *cis*- and *trans*-adducts, can be explained analogously by the free radical addition of mercapto compounds with 1-chlorocyclohexene as reported by Goering, *et al.*[13] (in Chart 4). On the other hand, if an ionic process can be considered for the first step, it is necessary to suppose a four-centered intermediate such as XIII before formation of *cis*-intermediate (X).

One of possible mechanism of the second step of this reaction is a radical mechanism in which the halogen addition and abstraction of hydrogen atoms occur independently in cyclohexenes.



(14)

(15)

(16)

(17)

(18)

Experimental

DL-*trans*-2,N-Dibromo-1-benzenesulfonamidocyclohexane (IX, X=Br)——DL-*trans*-2-Bromo-1-benzenesulfonamidocyclohexane (III, X=Br) (3.2 g.) was mixed with $CHCl_3$ (20 ml.). To the cooled mixture, Br_2 (0.6 ml.) and subsequently 20% aq. NaOH (10 ml.) were added dropwise under stirring. Immediately after the color of bromine vanished, the $CHCl_3$ layer was separated, washed with H_2O, dried over Na_2SO_4, and $CHCl_3$ was evaporated at 40° *in vacuo*, to leave a solid material, m.p. 105~124°. Recrystallization of it from CCl_4-petr. ether gave slightly yellow prisms which were purified further by passing through a silica gel

11) M. S. Kharasch, H. M. Priestley: J. Am. Chem. Soc., **61**, 3425 (1939).
12) R. E. Buckles, W. J. Probst: J. Org. Chem., **22**, 1728 (1957).
13) H. L. Goering, D. I. Relyea, D. W. Larson: J. Am. Chem. Soc., **78**, 348 (1956).

column and developing the column with $CHCl_3$ to obtain 1.2 g. (30%) of pale yellow prisms, m.p. 125~126°. *Anal.* Calcd. for $C_{12}H_{15}O_2NSBr_2$: C, 36.27; H, 3.18; N, 3.53. Found: C, 36.64; H, 3.79; N, 3.42.

Reaction of IX (X=Br) with Cyclohexene——During a period of 30 min., IX (X=Br) (3.9 g.) was added in small portions to ice-cooled cyclohexene (10 ml.). An exothermic reaction occurred. After the heat evolution subsided, the mixture was warmed on a water bath for 20 min., cooled to room temperature, and benzene (4 ml.) was added to give colorless needles, m.p. 159° (3.0 g.), which was not depressed on mixed fusion with authentic DL-*trans*-2-bromo-1-benzenesulfonamidocyclohexane (III, X=Br).

After the removal of III, the mother liquor was distilled to collect a fraction boiling below 82°. This fraction was used for the identification of cyclohexadiene (VI) as described below.

The residue freed from the low-boiling fraction was distilled under a reduced pressure to obtain a fraction (3 ml.) of $b.p_{35}$ 75~90°. To a solution of the fraction (0.5 ml.) in MeOH (2 ml.), a hot mixture of 2,4-dinitrophenylhydrazine (0.2 g.), conc. HCl (1 ml.), and MeOH (5 ml.) was added, and the whole was refluxed for 15 min. The crystals obtained thereby were collected and recrystallized from EtOH to orange-yellow needles, m.p. 164° (50 mg.). This product was identified as 2,4-dinitrophenylhydrazone of cyclohexen-3-one by comparison of infrared (IR) spectra and mixed melting point determination.

After the removal of this 2,4-dinitrophenylhydrazone, the mother liquor was evaporated, and the residue was extracted with two 10 ml. portions $CHCl_3$. The combined $CHCl_3$ layer was dried over Na_2SO_4, evaporated to dryness, and the residue was extracted with two 10 ml. portions of *n*-hexane. The *n*-hexane layer was dried over Na_2SO_4 and passed through an Al_2O_3-column to obtain a liquid of $b.p_{30}$ 90~110° (50 mg.). This showed the same IR spectrum as that of the authentic DL-*trans*-1,2-dibromocyclohexane (V, X=Br.).

Gas chromatography of the low-boiling fraction was carried out under the following condition. Column, polyethylenglycol 6000 (30~60 mesh, 2 m.); detector, hydrogen flame ionization detector; sample, 1 μl. The content of the diene was 4.0% calculated from the area of the peaks.

Reaction of N-Bromo-N-methylbenzenesulfonamide (XI) with Cyclohexene——N-Bromo-N-methylbenzenesulfonamide (XI) (12.5 g.) was added in small portions to cyclohexene (12.3 g.) and chilled to below 10° under stirring. After standing at room temperature for 30 min., the mixture was refluxed for 10 min. and warmed at 50° for 2 hr. The mixture was distilled to collect a fraction boiling below 82° (low-boiling fraction). A part of the residue (8.1 g.) after the distillation was chromatographed on an Al_2O_3 column. The first eluate eluted with $CHCl_3$ gave an oil, b.p. 164~166° (0.4 g.), which was identical with the authentic 1-bromocyclohexene (XII) by comparison of IR spectra. Subsequent eluates were combined and fractionally distilled to obtain fractions of $b.p_{28}$ 65~74° (1.3 g.), $b.p_{28}$ 94~106° (1.4 g.), and $b.p_{30}$ 162~164° (3.5 g.). A part of the first fraction ($b.p_{28}$ 65~74°) (150 mg.) was converted into 2,4-dinitrophenylhydrazone of m.p. 165° which was identical with the authentic sample of cyclohexen-3-one, 2,4-dinitrophenylhydrazone. The second fraction ($b.p_{28}$ 94~106°) was treated with 2,4-dinitrophenylhydrazine to give the same hydrazone of cyclohexen-3-one as above. The mother liquor combined from the above two fractions was extracted with two 5 ml. portions of *n*-hexane and the extract was passed through a column of neutral Al_2O_3 to give an oil, $b.p_{30}$ 92~100° (44 mg.), which was identical with the authentic DL-*trans*-1,2-dibromocyclohexane (V, X=Br) showing good agreement in IR spectrum. The last fraction ($b.p_{30}$ 162~164°) was rectified to obtain a colorless oil, $b.p_{30}$ 165~170°, which was identical with the authentic N-methylbenzenesulfonamide by comparison of IR spectra. The low-boiling fraction was gas chromatographed in the following condition: Column, polyethyleneglycol 6000 (30~60 mesh, 2 m.); detector, hydrogen flame ionization detector; sample, 1 μl. The content of VI was 8.0% calculated from the peak area.