of colorless needles, m.p. 171–171.5°; λ_{max}^{Nujol} 5.40 (s), 7.37 (s), 8.14 (w), 8.46 (s), 9.53 (mw), 10.17 (s), 10.34 (w), 11.08 (w), 11.39 (m), 11.70 (w), 12.16 (m), 12.64 (m), 13.07 (m), and 13.66 μ (w).

Anal. Calcd. for $C_8H_7Cl_5O_4S$: C, 25.5; H, 1.86; Cl, 47.2; S, 8.50. Found: C, 25.8; H, 1.81; Cl, 47.2; S, 8.43.

Potassium 1,2,4,7,7-Pentachloro-3-ketotricyclo[2.2.1.0^{2,6}]heptane-5-sulfonate (X).—By employing potassium hydroxide in place of sodium carbonate in the above reaction, 1.2–1.3 equiv. of chloride ion per mole was released. The methyl ester (IX) was obtained in varying but minor amounts, the principal products being methanol-soluble salts. From the methanol filtrate on successive partial evaporations, a series of three water-soluble crystalline crops were obtained which, on the basis of infrared spectra, were primarily the same compound. The first and last crops contained a tenacious unsaturated impurity (band at 6.1 μ), but the second crop was substantially free of carbon-to-carbon double bond absorption. All crops showed strong C=O absorption at 5.52 μ. The second crop was used for elemental analysis.

Anal. Calcd. for $C_7HCl_5O_4KS \cdot H_2O$: C, 20.23; H, 0.73; Cl, 42.7; S, 7.72. Found: C, 20.46; H, 1.03; Cl, 41.5; S, 7.72.

1,2,3,5,6,6-Hexachloro-5-hydroxy-4-(sulfomethyl)bicyclo[2.2.1]hept-2-ene Sultone (XII).—To 300 ml. of oleum (20% sulfur trioxide) was added 100 g. of 5-methylene-1,2,3,4,7,7-hexachlorobicyclo[2.2.1]hept-2-ene[11] with stirring and water-bath cooling to hold the temperature below 50°. After the mixture had been stirred for 30 min., during which time it became a thick crystal slurry, it was added to ice–water. The precipitated solid was extracted with methylene chloride, washed with water, dried over magnesium sulfate, and filtered, and about an equal amount of carbon tetrachloride was added. Partial evaporation yielded 83 g. of crystalline solid, m.p. 185–187.5°.

Recrystallization from methylene chloride–carbon tetrachloride yielded colorless needles, m.p. 192.5°; λ_{max}^{Nujol} 3.31 (w), 6.21 (m), 7.00 (w), 7.20 (s, partly Nujol), 7.59 (w), 7.94 (m), 8.12 (m), 8.24 (m), 8.48 (s), 8.80 (w), 8.97 (w), 9.27 (m), 9.43 (s), 9.54 (s), 9.83 (w), 9.98 (w), 10.35 (m), 10.76 (ms), 11.2 (sh), 11.33 (s), 11.77 (m), 12.28 (m), 12.51 (m), 13.20 (m), 14.12 (m), 14.82 (w), and 15.22 μ (w). The compound is neutral to congo red in aqueous ethanolic solution.

Anal. Calcd. for $C_8H_4Cl_6O_3S$: C, 24.35; H, 1.27; Cl, 54.0; S, 8.11; mol. wt., 393. Found: C, 24.35; H, 1.36; Cl, 54.1; S, 7.98; mol. wt., 423 (± 10%; ebullioscopic in benzene).

1,2,3,6,6-Pentachloro-4-(sulfomethyl)bicyclo[2.2.1]hept-2-en-5-one (XIII) and Barium Salt.—A solution of 3.93 g. (10 mmoles) of the sultone XII in 90 ml. of tetrahydrofuran and 10 ml. of water was refluxed for 27 hr. An aliquot was found to contain 7.3 mequiv. of chloride by Volhard titration. A blank experiment wherein 1 *N* hydrochloric acid in 1:9 water–tetrahydrofuran solution was refluxed for a similar period showed that one-quarter of the hydrochloric acid was consumed by reaction with the tetrahydrofuran; therefore, taking into consideration this loss of hydrogen chloride, approximately 1 equiv. of hydrogen chloride per mole of XII had been evolved. Potentiometric titration of a second aliquot with 0.1 *N* sodium hydroxide gave an unsharp end point in the vicinity of pH 5 (the fading end point attributable to the instability of XIII sodium salt toward aqueous base) indicating the formation of 2 equiv. of strong acid per mole of XII.

The reaction mixture was evaporated to obtain a gray solid, m.p. 159.5–164°, which was recrystallized from benzene–ether and dried in air to obtain 2 g. of grayish white crystals, m.p. 163–165°; λ_{max}^{Nujol} 5.61 (C=O) and 6.28 μ (C=C); λ_{max}^{ether} 235 mμ (ϵ ~7000, on side of intense band < 220 mμ), 312 mμ (ϵ 350). The compound is soluble in water, giving a solution acidic to congo red indicator.

Anal. Calcd. for $C_8H_5Cl_5O_4S \cdot 2H_2O$: C, 23.41; H, 2.21; Cl, 43.19; S, 7.81. Found: C, 23.76; H, 2.41; Cl, 43.3; S, 8.20.

To obtain a more precise analysis, XIII was converted to its barium salt by digesting it in aqueous solution with an equimolar amount of barium carbonate on the steam bath until effervescence ceased (2.5 hr.), the mixture was filtered while hot, the filtrate was concentrated and cooled, and the resultant precipitate was filtered out and dried in air to obtain tan nodular crystals, λ_{max}^{Nujol} 5.60 (C=O) and 6.26 μ (C=C).

Anal. Calcd. for $C_{16}H_8BaCl_{10}O_8S_2 \cdot H_2O$: C, 21.29; H, 1.12; Ba, 15.2; Cl, 39.31; H_2O, 1.99; S, 7.10. Found: C, 21.09; H, 1.17; Ba, 14.9; Cl, 39.30; H_2O, 1.86; S, 7.02.

The Addition of Dichlorocarbene to *cis,cis*-1,5-Cyclooctadiene

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The reaction cited in the title can be conducted very smoothly by refluxing the hydrocarbon in a suspension of sodium trichloroacetate in a mixture of tetrachloroethylene and a small amount of diethylene glycol dimethyl ether. The reaction affords two crystalline bis adducts, and X-ray analysis has shown that the major, lower melting product has the *cis* configuration.

The objective of this investigation was to develop a carbene reaction suitable for use as an experiment for beginning students. The starting materials should be readily available, the reaction time short, and the product an easily isolated solid. The reaction of tetrachloroethylene with dichlorocarbene to give hexachlorocyclopropane (m.p. 104°) meets the requirements only in part. The yield is satisfactory (74%) when the intermediate is generated from phenyl(bromodichloromethyl)mercury,[2] but the preparation of this reagent is too involved and expensive. The double bond of tetrachloroethylene is so inert that generation of dichlorocarbene from chloroform or from sodium trichloroacetate in the presence of this olefin affords hexachlorocyclopropane in yields of 0.2–10%.[3,4]

It seemed to us that the bis adduct of a nonconjugated diene should have favorable properties and that *cis,cis*-1,5-cyclooctadiene offered particular promise. The hydrocarbon is available commercially[5] and has been found to react readily with hexachlorocyclopentadiene at 100° to give a high melting bis adduct.[6] Indeed, Skatteböl[7] states in a preliminary report that the cyclodiene reacts with dibromocarbene generated from bromoform and potassium *t*-butoxide to give a liquid mono adduct and a bis adduct melting at 174–180°. Since the completion of our work, Fray[8] has reported that reaction of the diene with sodium tri-

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[1] Undergraduate National Institutes of Health Fellow, CA-01696-11CY.

[2] D. Seyferth, R. J. Minasz, A. J.-H. Treiber, J. M. Burlitch, and S. R. Dowd, *J. Org. Chem.*, **28**, 1163 (1963).

[3] W. R. Moore, S. E. Krikorian, and J. E. LaPrade, *ibid.*, **28**, 1404 (1963).

[4] E. K. Fields and J. Meyerson, *ibid.*, **28**, 1915 (1963).

[5] Columbia Carbon Co., Box 975, Princeton, N. J.

[6] K. Ziegler and H. Froitzheim-Kühlhorn, *Ann.*, **589**, 157 (1954).

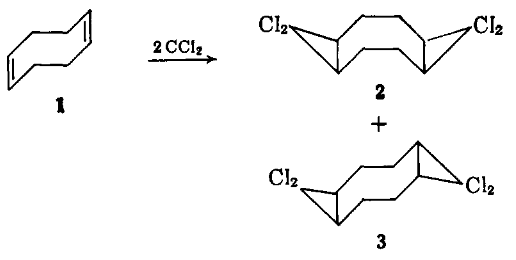
[7] L. Skatteböl, *Tetrahedron Letters*, **5**, 167 (1961).

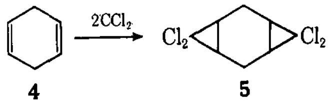
[8] G. I. Fray, *J. Chem. Soc.*, 4284 (1963).

chloroacetate in 1,2-dimethoxyethane for 16 hr. at 100–110° affords a liquid mono adduct in 59% yield along with 2% of a bis adduct, m.p. 174.5–175.5°. Neither result meets the specifications outlined.

Sodium trichloroacetate[8,9] seemed to be the precursor of choice, and we report below a simple, improved procedure for its preparation. We first tried magnetic stirring of *cis,cis*-1,5-cyclooctadiene with a suspension of sodium trichloroacetate in diglyme (diethylene glycol dimethyl ether) at a temperature maintained manually at about 120°. After a 2-hr. reaction period, the mixture was very black but tedious processing eventually afforded as the major product a bis adduct crystallizing from ethyl acetate as large needles, m.p. 176°. Recovery of the mother liquor material and repeated crystallization from toluene afforded a small amount of an isomer, m.p. 230° dec. The two substances are not separable by either thin layer or column chromatography. They often crystallize together, but can be sorted out because of a characteristic difference in crystalline form. A first idea for simplifying the procedure was to use an aprotic solvent of such a boiling point that refluxing would control the temperature in the desired range and provide stirring. Tetrachloroethylene boils at 121° and, as noted above, is very unreactive to dichlorocarbene. However, sodium trichloroacetate is insoluble in this solvent and no reaction with the diene was observed. It appeared that diglyme or an equivalent solvent is required to provide some solubility for the sodium salt, and the reaction was found to proceed materially better in a 7:10 mixture of diglyme–tetrachloroethylene than in diglyme alone. However, the solubility in this mixture is so great that the salt has to be added in small portions and the reaction mixture becomes very dark. The situation is improved greatly by the simple expedient of cutting down the amount of diglyme to a ratio 2.5:10. The salt is so sparingly soluble in this mixture that all of it can be added at the start of the experiment and it dissolves slowly as the reaction proceeds. Since boiling and carbon dioxide evolution provide adequate stirring, the mixture can be left unattended, and what little color develops is eliminated by washing the crude product with methanol. Thus, treatment of 4.4 g. of diene with the theoretical amount of sodium trichloroacetate in a 75-min. reaction period and with a very brief work-up affords 2.9 g. of the pure isomer with m.p. 176° in a yield of 29%. With twice the theoretical amount of sodium trichloroacetate, the yield rose to 62%.

Both isomers gave satisfactory analyses and were saturated to permanganate. Reduction of the more abundant isomer with lithium and *t*-butyl alcohol in tetrahydrofuran gave a product shown clearly by the n.m.r. spectrum to contain cyclopropyl hydrogens. Since the compounds presumably are *cis* and *trans* isomers, the junior author undertook to distinguish between them by X-ray analysis conducted under the guidance of Professor William N. Lipscomb and Mrs. Jean Ann Hartsuck, to whom we are greatly indebted. X-Ray data presented in the Experimental section led to the conclusion that the more abundant, lower melting isomer has the *cis* configuration. Cope, Moon, and Park[10] explored the reaction of *cis,cis*-1,5-cyclooctadiene with methylene iodide and zinc–copper couple, isolated the mono adduct, and by gas chromatography detected two substances presumed to be the *cis* and *trans* bis adducts; in contrast to the present results, the substances appeared in nearly equal amounts. We applied our best dichlorocarbene procedure to 1,4-cyclohexadiene (**4**) and isolated in low yield a crystalline bis adduct **5** of unknown configuration.





Experimental

Sodium Trichloroacetate.—A cooled solution of 3.2 g. of sodium hydroxide in 12 ml. of water was poured slowly and with cooling into a 125-ml. erlenmeyer flask with side tube containing 12.8 g. of trichloroacetic acid until only about one-tenth of the alkali remained. After addition of a drop of 0.04% bromocresol green solution, further alkali was added by capillary dropper to a neutral end point. The flask was stoppered, connected to the suction pump, placed within the rings of a steam bath, and wrapped in a towel. Evacuation for 15–20 min. gave an apparently dry white cake. This was broken up with a steel spatula and the material was dried further to a constant weight of 14.5 g. Mohr titration indicated the presence of only a trace of chloride ion.

Isolation of the Two Bis Adducts.—A mixture of 5 g. of *cis,cis*-1,5-cyclooctadiene,[11] 7 ml. of diglyme, and 10 ml. of tetrachloroethylene in a 125-ml. erlenmeyer was stirred magnetically and brought to 115°, and 24 g. of sodium trichloroacetate was added in 1-g. portions over a period of 1 hr. The mixture was stirred and maintained near boiling (115–120°) during the addition and for an additional half hour. The very dark reaction mixture containing suspended sodium chloride was cooled, 90 ml. of 95% ethanol was added, and the mixture was cooled thoroughly in an ice bath and filtered by suction. The cake containing an organic solid and sodium chloride was washed with cold ethanol to remove the dark mother liquor and to give an almost colorless granular solid. This solid was distributed between ether and water, and the white solid resulting from evaporation of the washed and dried ethereal layer on crystallization from about 20 ml. of ethyl acetate afforded 3.5 g. of large, colorless needles, m.p. 175–176°, of the *cis* bis adduct, *cis*-9,9,10,10-tetrachlorotricyclo[7.1.0.^{1,8}]decane (**2**).

Anal. Calcd. for $C_{10}H_{12}Cl_4$ (274.03): C, 43.83; H, 4.42; Cl, 51.75. Found: C, 43.84; H, 4.53; Cl, 51.65.

The ethyl acetate mother liquor from the crystallization was evaporated to dryness, and the solid residue on five crystallizations from toluene afforded 0.1 g. of *trans*-9,9,10,10-tetrachlorotricyclo[7.1.0.0^{1,8}]decane (**3**), m.p. 228–230° dec. (slight gassing).

Anal. Calcd. for $C_{10}H_{12}Cl_4$ (274.03): C, 43.83; H, 4.42; Cl, 51.73. Found: C, 43.81; H, 4.42; Cl, 51.64.

Evaporation of the ethanol filtrate from the original reaction mixture gave a thick brown oil, and a solution of this material in a little ethyl acetate on standing deposited 1 g. of pale yellow

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(9) W. M. Wagner, *Proc. Chem. Soc.*, 229 (1959).

(10) A. C. Cope, S. Moon, and C. H. Park, *J. Am. Chem. Soc.*, **84**, 4843 (1962).

(11) We are indebted to Professor A. C. Cope for a v.p.c. analysis conducted at Massachusetts Institute of Technology indicating that the sample used was 98.7% pure.

needles. Recrystallization gave material identical with the *cis* bis adduct.

Reaction of *cis,cis*-1,5-Cyclooctadiene with Dichlorocarbene from Chloroform.—A suspension of 10 g. of potassium *t*-butoxide in 50 ml. of dry ether was stirred magnetically in an ice bath, 2 g. of the diene was introduced, and then 5 ml. of chloroform was added dropwise in the course of 10 min. Stirring was continued for 1 hr., 50 ml. more ether was added, and the mixture was filtered by suction. After washing the filter cake thoroughly with ether, the filtrate was evaporated to dryness. Crystallization of the residual solid from ethyl acetate yielded 1.5 g. of colorless needles of nearly pure (m.p. 172–174°) *cis* bis adduct (mixture melting point determination).

***cis*-Tricyclo[7.1.0.0^{1,8}]decane.**—A solution of 2 g. of the *cis* bis adduct 2 in 20 ml. of tetrahydrofuran was stirred mechanically in a 125-ml. erlenmeyer flask mounted above an ice bath which could be raised for cooling when required to prevent boiling. Two grams of lithium wire which had been flaked with a hammer was added in portions along with enough *t*-butyl alcohol to dissolve the metal. After disappearance of all but a few small particles of lithium, the mixture was diluted with water and extracted with ether. Evaporation gave a yellow oil which was distilled at the pressure of the water pump (b.p. 135–140°). The n.m.r. spectrum in carbon tetrachloride clearly showed the presence of cyclopropyl hydrogens in a multiplet centering at τ 10.2 relative to tetramethylsilane.

Improved Procedure (L.F.F.).—A 250-ml. round-bottomed flask containing 5 ml. (4.4 g.) of *cis,cis*-1,5-cyclodecadiene, 14.5 g. (2 equiv.) of sodium trichloroacetate, 20 ml. of tetrachloroethylene, and 5 ml. of diglyme was fitted with a condenser connected to a gas bubbler containing a little tetrachloroethylene and heated over a microburner. Gas evolution continued at a steady rate for 75 min. and then stopped. Lumps of sodium trichloroacetate visible at the bottom of the flask gradually gave way completely to finely divided sodium chloride. The mixture acquired no more than a light tan color. At the end of the reaction, 75 ml. of water was added, the flask was fitted with a distillation adapter carrying a steam inlet tube, and the tetrachloroethylene was removed by distillation. The reaction product separating as a tan solid was extracted with methylene chloride; evaporation of the dried extract gave 8 g. of tan solid. The cake was covered with methanol, the lumps were crushed with a flattened stirring rod, the mixture was cooled, and the product was collected and washed free of brown mother liquor. The nearly colorless solid (3.3 g., m.p. 174–176°) consisting almost entirely of the *cis* bis adduct on crystallization from ethyl acetate (15 ml.) gave 2.9 g. (27%) of large needles of pure material, m.p. 175–176°.

In another run in which the amount of sodium trichloroacetate was increased to double the theoretical amount, gas evolution stopped after 1 hr. and 50 min. Evaporation of the dried extract gave 15.4 g. of tan product which, when washed with methanol, afforded 7.1 g. of material, m.p. 173–175°. Concentration of the methanol washings and recrystallization of the main product afforded a total of 6.6 g. (62%) of pure *cis* bis adduct, m.p. 175–176°.

7,7,8,8-Tetrachlorotricyclo[5.1.0.0^{1,6}]hexane (5).—A mixture of 3.5 ml. of 1,4-cyclohexadiene, 14.5 g. of sodium trichloroacetate, 20 ml. of tetrachloroethylene, and 5 ml. of triglyme was refluxed for 75 min., when bubbling stopped. After steam distillation for removal of solvent, further steam distillation afforded 0.53 g. of colorless solid, m.p. 169°. The substance crystallized from about 20 ml. of 95% ethanol in heavy prismatic crystals, m.p. 170–171°.

Anal. Calcd. for $C_8H_8Cl_4$ (245.97): C, 39.06; H, 3.28; Cl, 57.66. Found: C, 39.14; H, 3.39; Cl, 57.33.

X-Ray Analysis.—X-Ray photographs of a crystal of the lower melting isomer demonstrated C2h lattice symmetry, that is, a twofold axis perpendicular to a mirror plane, and hence showed that the crystal lattice is monoclinic. Measurement and calculation established the following dimensions of the unit cell: a = 14.8, b = 7.62, c = 12.1 Å.; β = 58°. Calculation from the molecular weight of 274 and the observed density of 1.49 g./ml. indicates the presence of four molecules per unit cell.

Crystals of the higher melting isomer have lattice symmetry D2h (three mutually perpendicular mirror planes) and, therefore, are orthorhombic. The units cell dimensions are a = 12.0, b = 6.11, c = 7.89 Å. On the assumption that the molecular weight is 274 and the density is the same as observed for the iso mer, calculation shows the presence of two molecules per unit cell.

The precise space group for the monoclinic crystal is C2, Cc, C2/m, or C2/c and that for the orthorhombic crystal is either Pnnm or Pnn2, but these possibilities in themselves do not distinguish between the two configurations. However, measurement of the molecular dimensions of models on the assumption of an intramolecular H–H distance of 2.4 Å. indicated that the *cis* isomer cannot preserve the symmetry of the space group Pnn2 and fit into this unit cell, whereas the *trans* isomer does fit in this space group. Furthermore, symmetry requirements show that the *cis* isomer cannot yield crystals of the Pnnm space group. Therefore, the higher melting bis adduct forming orthorhombic crystals must be the *trans* isomer.

Investigations in Heterocycles. XVI.[1] A New Synthesis of 1,2-Disubstituted 4-Thiopyrimidines *via* Enamines

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A simple one-step synthesis has been developed for the preparation of 1,2-disubstituted 4-thiopyrimidines by condensing an α,β-unsaturated amino ester (enamine) with an acyl isothiocyanate. The general structure of these compounds has been confirmed by chemical and spectral methods. The spectral properties of these compounds are described.

The recent monograph on pyrimidines by Brown[2] has outlined comprehensively the principal methods of synthesis and the chemical and physical properties of pyrimidines. It has been tacitly implied herein that, although a great variety of mercaptopyrimidines have been prepared, only the 2-mercaptopyrimidines have been synthesized directly from a 3-carbon intermediate and an appropriate condensing agent (*e.g.*, thiourea). However, the usual procedure employed to arrive at the 4-mercaptopyrimidines involves the synthesis of the 4-hydroxy- or 4-chloropyrimidines, which then are allowed to react with phosphorus pentasulfide or sodium hydrosulfide, respectively. This method is limited in that it permits substitution at position 1 only after a 4-aminopyrimidine derivative has been alkylated and the resulting alkyl 4-imino intermediate has been hydrolyzed to the corresponding 4-oxo derivative.[3] Thus, a minimum of four steps is required in the preparation of a 1-alkyl 1,4-dihydro-4-thiopyrimidine from the appro-

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[1] Presented in part before the Organic Division at the 145th National Meeting of the American Chemical Society, New York, N. Y., Sept., 1963.

[2] D. J. Brown, "The Pyrimidines," John Wiley and Sons, Inc., New York, N. Y., 1962.

[3] D. J. Brown, E. Hoerger, and S. F. Mason, *J. Chem. Soc.*, 211 (1955); see also pp. 373–382 of ref. 2.