Hydrogenation of Hydro-amides.—The hydro-amides were hydrogenated under conditions similar to those used with aromatic nitriles. A solution of 7–12 g. of the hydroamide in 15–25 ml. of primary amine was shaken with 3–5 g. of W-4a catalyst at temperatures of 55–75° until hydrogen uptake ceased. When ammonia was added, the solution was first cooled in a Thermos containing Dry Ice and the liquid ammonia added. The liner was then placed in the reaction vessel which was closed as quickly as possible to avoid evaporational loss. The reaction mixture was worked up as previously outlined. The mixed secondary amine was isolated as a separate fraction. The high boiling product was identified as a mixture of Schiff base and corresponding secondary amine by methods previously outlined—acid hydrolysis and hydrogenation. The amount of secondary amine present in the fraction was estimated on the basis of refractive index. The Schiff base and secondary amine obtained from hydroanisamide are solids at room temperature but crystallize slowly enough for the refractive index to be determined.

Benzal-(*p*-methoxybenzyl)-amine.—A solution of 12.0 g. of anisonitrile, 9.2 g. of benzonitrile in 20.5 g. of benzylamine was shaken for 3 hours at 55–60° with 5 g. of W-4a catalyst under a pressure of 80 atmospheres of hydrogen. The pressure drop was 33 atmospheres. The reaction product was worked up using the method previously outlined. A yield of 25.5 g. of benzylamine and 1.2 g. of anisamine were obtained. From the high boiling fraction 2.6 g. of product distilling at 160–165° (0.1 mm.), n^{20}_{D} 1.5986, was obtained. On acid hydrolysis, benzaldehyde was the only product in the steam distillate. The amine hydrochloride residue had a chloride equivalent to 178.0 (173.5 for *p*-methoxybenzylamine) indicating that the product was mostly benzal-(methoxybenzyl)-amine with about 3% of the corresponding secondary amine present. When the amine hydrochloride residue was made alkaline and distilled no appreciable amount of benzylamine could be found. In addition to the above fraction, a 4.2-g. fraction was obtained distilling at 165–175° (0.1 mm.) which was a mixture of the above Schiff base with anisal-(*p*-methoxybenzyl)-amine and 4.6 g. of anisal-(*p*-methoxybenzyl)-amine.

When 8 g. of anisonitrile was hydrogenated in solution with 19.6 g. of benzylamine, only anisal-(*p*-methoxybenzyl)-amine was obtained as a secondary product.

MISSOULA, MONTANA

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, PURDUE UNIVERSITY]

Conversion of the Lactone of *trans*-2-Hydroxycyclohexaneacetic Acid to its *cis* Isomer[1]

BY JAMES H. BREWSTER AND CLARE H. KUCERA

RECEIVED MARCH 7, 1955

trans-2-Hydroxycyclohexaneacetamide, prepared from the corresponding lactone, reacts with *p*-toluenesulfonyl chloride in pyridine to form a sulfonimido ether which can be hydrolyzed to the lactone of *cis*-2-hydroxycyclohexaneacetic acid. The course of these reactions is discussed.

In connection with other work it was desired to find a method for converting the lactone of *trans*-2-hydroxycyclohexaneacetic acid (II)[2,3] to its *cis* isomer with retention of configuration at one of the asymmetric carbon atoms.[4] It seemed likely that the tosylate of the *trans*-hydroxy acid I could yield the desired *cis*-lactone VII by displacement of tosylate by the carboxylate ion.[5] Attempts to carry out this process were, however, unfruitful, starting materials and the *trans* lactone being the only products which could be isolated.[6]

trans-2-Hydroxycyclohexaneacetamide (III) was prepared by reaction of the *trans* lactone with ammonia. Tosylation of this material in pyridine solution gave a compound, $C_{15}H_{19}O_3NS$, the structure of which is discussed below. This product furnished the *cis* lactone (VII) on saponification and treatment with acid. The two lactones have been characterized by infrared spectra, melting points and by preparation of the hydroxy amides and hydroxy-N-benzylamides. The *cis* lactone, in agreement with the findings of Newman and VanderWerf,[4] is much more resistant to ring-opening reactions than is the *trans* lactone[7]; it could not be converted to an isolable hydroxy acid. The infrared spectra of the two lactones are distinctly different. The carbonyl stretching absorption of the *cis* compound occurs at a higher wave length (5.70 μ) than does that of the *trans* compound (5.62 μ). Both values are consistent with the formulation of these substances as γ-lactones; the shift of this band is consistent with the greater reactivity of the *trans* compound.

Structure VI has been assigned to the intermediate tosylate on the basis of its composition, which shows that dehydration has accompanied the tosylation, and on the basis of its hydrolysis to the *cis*-lactone VII. The infrared spectrum shows that OH, NH, $C\equiv N$ and $C=O$ structural units are not present in this substance. Strong absorption bands at 7.40, 8.48 and 8.56 μ are consistent with the presence of either a sulfonamido or sulfonate linkage.

The reaction sequence III–VI is proposed to account for these results. The occurrence of inversion at the carbinol carbon atom in the formation of VI suggests that a tosylate IV is formed first; in-

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[1] Presented at the 126th Meeting of the American Chemical Society, New York, N. Y., Sept., 1954.

[2] Available by way of reaction of cyclohexene oxide with sodiomalonic ester; S. Coffey, *Rec. trav. chim.*, **42**, 387 (1923).

[3] The corresponding cyclopentane derivative, prepared by this method, has been shown unequivocally to have the *trans* structure; W. E. Grigsby, J. Hind, J. Chanley and F. H. Westheimer, THIS JOURNAL, **64**, 2606 (1942).

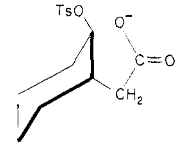
[4] The *cis*-lactone has been prepared by catalytic hydrogenation of the β,γ-unsaturated lactone derived from 2-ketocyclohexaneacetic acid; M. S. Newman and C. A. VanderWerf, *ibid.*, **67**, 233 (1945).

[5] Stereochemically identical displacements of tosylate have been noted previously; S. Winstein, *et al.*, *ibid.*, **70**, 828 (1948), and earlier papers; G. E. McCasland, R. K. Clark, Jr., and H. E. Carter, *ibid.*, **71**, 637 (1949); H. J. Lucas, F. W. Mitchell, Jr., and H. K. Garner, *ibid.*, **72**, 2138 (1950).

[6] Studies with other systems in this Laboratory indicate that the lactonization observed here may well have occurred under the influence of the toluenesulfonyl chloride rather than during the isolation of products; J. H. Brewster and C. J. Ciotti, unpublished work.

[7] This difference would not, at first sight, be expected if the cyclohexane ring has a chair structure. S. J. Angyal and J. A. Mills, *Rev. Pure Appl. Chem.* (*Australia*), **2**, 185 (1952), have pointed out that a cyclohexane ring with a *trans*-fused five-membered ring is twisted so that 1,3-interactions of axial hydrogen atoms are increased; these interactions are decreased when the five-membered ring is fused *cis*.

ternal nucleophilic displacement by the oxygen atom of the amide group would lead to the pseudo-lactam V.[5,8] It seems unlikely that this process is preceded by N-tosylation since amides appear normally to react with aromatic sulfonyl halides at the oxygen atom.[9] Tosylation of V would be expected to lead to VI.



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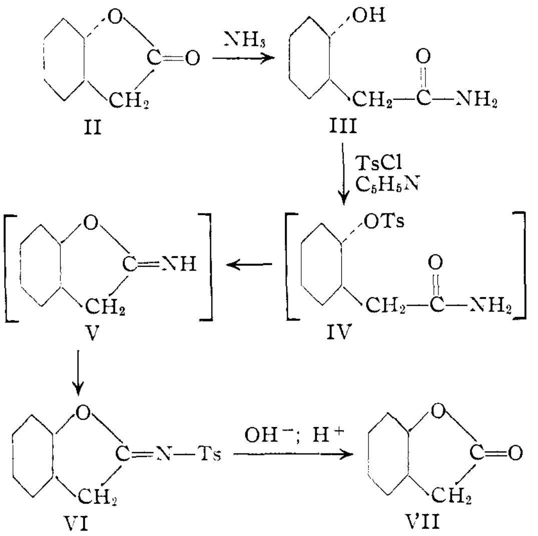

Experimental

The Lactone of *trans*-2-hydroxycyclohexaneacetic acid was prepared in 64% yield from cyclohexene oxide[10] and sodiomalonic ester by the method of Newman and VanderWerf[4] and purified by rectification through a Todd column packed with glass helices; b.p. 126° (8 mm.), n^{20}_D 1.4768, d^{20}_4 1.0868; lit.[4] b.p. 118–119° (6 mm.), n^{20}_D 1.4777, d^{20}_4 1.0860. The cooling curve of this material shows a plateau at 1–2°, lit.[4] −1.2°.

***trans*-2-Hydroxycyclohexaneacetic acid**, m.p. 104–105° (lit.[4] 104–105°), was prepared from the lactone in 90% yield by the method of Newman and VanderWerf.[4]

Attempted Tosylation of *trans*-2-Hydroxycyclohexaneacetic Acid.—Attempts to prepare the toluenesulfonate of the hydroxy acid with toluenesulfonyl chloride in pyridine or in sodium hydroxide following common procedures[11] were unsuccessful. In most cases at least 50% of the hydroxy acid could be recovered unchanged; if the reaction temperature was allowed to reach 80–90°, a small amount of neutral product, identified as the *trans*-lactone by comparison of infrared spectra, was obtained.

***trans*-2-Hydroxycyclohexaneacetamide.**—A solution of 9 g. of the *trans*-lactone in 100 ml. of ethanol was stirred while 200 ml. of concentrated aqueous ammonia was added in 50-ml. portions at 15-minute intervals. The mixture was heated under reflux overnight, the temperature of the reaction mixture rising to 70° as ammonia was driven off. The solution was concentrated at a water-pump until crystals began to form. The mixture was treated with 100 ml. of acetone and concentrated on a steam-cone until crystallization started. Cooling overnight yielded 6.5 g. (72%) of amide, m.p. 149.5–150.5° (lit.[4] 150.5–151.5°). This material previously had been prepared by a sealed tube method.[4]

Reaction of *trans*-2-Hydroxycyclohexaneacetamide with *p*-Toluenesulfonyl Chloride.—Six grams of the *trans*-amide and 120 g. of pyridine was treated slowly with 70 g. of *p*-toluenesulfonyl chloride; the reaction mixture was stirred at room temperature. The solution turned orange-red in color; after several hours crystals of pyridine hydrochloride began to form. After about 12 hr. 200 ml. of ice-water was added *cautiously;* the temperature of the solution rose to about 80°. The solution was cooled, neutralized with cold dilute hydrochloric acid and extracted with benzene. The benzene was evaporated under vacuum and the product was recrystallized from ethanol to yield 7 g. (62%) of product, m.p. 84.5–85.5°.

Anal. Calcd. for $C_{15}H_{19}O_3NS$: C, 61.42; H, 6.53; N, 4.78. Found: C, 61.68; H, 6.22; N, 4.73.

The compound gave a positive qualitative test for sulfur; its infrared spectrum showed bands at 7.48, 8.48 and 8.56μ, consistent with the presence of a sulfonamido group. No bands characteristic of OH, NH, CN, amido or olefinic groups could be discerned.

***cis*-2-Hydroxycyclohexaneacetic Acid Lactone.**—Thirty-six grams of the tosylated amide was dissolved in a minimum amount of ethanol and 200 ml. of 20% aqueous sodium hydroxide was added. The solution was heated under reflux, with stirring, overnight and then cooled and acidified to congo red with dilute hydrochloric acid. The solution was extracted continuously with ether for 72 hr.; the ether was dried and distilled under vacuum. Distillation of the residue gave 13.0 g. (75.5%) of *cis*-lactone, b.p. 108–112° (3 mm.), n^{20}_D 1.4788, d^{20}_4 1.0869; lit.[4] b.p. 112° (6 mm.), n^{20}_D 1.4773, d^{20}_4 1.0923. *Anal.* Calcd. for $C_8H_{12}O_2$: C, 68.54; H, 8.63; *MR*, 36.48. Found: C, 68.68; H, 8.91; *MR*, 36.40.

This product froze when cooled in ice; its melting curve showed a break at 6.8° and a plateau at 11.2°. Newman and VanderWerf[4] report a melting point of 14.8° for a sample of *cis*-lactone prepared by hydrogenation of the corresponding butenolide. The infrared spectrum of the present product showed it to be a γ-lactone (5.70 μ) distinctly different from the *trans* isomer, but gave no clue to the identity of the impurity responsible for the lowered melting point. A small portion of lactone was placed in a capillary tube and immersed in a small test-tube containing Dry Ice. This was centrifuged for 30–40 seconds during which time the Dry Ice evaporated and the lactone melted. The upper portion of the liquid was removed with a capillary pipet. After repeating this procedure three times, the liquid near the bottom of the capillary melted at 13.5–15.0°.

***cis*-2-Hydroxycyclohexaneacetamide.**—A sample of the *cis*-lactone, 2.46 g. (0.0175 mole), was dissolved in 10 ml. of ethanol and covered with 20 ml. of liquid ammonia. Boiling chips were added and the flask was heated in an autoclave at 80–100° at 17 atm. for three days. The autoclave was cooled and the flask removed and cooled in ice to induce crystallization. The product after crystallization from ethanol weighed 1.10 g. (40%), m.p. 120–121°. Yields of 60% were obtained by omitting the ethanol in the ammonolysis.

Anal. Calcd. for $C_8H_{15}O_2N$: C, 61.12; H, 9.62; N, 8.91. Found: C, 61.07; H, 9.65; N, 9.20.

The melting point was depressed by admixture with the *trans*-amide.

***cis*- and *trans*-N-benzyl-2-hydroxycyclohexaneacetamides** were prepared from the lactones by the method of Dermer and King.[12]

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[8] Precedent for this mode of alkylation of amides is found in the observation of S. Gabriel and W. Landsberger, *Ber.*, **31**, 2732 (1898), that *o*-chloromethylbenzamide forms pseudo-phthalimidine (by O-alkylation) when heated in toluene.

[9] See P. Oxley and W. F. Short, *J. Chem. Soc.*, 382 (1947); 1519 (1948); P. Oxley, D. A. Peak and W. F. Short, *ibid.*, 1618 (1948). It seems probable that the facile dehydration of amides to nitriles at low temperatures by means of aromatic sulfonyl halides in pyridine (first noted by these workers) involves a simple elimination reaction of an intermediate O-tosylate. Since the submission of this paper the same mechanism has been proposed by C. R. Stephens, E. J. Bianco and F. J. Pilgrim, THIS JOURNAL, **77**, 1701 (1955). Experimental work in this Laboratory confirms these results; R. M. Knee, M.S. Thesis, Purdue University, 1954; J. H. Brewster, unpublished.

[10] A. E. Osterberg, in H. Gilman and A. H. Blatt, "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1941, p. 185.

[11] See, for example, A. T. Roos, H. Gilman and N. J. Beaber, in H. Gilman, "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1941, p. 145.

[12] O. C. Dermer and J. King, *J. Org. Chem.*, **8**, 168 (1943).

trans-N-Benzylamide, m.p. 141–142°. *Anal.* Calcd. for $C_{15}H_{21}O_2N$: C, 72.84; H, 8.56; N, 5.66. Found: C, 73.20; H, 8.69; N, 5.84.

cis-N-Benzylamide, m.p. 97–98°. Found: C, 72.60; H, 8.80; N, 5.75.

Acknowledgments.—Microanalyses were performed by Dr. Ching S. Yeh and Mrs. Jean Fortney. The infrared spectra were obtained with the generous assistance of Dr. C. A. Ward, Mrs. LaVerne Walsh and Mr. P. A. Kinsey.

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[CONTRIBUTION FROM NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

Stereoisomeric Vinyllithium Compounds. III. Reactions with Aldehydes, Ketones and Methyl Iodide[1]

BY DAVID Y. CURTIN, HARRY W. JOHNSON, JR.,[2] AND EDWIN G. STEINER

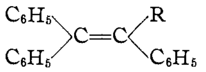
RECEIVED MARCH 19, 1955

The vinyllithium reagents prepared from *cis*- and *trans*-1-bromo-2-(*p*-chlorophenyl)-1,2-diphenylethylene have been shown to react with formaldehyde, benzophenone and methyl iodide to yield the corresponding primary alcohol, tertiary alcohol and methyl-substituted olefin, respectively, in good yield and with a high degree of over-all stereospecificity. Configurations assigned by relating the products of the formaldehyde and methyl iodide reactions to each other and to the known *cis*- and *trans*-3-(*p*-chlorophenyl)-2,3-diphenylacrylic acids show that configuration is retained in each case. Attempts to prepare tetraarylethylenes by treating triphenylvinyllithium with phenyldiazonium ion or diphenyliodonium ion were unsuccessful.

It was shown by Curtin and Harris[3] that *cis*- and *trans*-1-bromo-2-(*p*-chlorophenyl)-1,2-diphenylethylene (*cis*- and *trans*-I) could be converted to the corresponding *cis*- and *trans*-vinyllithium compounds with a high degree of stereospecificity. These vinyllithium derivatives were shown to undergo stereospecific reactions with methanol to give the corresponding *cis*- and *trans*-olefins and with carbon dioxide to give the corresponding *cis*- and *trans*-acids. It was the purpose of the present research to extend the study of the reactions of these isomeric lithium compounds.

It was of interest, first, to make a brief survey of the reactions of vinyllithium compounds with a number of substances. For this purpose triphenylvinyllithium was employed. This reagent was treated with formaldehyde, benzophenone, benzaldehyde, benzoyl chloride, ethyl benzoate and methyl iodide to give the products listed in Table I in the yields shown. Attempts to carry out replacement of the lithium atom by an aryl group using either phenyldiazonium ion[4] or diphenyliodonium ion[5] were unsuccessful.

TABLE I



PRODUCTS FROM REACTION OF TRIPHENYLVINYLLITHIUM

Reagent	Product R =	Lit. ref. to product	Yield, %
CH_2O	$-CH_2OH$	7	77
$(C_6H_5)_2CO$	$-COH(C_6H_5)_2$	7	61
C_6H_5CHO	$-CHOHC_6H_5$	8	65[9]
C_6H_5COCl	$-COC_6H_5$	10	52
$C_6H_5COOC_2H_5$	$-COC_6H_6$	10	71
CH_3I	$-CH_3$	11	40
$C_6H_5N_2{}^+Cl^-$	....	..	0
$(C_6H_5)_2I^+I^-$	....	..	0

Although the configuration of the vinyl bromide *cis*-I had been established by the dipole moment study of Bergmann,[6] he had concluded from the dipole moments that the *trans* isomer was not pure but contained as much as 50% of the *cis* isomer.[6] Since this latter conclusion was not in agreement with the work of Curtin and Harris, samples of the vinyl bromides (*cis*- and *trans*-I) were re-examined by Dr. Max Rogers who found the dipole moments to be those expected of the pure *cis* and pure *trans* isomers, respectively.[12]

When the *cis*-vinyl bromide (*cis*-I) was converted by means of butyllithium to the corresponding lithium derivative and the latter treated with formaldehyde, a single alcohol, here assigned the structure *cis*-3-(*p*-chlorophenyl)-2,3-diphenylallyl alcohol (*cis*-II), was obtained. Similar treatment of *trans*-I yielded the secondary isomeric alcohol, *trans*-II. The configurational assignments of the alcohols, *cis*- and *trans*-II, were based on the fact that the alcohol obtained from the methyl ester (*cis*-III) of 3-(*p*-chlorophenyl)-2,3-diphenylacrylic acid[3] by treatment with lithium aluminum hydride was identical with *cis*-II, while the alcohol from the ester (*trans*-III) was identical with *trans*-II.

When the lithium compound prepared from the bromide (*cis*-I) was treated with methyl iodide a single olefin, *cis*-1-*p*-chlorophenyl-1,2-diphenylpro-

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(1) Taken in part from the Ph.D. Thesis submitted to the University of Illinois by Edwin C. Steiner.

(2) National Science Foundation Fellow, 1953–1954. The authors are indebted to E. I. du Pont de Nemours and Co., Inc., for a Grant-in-aid which supported part of this work.

(3) D. Y. Curtin and E. E. Harris, THIS JOURNAL, **73**, 2716, 4519 (1951).

(4) Compare R. Oda and K. Nakano, *Repts. Inst. Chem. Research Kyoto Univer.*, **19**, 91 (1949) [*C. A.*, **45**, 7543 (1951)].

(5) F. M. Beringer, M. Drexler, E. M. Gindler and C. C. Lumpkin, THIS JOURNAL, **75**, 2708 (1953).

(6) E. Bergmann, *J. Chem. Soc.*, 402 (1936).

(7) C. F. Koelsch, THIS JOURNAL, **54**, 2045 (1932).

(8) C. F. Koelsch, *ibid.*, **54**, 3384 (1932).

(9) Isolated as the ring-closed product, 1,2,3-triphenylindene.

(10) E. P. Kohler and E. M. Nygaard, THIS JOURNAL, **52**, 4128 (1930).

(11) W. Schlenk and E. Bergmann, *Ann.*, **463**, 45 (1928).

(12) We are indebted to Dr. Rogers for communicating these results to us.