In any given solvent–catalyst system no effect on the styrene content was observed by varying the monomer:solvent volume ratio (M:S) between 1:1 and 1:5. Also in the *n*-BuLi systems no effect was produced by varying the catalyst concentration between 0.6 and 2.0 mg./ml. or between catalyst: monomer mole ratios of 1:1000 and 1:100.

In an effort to detect a tendency to form blocks of one monomer type in a given chain, traces of one particular kind of monomer were initiated by *n*-BuLi prior to the addition of the gross comonomer–solvent mixture. No significant differences in the copolymer compositions were found by varying the initiating monomer from styrene to isoprene.

In assessing the effect of a solvent on its ability to ionize the $(\sim C^-Li^+)$ ion pair, such factors as complexing ability, dielectric constant, and base or acid strength should be taken into account. The results are too meager to give a quantitative account at this point. Similar considerations have also been suggested for cationic copolymerizations.[19]

Although electrical effects, such as the degree of ionization, appear to play a very important role, we cannot rule out the possible influence of steric factors. Monomer molecules could, for example, be oriented by interaction with associated organometallic species of the type $(RLi)_n$ before adding to the growing chain. These association complexes may possibly act like tiny "surfaces," even though the solutions appear clear.[6,20] The existence of such association complexes is well known; for example, *n*-butyllithium is known to be associated to degrees of 5 and 7 in diethyl ether and benzene, respectively.[21] Other specific structures of the transition complex between propagating ion pair and adding monomer, such as ring structures, may also affect the copolymer composition.

PRINCETON, N. J.

---

[19] R. E. Florin, THIS JOURNAL, **73**, 4168 (1951).

[20] G. Natta, International Meeting on Chemistry of Coördination Compounds, Rome, Sept., 1957.

[21] G. Wittig, F. J. Meyer and G. Lange, *Ann.*, **571**, 167 (1951).

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF COLORADO]

Mechanisms of Elimination Reactions. XX. Reactions of 2-Bromocyclohexanols and Derivatives with Zinc[1]

BY STANLEY J. CRISTOL AND LEO E. RADEMACHER

RECEIVED AUGUST 25, 1958

Relative rates of reaction of the *cis* and *trans* isomers of 2-bromocyclohexanol, 2-bromocyclohexyl acetate and 2-bromocyclohexyl *p*-toluenesulfonate in absolute ethanol with zinc–copper couple have been determined. A significant difference in reactivity between isomeric pairs exists only in the case of the *p*-toluenesulfonates, the *trans* isomer reacting about 10 times as fast as the *cis* isomer.

Several reports[2] during the past few years have indicated that reactions of 1,2-bromohydrins and simple derivatives with zinc can be used to introduce double bonds into cyclic compounds regardless of whether the groups are in the *cis* or *trans* position. While no detailed study of the relative rates of reaction of stereoisomeric pairs has been reported, reaction conditions were usually quite similar. Since it was known that elimination reactions of 1,2-dibromides show a strong tendency to take the *trans* course,[3] it seemed likely that some difference in reactivity might be found in the case of *cis*- and *trans*-1,2-bromohydrins and simple derivatives thereof. We therefore undertook a study of eliminations from these compounds with zinc–copper couple and with iodide ion. The iodide-ion promoted elimination studies have been reported previously.[4] Since the completion of this work, House and Ro[5] have reported data which indicate a complete lack of preference for either the *cis* or *trans* elimination route in certain acyclic *β*-bromoalkyl acetates and methyl ethers.

We have determined the relative rates of reaction of *cis* and *trans*. isomers of 2-bromocyclohexanol (I), 2-bromocyclohexyl acetate (II) and 2-bromocyclohexyl *p*-toluenesulfonate (III) with zinc–copper couple by refluxing solutions of the compounds in absolute ethanol or glacial acetic acid over granular, copper-sulfate-treated zinc for various lengths of time and then determining the yields of cyclohexene and bromide ions. The results are summarized in Table I.

Also, large samples of *cis*- and *trans*-2-bromocyclohexanol were heated at reflux in ethanol over zinc–copper for 81 hours after which the organic products were separated by ether extraction, fractionally distilled, and converted to suitable derivatives. From the *cis* compound we isolated 8% cyclohexanol, 1% *trans*-2-ethoxycyclohexanol and 39% cyclohexene. From the *trans* isomer we obtained 11% *trans*-2-ethoxycyclohexanol and 46% cyclohexene, but were unable to detect any cyclohexanol. In both cases there were small amounts of tars which could not be distilled without decomposition.

---

[1] Previous paper in series: S. J. Cristol and R. P. Arganbright, THIS JOURNAL, **79**, 3441 (1957). This work was reported at the Fourteenth National Organic Symposium, Lafayette, Ind., in June, 1955.

[2] See for example: (a) L. F. Fieser and R. Ettorre, *ibid.*, **75**, 1700 (1953); (b) D. R. James, R. W. Rees and C. W. Shoppee, *J. Chem. Soc.*, 1370 (1955); (c) L. Crombie and S. H. Harper, *ibid.*, 1705, 1715 (1950); (d) L. Crombie, J. Gold, S. H. Harper and B. J. Stokes, *ibid.*, 136 (1956).

[3] (a) W. G. Young, Z. Jasaitis and L. Levanas, THIS JOURNAL, **59**, 403 (1937); (b) W. G. Young, S. J. Cristol and T. S. Skei, *ibid.*, **65**, 2099 (1943).

[4] S. J. Cristol, J. Q. Weber and M. C. Brindell, *ibid.*, **78**, 598 (1956).

[5] H. O. House and R. S. Ro, *ibid.*, **80**, 182 (1958).

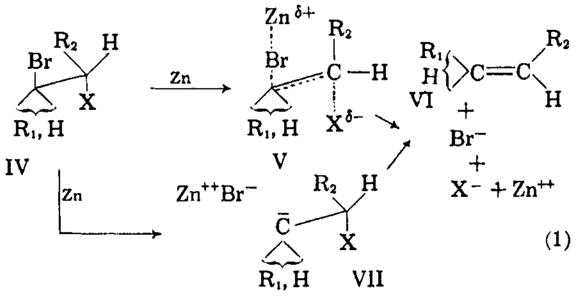
TABLE I

RESULTS OF ZINC–COPPER PROMOTED ELIMINATION REACTIONS OF 2-BROMOCYCLOHEXANOLS AND DERIVATIVES

Compound	Solvent	Reaction time hr.	% yield Olefin	% yield Br^-
trans-I	EtOH	23	16	40
	EtOH	80	21	75
	EtOH	108	23	82
	AcOH	4.5	7	23
cis-I	EtOH	23	15	49
	EtOH	81	29	84
	EtOH	108	22	84
	AcOH	4.5	4	39
trans-II	EtOH	1	2.2	3.8
	EtOH	24	46	65
	EtOH	48	55	86
cis-II	EtOH	24	35	57
	EtOH	48	44	75
trans-III	EtOH	0.5	57	56
	EtOH	1.0	70	94
cis-III	EtOH	2.5	26	40
	EtOH	10	73	85
trans-I	EtOH (no zinc)	48	0.1	..

From these data one may see that the rates of bromide-ion production are essentially equal for the *cis*- and *trans*-bromohydrins and their acetates but that a significant preference for *trans* elimination is apparent in the case of the *p*-toluenesulfonates.

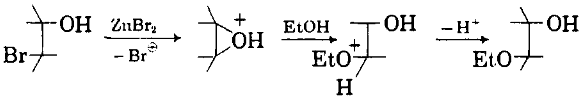
Other investigators have found that elimination reactions of this type show a strong tendency to take the *trans* course when the leaving group X^- (Eq. 1) is the anion of a strong acid, but when X^- is the anion of a weak acid this tendency disappears. For example, Young and his co-workers[8] found that elimination of bromine from compounds IV, where X = Br, R_1 and R_2 = alkyl groups, gave almost exclusively olefins arising from *trans* elimination. This preference can be explained by assuming that a transition state, V, is involved[4,6] in which the formation of the double bond involves simultaneous removal of the groups X and Br. House and Ro[5] reported, however, that with compounds IV in which X = acetoxy or methoxy and R_1 and R_2 = alkyl or aryl groups, identical olefin mixtures were obtained from either *threo* or *erythro* IV, and they proposed an intermediate such as VII in which the ionic carbon is completely racemized before the double bond is formed.



(1)

By analogy to base-promoted dehydrohalogenations[7] one might expect a difference in mechanisms in these bromohydrin eliminations, *i.e.*, *trans* elimination going by way of a transition state such as V and *cis* by way of an intermediate such as VII, and the nature of the products suggests that such may be the case in part; *i.e.*, appearance of cyclohexanol in the products from the *cis*-bromohydrin, presumably arising *via* extraction by an ionic intermediate of a proton from the solvent, and its apparent absence in the products from the *trans*-bromohydrin would be expected if such a difference in mechanisms were operative. In view of the similarity in rates of *cis* and *trans* eliminations it appears as likely, however, that both go by way of an ionic intermediate such as VII but the carbanion is of much shorter life in the case of *trans* elimination.

The formation of *trans*-2-ethoxycyclohexanol in a much larger amount from the reaction of the *trans*-bromohydrin than from the *cis* isomer probably has no significance with respect to the nature of the transition state or intermediates involved in the elimination reaction since it is possible that it arises from the sequence of reactions



Acknowledgments.—The authors are indebted to the Office of Naval Research for support of this work. L. E. R. also is indebted to the Eastman Kodak Company for a fellowship.

Experimental

Preparation of Materials.—Baker and Adamson reagent-grade, 30-mesh zinc (100 g.) was shaken with 200 ml. of 1% copper sulfate solution, washed with water and then with absolute ethanol, and stored in absolute ethanol. Commercial absolute ethanol and glacial acetic acid were used as received.

trans-**2-Bromocyclohexanol**[8] was recrystallized from petroleum ether at −30°, m.p. 26.5–27.0°. The *cis* isomer[9] was prepared by treating the mixture obtained from aluminum isopropoxide reduction of 2-bromocyclohexanone with alcoholic sodium hydroxide to convert the *trans*-bromohydrin to cyclohexene oxide and then distilling at 2 mm. pressure. The crude *cis*-bromohydrin was recrystallized from Skellysolve F to give white needles, m.p. 29.0–29.5°. The *p*-toluenesulfonates[4] were prepared from *p*-toluenesulfonyl chloride and the appropriate bromohydrin. The acetates, prepared from acetic anhydride and the appropriate bromohydrin, were kindly provided by Mr. J. Q. Weber. The *cis*-acetate is apparently a new compound, b.p. 71–75° (1 mm.), $n^{20}D$ 1.4894.

Anal. Calcd. for $C_8H_{13}BrO_2$: C, 43.15; H, 5.93. Found: C, 43.71; H, 6.28.

Reactions of Compounds with Zinc–Copper Couples.—About 2 mmoles of the compound was dissolved in 20 ml. of absolute ethanol or glacial acetic acid. A volume of zinc–copper–ethanol slurry equal to 1.4 to 1.6 g. of dry metal was added. An efficient reflux condenser capped with aluminum foil was fitted to the reaction flask and the mixture was heated, the ethanol mixtures at reflux, and the acetic acid mixtures at 90°, for the desired time. The flask then was chilled in ice-water, the condenser was rinsed down with a small amount of ethanol or acetic acid and then rearranged for distillation. The mixture was distilled rapidly into a receiver cooled in ice (vacuum was used when the solvent was acetic acid to keep the temperature below 90°) until about 2 ml. of liquid remained in the reaction flask. The olefin in the distillate was determined by adding water, excess standard bromate–bromide solution, and sulfuric acid and then

---

(6) S. Winstein, D. Pressman and W. G. Young, THIS JOURNAL, **61**, 1645 (1939).

(7) See for example; S. J. Cristol, *ibid.*, **69**, 338 (1947); S. J. Cristol, N. L. Hause and J. S, Meek, *ibid.*, **73**, 674 (1951),

(8) S. Winstein and R. E. Buckles, *ibid.*, **64**, 2780 (1942).

(9) R. B. Loftfield, private communication.

titrating the excess bromine.[10] To determine the bromide ion produced in the reaction the residue in the reaction flask was extracted repeatedly with water and dilute nitric acid until the extracts were free of halide ion. The combined extracts then were extracted with ether to remove unreacted starting material, after which the bromide ion content was determined by the Volhard method.

Identification of Products from the Reaction of 2-Bromocyclohexanols.—The general procedure above was followed except that 110 mmoles (19.7 g.) of bromohydrin, 300 ml. of ethanol and 75 g. of zinc-copper were used. After the olefin content of an aliquot (5%) of the reaction mixture had been determined, the remainder was distilled using a Todd column until most of the cyclohexene and ethanol was removed. The column was washed down with ether and the residues were extracted 3 times with ether; the combined extracts were washed with water, dilute nitric acid and sodium bicarbonate solution, and dried with sodium sulfate. Distillation of the ether left, from the *cis*-bromohydrin, 3.14 g. of light brown oil and, from the *trans*-isomer, 2.10 g. of light brown oil. The oil from the *cis*-bromohydrin was distilled and collected in 3 fractions. The first fraction was 0.90 g. of cyclohexanol; b.p. 154–166° at 630 mm., n^{22}D 1.4581 (lit.[11] b.p. 160° at 760 mm.); 3,5-dinitrobenzoate, m.p. 107–110° (lit.[12] 112–113°). A mixture of the 3,5-dinitrobenzoate with authentic material had m.p. 110–112°. The second fraction, 0.38 g., had b.p. 166–184°. The third fraction was 0.10 g. of *trans*-2-ethoxycyclohexanol, b.p. 184–186° (630 mm.), n^{21}D 1.4561 (lit.[13] b.p. 187° (760 mm.), n^{20}D 1.4563); 3,5-dinitrobenzoate, m.p. 83.5–84.5° (lit.[14] m.p. 82–83°). A mixture of the 3,5-dinitrobenzoate with authentic material had m.p. 83–84°. The residue was 1.75 g. of black tarry material which did not distil at 245°.

The oil from the *trans*-bromohydrin was distilled and separated into two fractions, the first boiling at 174–186°, and a second boiling at 184–194° at 630 mm., n^{21}D 1.4561; 3,5-dinitrobenzoate, m.p. 83.5–84.5°, mixed with the 3,5-dinitrobenzoate of *trans*-2-ethoxycyclohexanol, m.p. 82.5–84°. The first fraction gave a 3,5-dinitrobenzoate melting at 72–77°. This was recrystallized twice to give m.p. 80–82.5°, and mixed with the 3,5-dinitrobenzoate of *trans*-2-ethoxycyclohexanol, m.p. 81–83°. The mother liquors from the recrystallizations were combined and evaporated to dryness. The residue was taken up in Skellysolve F which was allowed to evaporate over a two-week period. The resulting crystals, m.p. 72–80°, were examined under a microscope; only one type, long needles, could be seen. Because of the high initial boiling point of the distillate and the above observations on the 3,5-dinitrobenzoate it was concluded that no appreciable amount of cyclohexanol was formed in the reaction.

---

[10] (a) A. W. Francis, *Ind. Eng. Chem.*, **18**, 821 (1926); (b) S. J. Green, *J. Inst. Petroleum*, **27**, 66 (1941).

[11] N. A. Lange, "Handbook of Chemistry," 6th edition, Handbook Publishers, Inc., Sandusky, Ohio, 1946.

[12] T. Reichstein, *Helv. Chim. Acta*, **9**, 799 (1926).

[13] M. Mousseron and R. Granger, *Compt. rend.*, **205**, 327 (1937).

[14] M. Mousseron, R. Jacquier and M. Mousseron-Canet, *ibid.*, **235**, 177 (1952).

BOULDER, COLO.

[CONTRIBUTION FROM THE DANIEL SIEFF RESEARCH INSTITUTE, THE WEIZMANN INSTITUTE OF SCIENCE]

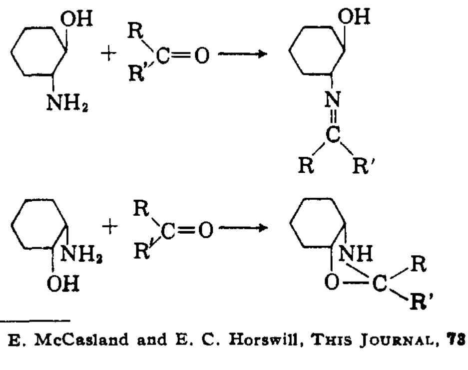
Condensation Products of the Epimeric 2-Aminocyclohexanols with Carbonyl Compounds

BY E. GIL-AV

RECEIVED SEPTEMBER 2, 1958

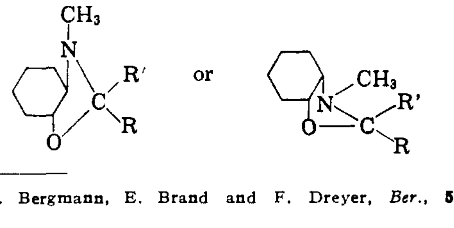
The condensation of the epimeric 2-aminocyclohexanols with certain carbonyl compounds, known to favor the formation of oxazolidines, was investigated. Products, having a correct analysis, could be isolated in three cases. The *trans* epimer forms Schiff bases with both acetophenone and *m*-nitroacetophenone. The *cis* epimer yields with acetone a product which is a mixture of an oxazolidine and a Schiff base.

In the course of studies on epimeric aminocyclanols, McCasland and Horswill[1] examined the possibility of differentiation between the *cis*- and the *trans*-2-aminocyclohexanols on the basis of their reaction with carbonyl compounds. In accordance with the behavior of such pairs of diastereoisomers toward other reagents, they expected to find differences in the nature of the products formed or in the rates of reaction. In particular, they anticipated that, whereas the *trans* compound would tend to form a Schiff base, the *cis* derivative might lead to an oxazolidine



Their experiments with benzaldehyde showed that both epimers give only Schiff bases with similar yields. They further examined the ultraviolet spectrum of the "oxazolidine" of M. Bergmann[2] and found that it is in fact a Schiff base, $CH_2OHCHOHCH_2N{=}CHC_6H_5$.

These findings demonstrated the lack of stability of oxazolidines capable of undergoing isomerization to Schiff bases, and further studies on the condensation of the epimeric aminocyclanols with carbonyl compounds therefore were abandoned. It it also of interest to mention that an attempt was made by the same authors to study the reaction of carbonyl compounds with the diastereoisomeric 2-methylaminocycohexanols which would be expected to lead to oxazolidines of unambiguous structure



---

[1] G. E. McCasland and E. C. Horswill, THIS JOURNAL, **73**, 3923 (1951).

[2] M. Bergmann, E. Brand and F. Dreyer, *Ber.*, **54**, 936 (1921).