perchlorate ion is not nucleophilic, this imine probably reacts almost entirely by SN1 in dilute perchloric acid. 1,2-Iminoethane probably reacts only by SN2. The other imines would react by a combination of SN1 and SN2. The relative rates of these acid-catalyzed hydrations of imines can be accounted for on the basis of a transition from SN1 to SN2 mechanism as in the case of epoxides[24] and the assumption that reaction is predominantly SN2 at a primary carbon atom, a mixture of SN1 and SN2 at a secondary carbon atom and predominantly SN1 at a tertiary carbon atom.

The SN2 rate at a primary carbon atom could well be approximately equal to the combined SN1 and SN2 rates at a secondary carbon atom and definitely slower than the SN1 rate at a tertiary carbon atom. Thus 1,2-imino-2-methylpropane would be the fastest reacting and the others would vary, depending on the different contributions of SN1 and SN2 reactions at secondary carbon atoms.

Although the steric results of the opening of the rings of L(+)-N-ethyl-2,3-iminobutane by ammonia and ethylamine and of L(−)-2,3-iminobutane by ethylamine are in all cases inversions of configurations,[12] an SN1 mechanism even under basic conditions is not ruled out because in the transition state the carbonium carbon atom is shielded by the departing nitrogen atom from attack by a nucleophilic amine molecule on the same side of the carbon atom. Thus inversion of configuration is not incompatible with SN1 mechanism, but on the other hand retention of configuration cannot occur in an SN2 reaction. Actually L(+)-*trans*-N-ethyl-2,3-iminobutane with aqueous ethylamine[12] gave 99.5% *meso*-2,3-bis-(ethylamino)-butane and 0.5% L(+)-2,3-bis-(ethylamino)-butane. The active product mustresultfrom an SN1 reaction, and a frontal attack on a carbonium ion would seem to be the only way in which it could be formed. Here the conditions are quite unfavorable for frontal attack on the carbonium ion, owing to the presence of the two ethyl groups, one on the imine nitrogen, the other on the attacking amine nitrogen atom. The fact that some frontal attack took place points to a significant contribution of SN1 in the weakly basic medium. This would be enhanced under the much more favorable conditions of acid-catalyzed hydration, as in the case of epoxides.[25] Therefore it is reasonable to expect that in acid solution there would be a mixture of SN1 and SN2 reactions at the two secondary carbon atoms of this imine.

(24) C. K. Ingold, "Structure and Mechanism in Organic Chemistry," Cornell University Press, Ithaca, N. Y., 1953, p. 344.

(25) Reference 23, p. 38.

PASADENA, CALIFORNIA

[CONTRIBUTION FROM THE CHEMISTRY DIVISION OF OAK RIDGE NATIONAL LABORATORY]

Molecular Rearrangements. XI. The Deamination of 1,1-Diphenyl-2-amino-1-propanol[1]

BY BEN M. BENJAMIN, HOWARD J. SCHAEFFER AND CLAIR J. COLLINS

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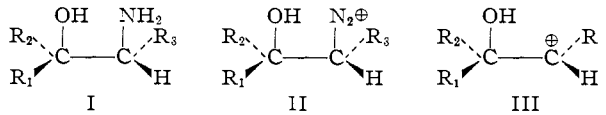
It has been shown that the addition of phenylmagnesium bromide and of *p*-tolylmagnesium bromide to α-aminopropiophenone are 98–99% sterospecific. The rearrangement, in the presence of nitrous acid, of (+)- or (−)-1,1-diphenyl-2-aminopropanol (IV) stereospecifically labeled in only one of the two phenyls, has been shown to produce α-phenylpropiophenone (VII) which has undergone approximately 88% inversion (with 12% retention) at the migration terminus. These results are in agreement with those of McKenzie, Roger and Wills.[4a] The product from the deamination of (+)-IV was resolved into a (−)-fraction [$[\alpha]^{24}D$ −210°] and a very nearly racemic [$[\alpha]^{24}D$ −1.6°] fraction. Degradation of these two fractions followed by radioactivity assay of the degradation products disclosed that migration of the labeled phenyl resulted in inversion to produce (−)-VII, whereas migration of the unlabeled phenyl resulted in retention to produce (+)-VII. The deamination of labeled 2-amino-1,1,2-triphenylethanol also has been studied. The results of the present research are explained in terms of open carbonium ion intermediates whose rotation about the C–C$^+$ bond is restricted and whose phenyl groups migrate solely through *trans*-transition states.

In the rearrangement with nitrous acid of amino alcohols of general structure I, it often has been assumed: (1) that the ion II is first formed, followed



by a one-stage migration of R_1 or R_2; (2) that the rate of rotation about the bond connecting the two central carbon atoms is very fast compared to rearrangement; and (3) that the steric factor, called the "*cis*-effect" by Curtin,[2] "is a function only of the difference in free energy between the two transition states for the rearrangement step and is independent of the relative populations of the conformations of the initial molecule."[3] An alternate possibility involves the formation, from II, of ion III. The relative proportions, then, of products formed will depend upon the populations of the conformations of ion III which will allow migration of R_1 or R_2; this, in turn, will depend upon the rate

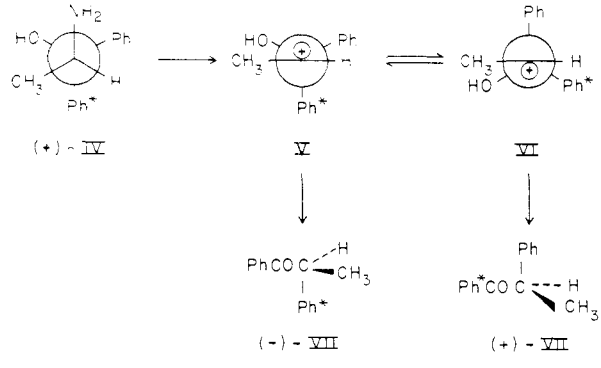
(1) (a) This paper is based upon work performed at Oak Ridge National Laboratory, which is operated by Union Carbide Nuclear Co. for the Atomic Energy Commission. Paper X, W. A. Bonner and C. J. Collins, THIS JOURNAL, **78**, 5587 (1956); (b) portions of this research were presented at the International Conference on Radioisotopes in Scientific Research, Paris, France, Sept. 13, 1957.

(2) P. I. Pollak and D. Y. Curtin, THIS JOURNAL, **72**, 961 (1950); D. Y. Curtin and P. I. Pollak, *ibid.*, **73**, 992 (1951); D. Y. Curtin, E. E. Harris and P. I. Pollak, *ibid.*, **73**, 3453 (1951).

(3) (a) Quoted from D. Y. Curtin and M. C. Crew, *ibid.*, **77**, 355 (1955); (b) W. G. Dauben and K. S. Pitzer, Chapter 1, "Steric Effects in Organic Chemistry," edited by M. S. Newman, John Wiley and Sons, Inc., New York, N. Y., 1956, pp. 11, 44.

of rotation about the central carbon–carbon bond as compared to the rates at which R_1 and R_2 shift to the migration terminus. In the rearrangements of the *erythro* (I, R_1 = anisyl, R_2 = phenyl, R_3 = methyl) and *threo* (I, R_1 = phenyl, R_2 = anisyl, R_3 = methyl) isomers of 1-*p*-anisyl-1-phenyl-2-amino-1-propanol, studied by Curtin and Crew,[3a] the ratios of the two ketones produced (*p*-anisyl phenylethyl ketone to phenyl α-*p*-anisylethyl ketone) were, respectively, 88:12 and 6:94. It appeared to us that there is a striking parallel between these results,[3a] and those obtained by McKenzie and his co-workers[4] in the deamination[5] of optically active 1,1-diphenyl-2-amino-1-propanol (IV), since it was clearly shown[4] by McKenzie that the product consisted of a mixture of the enantiomeric ketones (VII) in the ratio of approximately 88:12.

The stereochemical relationships of (+)- and (−)-IV and (+)- and (−)-VII have been worked out by Bernstein and Whitmore.[4b] If the mechanism[2,3] generally accepted is the correct one for the deamination of IV, then both phenyls must migrate in such a way that the configuration of the migration terminus is *inverted*. The considerable amount of racemization (about 25%) which attends this reaction would then be required to arise through instability of the reactant (IV) or product (VII) to the reaction conditions. Since both product and reactant are presumed[5a] to be unracemized under the conditions of the deamination reaction, however, the approximately 12% of product VII with retained configuration[4a] must arise from the conversion VI → (+)-VII—presuming the reacting amino alcohol IV to have the (+)-configuration as shown in the formulas



This hypothesis has now been tested and found correct by the synthesis of, and subsequent deamination experiments, with, the enantiomorphs of IV labeled with carbon-14 in only one of the two phenyls. Racemic IV was prepared by the addition of phenylmagnesium bromide to the stannic chloride complex salt of 2-aminopropiophenone-*phenyl*-C^{14}. Resolution of IV was accomplished through the *d*-10-camphorsulfonate. The optically pure amino alcohols were deaminated by the procedure of McKenzie, Roger and Wills.[4a] In experiments 1 and 2 the ketonic products produced quantitatively were cleaved with isoamyl nitrite in ethanolic alkali to yield benzoic acid and acetophenone oxime, which were assayed for radioactivity content. In experiment 3 the product was resolved by repeated crystallization from ethanol into a (−)-ketone and into an almost completely racemic fraction. Both of these fractions were cleaved as before to yield the degradation products, benzoic acid and acetophenone oxime which likewise were assayed for radioactivity. The results of all of these experiments are given in Table I.

TABLE I

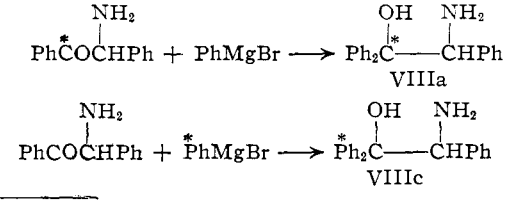
SUMMARY OF DEAMINATION EXPERIMENTS UPON (+)- AND (−)-IV

Expt.	$[\alpha]^{24}D$ of Reactant IV	$[\alpha]^{24}D$ of Product VII	Retention, %	% C^{14} in *PhCOOH[a]	% C^{14} in *PhCOCH$_3$
1	−59.3°	+158.5°	12.5	11.1	89.9
2	−59.3	+158.3	12.5	13.3	89.9
3	+59.3	−161.6	11.5	44.3[b]	53.0[b]
				4.4[c]	98.0[c]

[a] The molar radioactivity of the acetophenone-C^{14} oxime is more reliable than that of the benzoic-C^{14} acid, since during the cleavage of VII, some of the acetophenone fragment is oxidized to benzoic acid. This accounts for the fact that the sum of radioactivity content of the two fractions is usually greater than 100%. The radioactivity assay (expt. 3) of the acetophenone oxime from (−)-VII is proof that the initial Grignard addition to α-aminopropiophenone was at least 98% stereospecific. This high degree of stereospecificity is consistent with the observations of Curtin and Crew (ref. 3) upon similar Grignard addition reactions. [b] From nearly racemic fraction of product, $[\alpha]^{24}D$ −1.6°. [c] From completely resolved fraction of product whose $[\alpha]^{24}D$ −210°.

In order to test the generality of the extremely high degree of stereospecificity (see later discussion) noted in the addition of phenylmagnesium bromide to α-aminopropiophenone-*phenyl*-C^{14}, *p*-tolylmagnesium bromide was added to the stannic chloride complex of α-amino-(propio-1-C^{14})-phenone, and the yields of *erythro*- and *threo*-1-phenyl-1-*p*-tolyl-2-amino-1-propanol-1-C^{14} [6] were determined by the isotope dilution method. In this way it was shown that the product of this reaction consisted almost exclusively of *erythro*-1-phenyl-1-*p*-tolyl-2-amino-1-propanol since there was not more than 1% of the *threo* isomer produced.

Finally, the chain- and ring-labeled isotope-position isomers of 2-amino-1,1,2-triphenylethanol (VIII) were prepared.



(4) (a) A. McKenzie, R. Roger and G. D. Wills, *J. Chem. Soc.*, 779 (1926); (b) H. I. Bernstein and F. C. Whitmore, THIS JOURNAL, **61**, 1324 (1939).

(5) This is a classic reaction which has been widely quoted as evidence for inversion at the migration terminus: (a) C. K. Ingold, "Structure and Mechanism in Organic Chemistry," Cornell University Press, Ithaca, N. Y., 1953, pp. 504–505; (b) D. J. Cram, Chapter 5, "Steric Effects in Organic Chemistry," edited by M. S. Newman, John Wiley and Sons, Inc., New York, N. Y., 1956, p. 253; (c) P. D. Bartlett, "Organic Chemistry," Vol. III, edited by H. Gilman, John Wiley and Sons, Inc., New York, N. Y., 1953, Chapter 1, pp. 59–60.

(6) The terms *erythro* and *threo* have been employed for these compounds in the same sense as that used by Curtin and Crew (ref. 3a, footnote 4).

The amino alcohols VIIIa and VIIIc were then subjected to nitrous acid deamination; and the benzhydryl phenyl ketone products were subjected to degradation procedures.

$$\text{VIIIa} \xrightarrow{HNO_2} \text{PhCOCHPh}_2 \xrightarrow{KMnO_4} \text{PhCOOH} + \underset{\text{IXa}}{\text{Ph}_2\text{C=O}}\ 0.9\%$$

$$\text{VIIIc} \xrightarrow{HNO_2} \text{PhCOCHPh} \xrightarrow{KMnO_4} \text{PhCOOH} + \underset{\text{IXcd}}{\text{Ph}_2\text{C=O}}\ 9.3\%$$

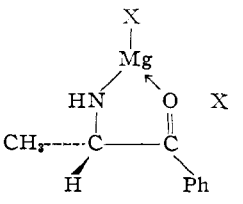
The percentages of the original molar radioactivities of VIIIa and VIIIc are shown under the appropriate benzophenone fractions.

Discussion

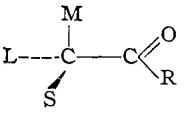
From the foregoing data we conclude: (1) The addition of *p*-tolylmagnesium bromide to the stannic chloride salt of α-amino-(propio-1-C^{14})-phenone is at least 99% stereospecific. This follows from the observation that not more than 0.8% of *threo*-1-phenyl-1-*p*-tolyl-2-amino-1-propanol[6] was formed during this reaction, whereas the *erythro* isomer was produced in 70% yield.

(2) The addition of phenylmagnesium bromide to the stannic chloride salt of α-aminopropiophenone-*phenyl*-C^{14} is at least 98% stereospecific. This follows from our results upon the deamination of (+)-IV to (−)-VII and (+)-VII (see Table I). The (−)-α-phenylpropiophenone (VII) from this reaction was shown to have 98% of its radioactivity in the α-phenyl group, thus demonstrating stereospecificity during the Grignard reaction to the extent of 98%. It follows also from this observation that neither the reactant (+)-VI, nor the products (+)- or (−)-VII is racemized significantly under the conditions of the deamination reaction, for to the extent that such racemization takes place, there should be an interchange of the labeled and unlabeled phenyls; such an exchange would result in an equal distribution of radioactivity in the two phenyls of (+)- or (−)-VII.

(3) The high degree of stereospecificity exhibited during these two Grignard additions undoubtedly arises through an intermediate such as X, in which



the preferred side of attack is that by which the Grignard reagent is flanked by hydrogen and phenyl, rather than by methyl and phenyl.[7] The intermediate X, possessing a five-membered ring, might be expected to provide a much higher degree of asymmetric induction than is found in most stereospecific syntheses; for example, in cases not involving the rigid geometry of X, it has been postulated[7] that the reagent attacks the molecule (*e.g.*, XI) preferentially from such a direction as to



XI

be flanked by the medium (M) and small (S) groups. Because the conformation of the molecule (XI) being attacked is not rigidly fixed, however, as it is in intermediate X, the carbonyl group may not always be exposed between the M and S flanks and thus can suffer attack sometimes between the L (large) and S, or even between the L and M groups. The difference in degree of stereospecificity, then, exhibited by X and XI may be summed up by the statement that in the case of the intermediate X, the environment adjusts to the intermediate, whereas in the case of molecules such as XI the molecule must adjust to the environment.[8]

(4) During the deamination of (+)-IV, Ph (labeled) migrates nearly exclusively to yield product of *inverted* (−) configuration whereas Ph (unlabeled) migrates nearly exclusively to yield product of *retained* (+) configuration. *The formation of (+)-VII thus is not the result of the decomposition of intermediate II with a simultaneous migration of Ph since Ph (unlabeled) approaches the migration terminus from the same side as that occupied by the amino group and not, as has been assumed,[3] through a transition state in which methyl and phenyl are in a* cis *configuration.*

(5) Because of the high degree of stereospecificity associated with the additions of phenylmagnesium bromide and *p*-tolylmagnesium bromide to α-aminopropiophenone, it is almost certain that the addition of phenyl-C^{14}-magnesium bromide to α-aminodesoxybenzoin hydrochloride to yield VIIIc proceeds also with 98–100% stereospecificity. In the deamination of VIIIc, therefore, we propose that Ph (unlabeled) migrates to the opposite side of the migration terminus originally bonded to nitrogen, whereas Ph* (labeled) migrates to the same side of the migration terminus originally bonded to nitrogen.

(6) Although these data do not rule out the intervention of ions of general structure II during the deamination of IV, we believe the simplest general explanation of the data of Table I to be one in which (a) ions of type II are unimportant, (b) the open carbonium ions V and VI are formed and (c) the equilibrium V ⇄ VI involving rotation about the central carbon–carbon bond is not extremely fast compared with the rate of phenyl migration. Al-

(7) For previous discussions of similar intermediates see H. S. Moser and E. La Combre, THIS JOURNAL, **72**, 3994, 4991 (1950); W. E. Doering and T. C. Aschner, *ibid.*, **71**, 838 (1949); W. E. Doering and R. W. Young, *ibid.*, **72**, 631 (1950). D. J. Cram and F. A. Abd Elhafez, *ibid.*, **74**, 5833 (1952), have recognized the specific intermediates X and XI. See also V. Prelog, O. Cedar and M. Wilhelm, *Helv. Chim. Acta*, **38**, 303 (1955).

(8) Other work which seems to support stereospecificity of 50:1 to 100:1 when intermediates similar to X can intervene are: (a) A. McKenzie and H. Wren, *J. Chem. Soc.*, **97**, 473 (1910), in which it is reported that only one product was isolated from the addition of methylmagnesium iodide to 1-benzoin; this experience was repeated when racemic benzoin was employed. These authors state "...it was obvious from the yield that the other isomeride could have been present only in small amount or not at all."; (b) the work of Curtin and co-workers (ref. 2, 3a), in which a variety of Grignard additions to α-aminoketones result in the isolation of only one racemic modification of product; and (c) L. H. Welsh, THIS JOURNAL, **71**, 3500 (1949), in which is reported a 70-fold difference in the rates of rearrangement of N-benzoylephedrine and N-benzoyl-ψ-ephedrine.

though the presence of open carbonium ions has been demonstrated previously in the deamination of secondary amines,[9] we believe the present work is the first clear-cut experimental evidence which demands the presence of open carbonium-ion intermediates in the amino alcohol deamination, a reaction which previously had generally been held[2,3] to be concerted.

Acknowledgment.—The authors are pleased to acknowledge the stimulation derived from a discussion of the contents of this manuscript with Professor Cram.

Experimental

Preparation of 1,1-Diphenyl-2-aminopropanol-C^{14} (IV).—Phenyl-labeled propiophenone-C^{14}, prepared by treating phenyl-labeled benzoyl-C^{14} chloride with diethylcadmium, was converted to the isonitroso derivative.[10] The product was reduced with stannous chloride to the stannic chloride complex salt of 2-aminopropiophenone.[11] The dry powdered salt (22.5 g.) was added in small portions to the Grignard reagent prepared from 83 g. of bromobenzene and 12.7 g. of magnesium. After the addition was complete, the mixture was heated at reflux temperature for 1 hr. The Grignard addition product was then hydrolyzed with a solution of ammonium chloride and ammonium hydroxide. The ether was removed by evaporation in a current of air and the remaining solid material was collected on a filter. The organic material was separated from inorganic salts by washing the mass thoroughly with ether. Crude racemic amino alcohol IV was extracted from the ether solution with dilute hydrochloric acid. It was precipitated from the acid solution by careful addition of dilute sodium hydroxide. The crystals (11.5 g.) were collected on a filter, washed with water and dried in vacuum, m.p. 101–102°.

Resolution of 1,1-Diphenyl-2-aminopropanol-C^{14}.—The racemic phenyl-labeled amino alcohol IV (11.2 g.) was mixed with 5 g. of non-radioactive pure (−)-isomer of IV and the mixture was dissolved in 60 ml. of ethanol. To this was added a solution of 17 g. of *d*-10-camphorsulfonic acid in 60 ml. of water. After several hours the *d*-10-camphorsulfonate of the amine precipitated. This was removed by filtration and crystallized twice from alcohol; $[\alpha]^{24}D$ +37.8° (ethanol). The free (−)-amine was obtained by treating the above salt with dilute sodium hydroxide. It was crystallized twice from hexane; m.p. 101.5–102.5°, $[\alpha]^{24}D$ −59.3° (ethanol), 2.601 mc. of carbon-14/mole.

The free amine (9 g.) was recovered from the salts in the crystallization liquors from above and mixed with 5 g. of non-radioactive pure (+)-IV. This was dissolved in 50 ml. of alcohol and was treated with 9.3 g. of *d*-tartaric acid in 25 ml. of water. When the *d*-tartrate salt of IV had precipitated, it was removed by filtration and crystallized twice from alcohol; $[\alpha]^{24}D$ −54.4° (water). The free (+)-amine was recovered as described for the (−)-isomer; m.p. 101.5–102.5°, $[\alpha]^{24}D$ +59.3° (ethanol), 2.691 mc. of carbon-14/mole. A total of 4.5 g. of (−)-isomer and 4 g. of (+)-isomer of IV was recovered after working up the mother liquors. Non-radioactive optically pure IV was prepared by an alternate procedure[4a] starting with pure *l*-alanine purchased from California Foundation for Biochemical Research. The amino alcohol product was purified by repeated crystallization from hexane. The highest rotation obtained was $[\alpha]^{24}D$ −59.6° (ethanol).

Reaction of 1,1-Diphenyl-2-aminopropanol-C^{14} with Nitrous Acid.—The procedure of McKenzie,[4a] *et al.*, was used. Pure (−)-IV (1 g.) was dissolved in 37 ml. of 25% acetic acid, and the solution was cooled to 0°. A solution of 1 g. of sodium nitrite in 5 ml. of water was added dropwise during 15 minutes, and the solution was stirred at 0° for 5 hr. The oily ketone which separated was removed from the solution, after dilution with water, by ether extraction (three 50-ml. portions). The ether extracts were washed with water, sodium carbonate solution, water, and then the ether was evaporated in a current of air. The yield of dried ketone VII was quantitative; $[\alpha]^{24}D$ +158.5° (ethanol). In a second experiment (−)-IV also gave a quantitative yield of ketone, $[\alpha]^{24}D$ +158.3° (ethanol). In a third experiment (+)-IV was deaminated and gave a quantitative yield of ketone, $[\alpha]^{24}D$ −161.6°. This material was resolved by repeated crystallization from alcohol; m.p. 36°, $[\alpha]^{24}D$ −210°, 2.693 mc. of carbon-14/mole. A small sample (*ca.* 0.3 g.) of almost racemic ketone III was recovered from the mother liquors; m.p. 50–51°, $[\alpha]^{24}D$ −1.6°.

Cleavage of 2-Phenylpropiophenone-C^{14} (VII).—To the total product from the deamination of (−)-IV described above was added 6 ml. of absolute alcohol containing 0.2 g. of sodium hydroxide. When the solution was well mixed, 0.6 g. of amyl nitrite was added and the solution was placed in the refrigerator (approximately 0°). After seven days the solution was diluted, neutralized with hydrochloric acid and extracted with ether. The ether was evaporated and the remaining solid material was treated with two 10-ml. portions of sodium bicarbonate solution followed by 5 ml. of water. A gummy material remained in the flask. The combined aqueous solutions were treated with Norite, filtered and neutralized. The precipitated benzoic acid was removed and sublimed; m.p. 122°, 0.289 mc. of carbon-14/mole. Acetophenone oxime was extracted from the gummy material, with five 10-ml. portions of hot water. The hot water was poured through a filter and was cooled in an ice-bath. The precipitate was collected and sublimed at 60°, m.p. 60°, 2.338 mc. of carbon-14/mole. The ketone from the second deamination experiment was cleaved to give benzoic acid, 2.337 mc. of carbon-14/mole; acetophenone oxime, 0.347 mc. of carbon-14/mole.

The resolved ketone ($[\alpha]^{24}D$ −210°) obtained from the product of the third deamination experiment was cleaved to give benzoic acid, 0.1158 mc. of carbon-14/mole; and acetophenone oxime, 2.636 mc. of carbon-14/mole. The racemic ketone was cleaved to give benzoic acid, 1.192 mc. of carbon-14/mole; and acetophenone oxime, 1.425 mc. of carbon-14/mole.

Preparation of *erythro*- and *threo*-1-Phenyl-1-*p*-tolyl-2-aminopropanol.—Procedures very similar to those already described[2] were used for preparing the diastereomeric forms of this amino alcohol. The main difference is that the stannic chloride complex salt of the appropriate amino ketone, instead of the usual amino ketone hydrochloride, was added to a Grignard reagent. The general method of preparation is demonstrated by the procedure for synthesis of the carbon-14 labeled *erythro* compound given in the following section. Both diastereomers were purified by crystallization from hexane followed by sublimation. The *erythro* isomer had a m.p. of 86–87° instead of 73–75° as reported.[2] No hemihydrate was found.

Anal. Calcd. for $C_{16}H_{19}NO$: C, 79.63; H, 7.94. Found: C, 79.56; H, 8.01.

The diacetyl derivative of the *erythro* isomer had a m.p. of 192–193°.

Anal. Calcd. for $C_{20}H_{23}NO_3$: C, 76.29; H, 7.47. Found: C, 76.43; H, 7.46.

(9) (a) W. A. Bonner and C. J. Collins, THIS JOURNAL, **78**, 5590 (1956), have demonstrated open carbonium ion intermediates in the deamination of 1,2,2-triphenylethylamine, a system whose solvolytic reactions also give rise to open carbonium ions. (b) D. J. Cram and J. E. McCarty, *ibid.*, **79**, 2866 (1957), have demonstrated open carbonium ion intermediates in the deamination of 3-phenyl-2-butylamine, a system whose solvolytic reactions are best explained through the intervention of bridged ions. However, the claim of Cram and McCarty that "the neighboring β-substituents must still approach the face of the carbonium ion opposite from that which the nitrogen left..." is not supported by our data. (c) A. Streitwieser and W. D. Schaeffer, *ibid.*, **79**, 2888 (1957), have postulated open carbonium ion intermediates, among others, in the deamination of 1-aminobutane-1-*d*. These authors conceive that the migrating group in such deaminations is engaged in a modified participation and thus undergoes a simultaneous shift as the leaving group is lost from the molecule. Our own data and conclusions are not in agreement with this concept. See particularly A. Streitwieser, *J. Org. Chem.*, **22**, 866 (1957), who assumes a concerted rearrangement during deamination of 1,1-diphenyl-2-aminopropanol (IV). (d) The general possibility that the stereochemistry of the products from ions such as III, V and VI might be controlled by restricted rotation about the central carbon–carbon bond has been mentioned, without experimental evidence, by S. Winstein and E. Grunwald, THIS JOURNAL, **70**, 835 (1948); S. Winstein and B. K. Morse, *ibid.*, **74**, 1134 (1952); S. Winstein and L. L. Ingraham, *ibid.*, **77**, 1739 (1955).

(10) W. H. Hartung and J. G. Munch, THIS JOURNAL, **51**, 2262 (1929).

(11) L. Behr-Bregowski, *Ber.*, **30**, 1515 (1897).

The *erythro*-hydrochloride had a m.p. of 255–256°.

Anal. Calcd. for $C_{10}H_{20}ClNO$: C, 69.17; H, 7.26. Found: C, 69.30; H, 7.25.

The m.p. 100–101° was found for the *threo* isomer after purification by sublimation.

Determination of Yields of *erythro* and *threo* Isomers in the Synthesis of 1-Phenyl-1-*p*-tolyl-2-aminopropanol.—Carbonyl-labeled propiophenone-C^{14}, prepared by the Friedel-Crafts synthesis from propionic-1-C^{14} acid and benzene, was converted through the isonitroso derivative to the stannic chloride complex of 2-aminopropiophenone as described above. After the salt (15.1 g., 0.0502 mole) was dried and finely powdered, it was added in small portions to the Grignard reagent prepared from 85.5 g. of *p*-bromobenzene and 12.2 g. of magnesium. The mixture was heated at reflux temperature for 1 hr. and then hydrolyzed with ammonium chloride solution. The ether layer was removed and the aqueous layer was washed three times with 100-ml. portions of ether. The combined ether extracts were filtered and the ether was removed by evaporation. The organic material was quantitatively transferred to a 250-ml. volumetric flask and diluted to the mark with benzene. Two 50-ml. aliquots were removed with a pipet. From the remaining 150 ml. of benzene solution there was isolated about 5 g. of crude *erythro* compound. This was crystallized three times from hexane and sublimed; m.p. 86–87°, 2.734 mc. of carbon-14 mole.

One 50-ml. aliquot was added to 2.000 g. of pure non-radioactive *erythro* isomer which was then reisolated and crystallized three times from hexane (Norite) and sublimed; m.p. 86–87°, 1.252 mc. of carbon-14/mole. The yield was 70.0%. The other 50-ml. aliquot was added to 2.000 g. of pure non-radioactive *threo* isomer which was then reisolated, crystallized four times from hexane (Norite) and sublimed. To the sublimed *threo* isomer (0.5 g.) was added 30 mg. of pure non-radioactive *erythro* isomer. The mixture of compounds was crystallized twice from hexane and again sublimed; m.p. 100–101°, 0.02615 mc. of carbon-14/mole. The yield of *threo*-1-phenyl-1-*p*-tolyl-2-aminopropanol was therefore 0.8%.

Synthesis of 1,1,2-Triphenyl-2-aminoethanol-C^{14} (VIII).—The chain-labeled amino alcohol VIIIa was synthesized by the action of excess phenylmagnesium bromide on ethyl phenylaminoacetate-1-C^{14} hydrochloride[12]; m.p. 153.5–155°,[13] 2.158 mc. of carbon-14/mole. Phenyl-labeled amino alcohol VIIIc was synthesized by the action of phenyl-C^{14}-magnesium bromide upon aminodesoxybenzoin hydrochloride; m.p. 153–154°, 0.8883 mc. of carbon-14/mole.

Deamination of VIIIa and VIIIc.—The amino alcohol (250 mg.) was dissolved in 20 ml. of 50% aqueous acetic acid, and the solution was cooled in an ice-salt-bath. To this cold solution was added a solution of 179 mg. of sodium nitrite in 3 ml. of water dropwise while stirring over a period of 1 hr. The mixture was allowed to warm to room temperature and stirring was continued overnight. The solid phenyldesoxybenzoin which formed was removed by filtration and was then crystallized from ethanol (68% yield after purification); m.p. 135–136°.[14]

Radiochemical Structure Determination of VIIIa, VIIIc and Their Deamination Products, IXa and IXcd.—The position of carbon-14 in the compounds was demonstrated by oxidation of each compound to benzophenone as described previously.[14] In each case the benzophenone was converted to its 2,4-dinitrophenylhydrazone which was purified by crystallization from dioxane before assaying for carbon-14 content. The radiochemical assay data are given in Table II.

TABLE II

DATA FOR RADIOCHEMICAL STRUCTURE DETERMINATION OF GLYCOLS VIIa AND VIIIc AND THEIR DEAMINATION PRODUCTS, IXa AND IXcd

Compound	Assay mc./mole	Benzophenone 2,4-dinitrophenylhydrazone Assay, mc./mole
VIIIa	2.158	2.131
VIIIc	0.8883	0.9034
IXa	2.158	.0183
IXcd	0.8883	.0826

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[CONTRIBUTION FROM THE LABORATORIES OF THE PITTSBURGH PLATE GLASS CO. AND THE ALDRICH CHEMICAL CO.]

Unsaturated Phenols. IV.[1] Crotylphenols

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Butadiene reacts with phenol in the presence of some Friedel-Crafts catalysts to yield largely a mixture of butenylphenols, with some higher phenols and ethers. *o*- and *p*-crotylphenol have been characterized. A correlation between the acidity functions of acid actalysts and their activity is discussed.

Although the synthesis of compounds related to the tocopherols has prompted studies of the reactions of phenols, specifically hydroquinones, with butadiene,[3] isoprene,[4] 2,3-dimethylbutadiene[4] and phytadiene,[5] the reaction of the simplest phenol with the simplest diene has been described only briefly. A patent[6] has alleged that *p*-crotylphenol is the major component of the monoalkenylphenolic fraction formed in 36% yield in the high temperature reaction of phenol with butadiene catalyzed by solid phosphoric acid.[7] Proell[8] has described the reaction of butadiene with phenol catalyzed by alkanesulfonic acid yielding a mixture of butenylphenols. Claisen[9] had previously described the preparation of chromans from phenol and dienes such as isoprene, and the preparation of pentenylphenols from these reactants under milder conditions has been studied by Pines and Vesely.[10]

The reaction of phenol with 1,3-butadiene at

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