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CONCERNING ASYMMETRIC INDUCTION WITH (−) AND (+) DIISOPINOCAMPHEYLBORANES*

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Abstract—A general scheme for the mode of asymmetric induction with (+)- and (−)-diisopinocampheylboranes in reactions with *cis*-olefins, terminal methylenes, ketones, and aldehydes is presented. It is proposed that the environment of the atom which becomes the new asymmetric center exerts a major influence on the reaction. The rationalization is based on the assumption that a 4-membered transition state[1] will be formed in such a manner that the interactions of the substituents on the developing asymmetric center with certain key groups of the reagents are minimized. The scheme leads to the correct prediction of configuration of the asymmetric products of the reaction. Certain previously reported results of reduction of ketones and aldehydes with diisopinocampheylborane proved incorrect.

AMPLE evidence has been assembled in recent years indicating that hydroboration of olefins results in *cis* addition, and a 4-membered transition state was proposed for the reaction.[1] In considering the asymmetric hydroboration of olefins with (−)- or (+)-diisopinocampheylborane, Brown *et al.* suggested a model for the reagent (Fig. 1).[2] The mechanism of the hydroboration was again assumed to proceed via a 4-membered transition state, and the model was successfully used to predict the configuration of the alcohols obtained from *cis*-olefins, cyclic olefins, and terminal methylenes. The hydroboration of *trans*-olefins, and hindered olefins with the diisopinocampheyl reagents is known to proceed by displacement of α-pinene, and failure of the model to predict the correct configuration of the obtained alcohols is not unexpected.[2c] Nevertheless, it may be noted that in the case of *trans*-olefins, and hindered olefins the model consistently led to the prediction of the opposite configuration.

Since in actuality the tetraisopinocampheyldiboranes are the reactive species, the group of McKenna *et al.* has advanced a rather complex model based on this dimer.[3] The model has been applied to *cis*-olefins, cyclic olefins, and to 1-deutero *cis*-olefins. No attempt was made to interpret the hydroboration of terminal methylenes or carbonyls.

Streitweiser *et al.* have hydroborated *cis*-1D-but-1-ene with (−)-diisopinocamphenylborane and apparently obtained (−)-R-ID_1-butanol.[4] They found it difficult to rationalize the results on the basis of Brown's model, and put forward a modified transition state for the reaction. In their view, the asymmetric hydroboration reactions could be properly interpreted by assuming a 3-membered transition state, formally similar to the π-complexes of olefins.

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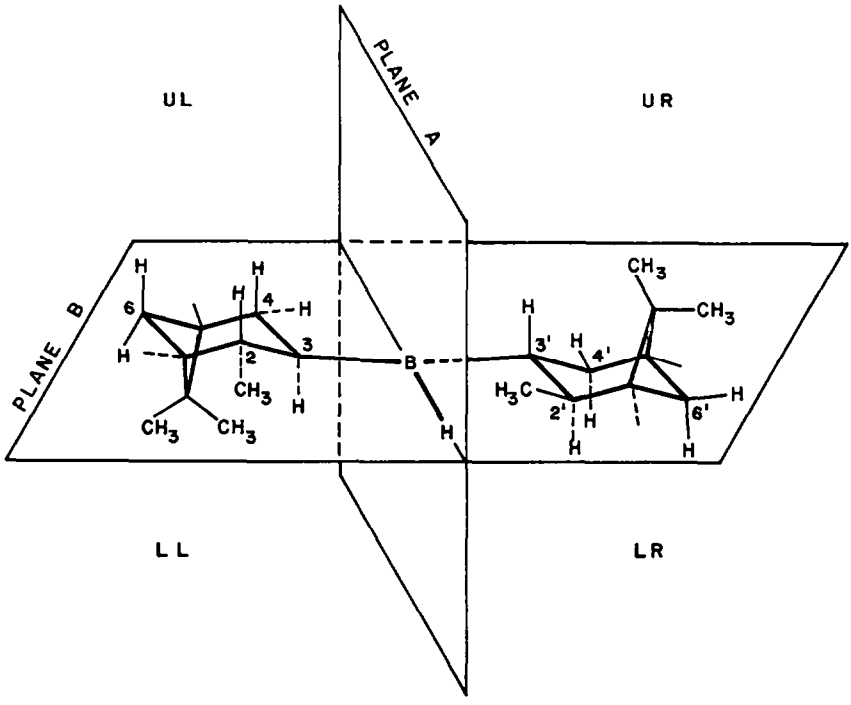


FIG. 1.

It occurred to us that asymmetric hydroborations could be correctly interpreted in a simple manner on the basis of a modified interpretation of the transition state proposed by Brown. The structure and the disposition in space of the various groups of (−)-diisopinocampheylborane (prepared from (+)-α-pinene)[2a] is given in Fig. 1. The B—H bond in Fig. 1 is drawn to lie at the intersection of the perpendicular Planes A and B, and the C-3—B—C-3′ bonds are drawn to lie in Plane B. In this presentation the Me group at C-2 is located in the lower left (LL) quadrant while that

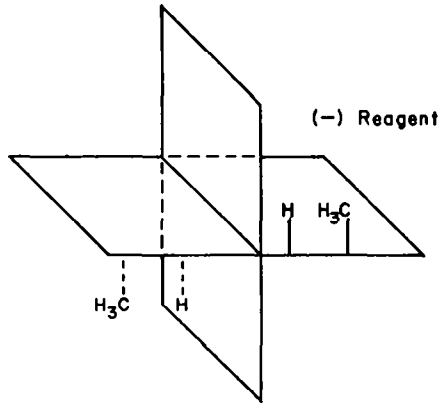
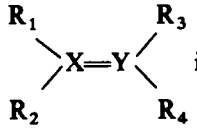


FIG. 2.

at C-2′ in the upper right (UR) quadrant. The protons at C-3 and C-3′ are also located in the LL and UR quadrants respectively. On the other hand, the C_4 methylene protons are in the UL, and those at C-4′ in the LR quadrant. A schematic disposition of the C-2 and C-3 groups as viewed from the front of the page toward Plane B is given in Fig. 2.

In principle, asymmetric hydroboration reactions involve systems of the type



in which either one or both atoms X and Y may become asymmetric centers. For cases when X and Y become asymmetric, determination of the configuration at one of the centers, allows the deduction of that at the other. Until now the asymmetric hydroboration of *cis*-olefins,[2a] terminal methylenes,[5] ketones[6] and aldehydes[7] was investigated. For reasons previously given, *trans*-olefins which undergo hydroboration by displacement of α-pinene will not be discussed. *cis*-Olefins can be divided into two types: symmetrically substituted (e.g. $CH_3 \cdot CH = CH \cdot CH_3$)

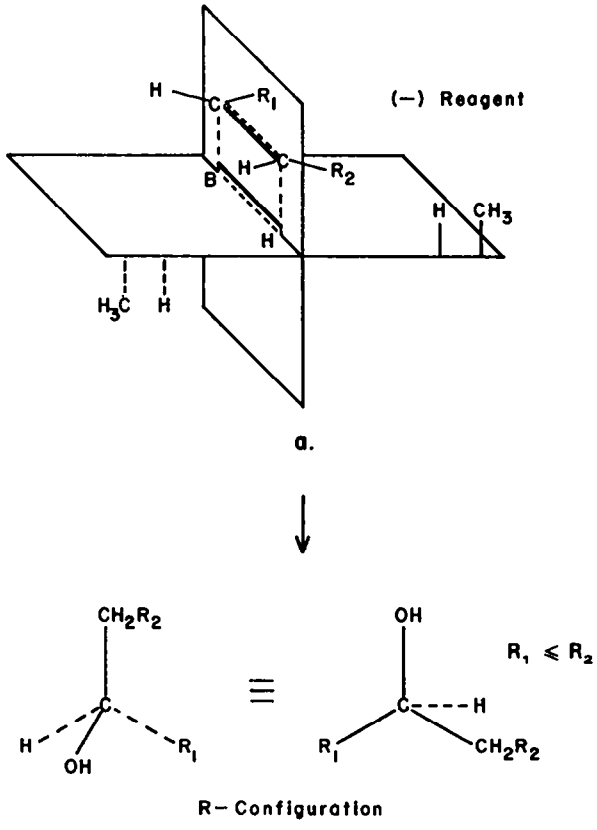


FIG. 3.

and asymmetrically substituted (e.g. $CH_3 \cdot CH = CH \cdot C_2H_5$). We will first consider the reaction of symmetrically substituted *cis*-olefins. The olefin (and for that matter, other substrates) can approach the reagent from the top (UL and UR quadrants) or from the bottom (LL and LR quadrants). Because of the symmetry of the diisopinocampheylborane, the same product will be obtained in either case. For simplicity of presentation, only a top-side approach will be discussed.

Inspection of models (Fig. 1) indicates that the *cis*-olefin ($R_1 \cdot CH = CH \cdot R_2$; $R_1 \leqslant R_2$) could gain access to the (−)-reagent preferably along Plane A as indicated

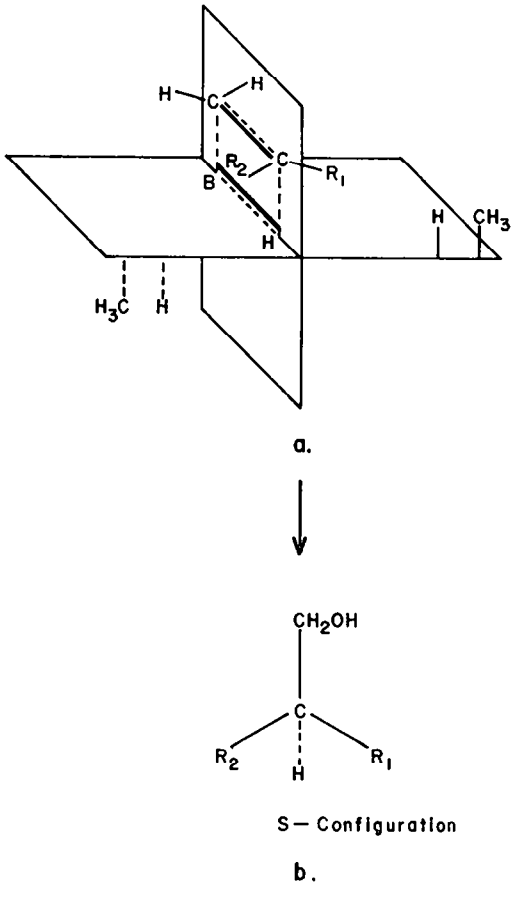


FIG. 4.

in Fig. 3, and form a 4-membered transition state. The reason for such an approach is that the axial C-2 and C-4 protons, and the "syn" C-6 proton, all of which are located in the UL quadrant, would interfere with the large alkyl substituent. The olefin can "slide in" along the B-H axis with the alkyl group oriented towards the C-3′ hydrogen located in the upper-right (UR) quadrant. Of importance in this respect might be the fact that the C-3′ proton, in contrast to the previously mentioned protons of the UL quadrant, is located in the back of the boron atom, and is oriented

away from the B—H bond. Under these circumstances, hydroboration should take place from underneath the olefin, and upon oxidative work-up the *R*-alcohol should be obtained (Fig. 3), as in fact is the case.[2a]

In regard to the nonsymmetrically substituted *cis*-olefins ($R_1 = R_2$), it may be *a priori* assumed that boron addition will preferably take place on the carbon bearing the smaller substituent. Thus for R_1, smaller than R_2, the mode of approach of the olefin can again be presented as in Fig. 3. The resulting alcohol should have the *R*-configuration, and this agrees with experimental results.[2a] In many instances the alternative approach will not be totally suppressed, and some addition of boron to the carbon bearing the larger substituent (R_2) can be anticipated. Probably the relative amounts of the alcohols formed will depend on the differences in the effective sizes of R_1 and R_2.[2a]

Hydroboration of terminal methylenes $R_1 \cdot R_2 \cdot C = CH_2$ ($R_2 > R_1$) will yield primary alcohols of the type $R_1\ R_2 \cdot CH \cdot CH_2\ OH$. The asymmetry in this instance will be decided by the mode of addition of the hydride ion to the carbon bearing the R_1 and R_2 substituents. The predominant discriminatory factor in the formation of the 4-membered transition state will be the magnitude of interaction of the R_1 and R_2 groups with the C-2 proton in UL quadrant and C-2′-methyl in UR quadrant. There is little doubt that the formation of the transition state will be facilitated when the "effectively" larger substituent R_2 of the substrate, and the C-2′-Me of the reagent are located in opposite quadrants. Thus, for the top-side approach, the orientation of the groups in the transition state could be presented as in Fig. 4. This would then result in the addition of the hydride ion from the botton, and formation of the *S*-alcohol, in agreement with experimental observation.[5]

The hydroboration of *cis*-1D-but-1-ene ($C_2H_5 \cdot CH = HCD$) apparently leads to IR-1D_1-butanol.[4] In analogy to previous arguments, this reaction should be "decided" by the environment of the deuterium-bearing carbon, which becomes the asymmetric center, rather than by the environment of the alkyl-bearing carbon. The results of the reaction can be correctly predicted by assuming a mode of approach, and a transition state similar to that described for *cis*-substituted olefins (Fig. 3; R_1 = D). As previously indicated, in such presentation (Fig. 3), it is implied that in the case of a top-side approach, the alkyl (or alkyls) of the *cis*-olefin in the transition state will be located in the UR quadrant.

There remains the question of the hydroboration of ketones and aldehydes. In a formal sense, the hydroboration of ketones ($R_1R_2 \cdot C = O$) should proceed in a manner analogous to that of terminal methylenes ($R_1R_2 \cdot C = CH_2$), and give S-alcohols. The reaction of 3-keto-4-methyl-1-pentanol tetrahydropyranyl ether with (−)- and (+)-diisopinocampheylborane was investigated in our laboratory. As anticipated, the reaction of the ketone with the (−)-reagent gave the (−)-3*S*-alcohol, and with the (+)-reagent the (+)-3*R*-alcohol.[8] The configurations of the alcohols were determined by Horeau's method,[9] and agreed with that made by Büchi *et al.*[10] for the corresponding (−)-1,3-diol which was correlated with L-glyceraldehyde. The *3S-alcohol* was converted to 3*R*-3D_1-1-hydroxy-4-methylpentane-tetrahydropyranyl ether, and the *3R-alcohol* to 3*S*-3D_1-1-hydroxy-4-methylpentane-tetrahydropyranyl ether.[8] The corresponding 3*R*-3D_1, and 3*S*-3D_1 alcohols were then degraded, without disturbing the asymmetry of the deuterium-bearing carbons, to the 1*S*-1D_1- and 1*R*-1D_1-isobutanols respectively.[11] Because of the change of group priorities,

TABLE 1. CONFIGURATIONS AND OPTICAL PURITIES OF THE PREPARED ALCOHOLS

No.	Ketone	Sign of reagent, procedure, solvent	Product, $[\alpha]_D^{25}$ (neat)	Optical purity, %	Configurations		
					Predicted	Proved	% D[d]
1	$C_2H_5-\overset{\overset{O}{\|}}{C}-CH_3$	(+), A, THF[a]	$C_2H_5-\overset{\overset{OH}{\|}}{\underset{\underset{H}{\|}}{C}}-CH_3$ (−) 0·97°	7[c]	R	R (+0·4°)[d]	
2	$(CH_3)_2CH-\overset{\overset{O}{\|}}{C}-CH_3$	(+), B, THF	$(CH_3)_2CH-\overset{\overset{OH}{\|}}{\underset{\underset{H}{\|}}{C}}-CH_3$ (−) 1·07°	20[c]	R	R (+0·89°)[d]	
3	$(CH_3)_3C-\overset{\overset{O}{\|}}{C}-CH_3$	(−), B, THF	$(CH_3)_3C-\overset{\overset{OH}{\|}}{\underset{\underset{H}{\|}}{C}}-CH_3$ (+) 0·95°	12·4[c]	S	S (−1·61°)[d]	
4	$(CH_3)_2CH-\overset{\overset{O}{\|}}{C}-CH_3$	(−), A, DG[b]	$(CH_3)_2CH-\overset{\overset{OH}{\|}}{\underset{\underset{H}{\|}}{C}}-CH_3$ (+) 0·87°	16·3[c]	S	S	
5	$(CH_3)_2CH-\overset{\overset{O}{\|}}{C}-C_2H_5$	(−), B, THF	$(CH_3)_2CH-\overset{\overset{OH}{\|}}{\underset{\underset{H}{\|}}{C}}-C_2H_5$ (−) 6·05°	61·7[e]	S	S (−2·55°)[d]	

6	$(CH_3)_2CH$—CHO	(−) D,[f] A, THF	$(CH_3)_2CH$—C(D)(H)—OH (−) 0·165 ± 0·02°[g]	27·05[h]	R	R	100
7	$(CH_3)_2CH$—CHO	(+) D,[f] A, THF	$(CH_3)_2CH$—C(H)(D)—OH (+) 0·168 ± 0·02°[g]	27·6[h]	S	S	100
8	C_6H_5—CHO	(−) D,[f] A,[i] THF	(C_6H_5)—C(D)(H)—OH (−) 0·095°	6[j]	R	R[j]	91·3 ± 1·9
9	$(CH_3)_2CH$—CDO[k]	(+), A, THF	$(CH_3)_2CH$—C(D)(H)—OH (−) 0·178 ± 0·02°[g]	29·2[h]	R		97·8

[a] Tetrahydrofuran.
[b] Diglyme.
[c] Calculated on the basis of the highest rotation reported; for pertinent literature see Ref. 6.
[d] Established by Horeau's procedure.[9] The specific rotation of the α-phenylbutyric acid is given in parentheses.
[e] Based on $[\alpha]_D^{18}$ −9·8° (neat) reported by P. A. Levene and R. E. Marker, *J. Biol. Chem.* **101**, 413 (1933).
[f] Diisopinocampheyldeuteroborane.
[g] Rotation of neat sample in 1 dm tube.
[h] Based on $[\alpha]_D^{25}$ (+) 0·61° (neat, l = 1 for the (+)S-alcohol.[11])
[i] A transient yellow color developed on addition of each drop of aldehyde.[7]
[j] Based on $[\alpha]_D^{25}$ (+) 1·58° (neat, l = 1) for the optically pure 1*S*-alcohol.[14]
[k] Prepared by the oxidation of isobutanol-1-d_2 with lead tetraacetate in pyridine (Partch, *Tetrahedron Letters* 3071 (1964). The mass spectrum of the 2,4-dinitrophenylhydrazone showed 98·4% of one deuterium. The isobutanol-1-d_2 was prepared by the reduction of neooctylisobutyrate with lithium aluminum deuteride in ether.
[l] By mass spectroscopy.

the configurations of the alcohols are reversed with respect to their precursors.[12] The assignments of the configurations of the 1-D_1-isobutanols were then confirmed by oxidation to isobutyraldehydes[11] with NAD and yeast alcohol dehydrogenase (ADH). The enzymatic oxidation stopped when ca. 40% of the alcohol was utilized. The NAD-yeast alcohol dehydrogenase oxidation is known to proceed with the loss of the pro-*R* proton.[13] It would therefore be anticipated that the 1*S*-1D_1-alcohol would yield a C-1 deuterated aldehyde, while the 1*R*-1D_1-alcohol would yield a protiated aldehyde. However, since the alcohols *were not optically pure*, and because of the operation of isotope effects, allowances for these factors had to be made. The actual results were as expected, and the oxidation of the 1*S*-1D_1-alcohol proceeded essentially without loss of deuterium, while the oxidation of the 1*R*-1D_1-alcohol proceeded with considerable loss of deuterium. In summary, the configurational assignments of the 3*R*-and the 3*S*-1,3-dihydroxy-4-methylpentane-1-tetrahydropyranyl ethers seem firmly established. The configurations conform with our predictions of the mode of reaction of the asymmetric diisopinocampheylboranes with ketones.

The outlined interpretation of the reduction of ketones leading to the correct configurational assignment of the resulting alcohols was in direct contradiction to the results of Brown and Bigley.[6] These authors claimed that reduction of ketones of the type $RCO \cdot CH_3$ (R = C_2H_5, iso-C_3H_7 and t-C_4H_9) with (−)-*diisopinocampheylborane gave R*-alcohols. We repeated the experiments of Brown and Bigley, and we have obtained from the reduction of $C_2H_5\ CO \cdot CH_3$ and $(CH_3)_2\ CH \cdot CO \cdot CH_3$ with (+)-*diisopinocampheylborane* (from (−)-α-pinene) the *R and not the S alcohol.* (Table 1) When the reduction of ketones $(CH_3)_3\ C \cdot COCH_3$, $(CH_3)_2\ CH \cdot CO \cdot CH_3$, and $(CH_3)_2 \cdot CHCO \cdot C_2H_5$ was carried out with (−)-*diisopinocampheylborane* (from (+)-α-pinene), *the S alcohols* were obtained (Table 1).

To minimize the dissociation of the reagents, all experiments, except one, were carried out at 0–3° (ice bath temp) in the presence of a 10% excess of α-pinene. The reaction with pinacolone (Table 1, entry 3) proceeded very slowly, and was first kept for the usual length of time at ice bath temperature, and then was stored for 12 hr at ambient temperature. Some evolution of hydrogen was observed at the termination of the reactions. In addition GLC analysis for excess ketone indicated a greater consumption of the ketones than was expected from the amount of the evolved hydrogen. This suggests that in spite of the precautions some displacement[2c] of α-pinene from the reagent did occur. However, judging from the results there is little doubt that the main course of events was the direct reaction of the reagents with the substrates.

It is apparent that our results are consistent within themselves, but opposite to those of Prof. Brown *et al.* We have communicated our observations to Prof. Brown, and the reason for this discrepancy is being investigated.

It was previously pointed out that straight-chain aliphatic *S*-alcohols, irrespective of the position of the hydroxyl, show positive rotation.[12] The 2*S*-hydroxy-1-methyl butane and 2*S*-hydroxy-1-dimethyl butane described here have positive rotations and appear to conform to the above rule (Table 1). In contrast, the 3*S*-hydroxy-2-methyl pentane has a negative rotation, and does not conform with the generalization about the optical activity of alcohols.

Reduction of aldehydes is analogous to that of ketones, and obviously the hydrogen is the smaller substituent. Thus reduction of aldehydes with (−)-diisopinocampheyl-

deuteroborane will result in 1*R*-1D_1-alcohols. Alternatively, reduction of 1D-aldehyde with the (−)-reagent will produce the 1*S*-1D_1-alcohol. In fact the reduction of isobutyraldehyde with (+)- and (−)-diisopinocampheyldeuteroborane gave (+)-1*S*-1D_1-isobutanol and (−)-1*R*-1D_1-isobutanol respectively. Furthermore reduction of 1D-isobutyraldehyde with the (+) reagent gave the (−)-alcohol (Table 1). Authentic optically pure (+)-1*S*-1D_1-isobutanol ((80% 1D_1; α_D^{25} +0·49°; (neat, 1 = 1)) was prepared by reduction of 1D-isobutyraldehyde with fermenting yeasts[11, 14] In addition, the respective alcohols were oxidized to isobutyraldehydes with NAD and yeast alcohol dehydrogenase. Here again, oxidation of the (+)-1*S*-1D_1 isobutanol proceeded with retention of the isotopic hydrogen while the oxidation of the (−)-1*R*-1S-isobutanol proceeded with a great loss of deuterium. Hence the configurations of the (+)-1*S*, and (−)-1*R*-1D_1 isobutanols are firmly established, and are in full agreement with our predictions on the mode of reduction of aldehydes with diisopinocampheylboranes.

It was recently reported[7] that reduction of benzaldehyde with (−)-diisopinocampheyldeuteroborane gave (+)-1*S*-1D_1-benzylalcohol in "agreement with Brown's predictions". If correct, this result would be in contradiction to our anticipated formation of the 1*R*-1D_1-benzyl alcohol. We have therefore repeated the reduction of benzaldehyde with the (−)-diisopinocampheyldeuteroborane and purified the product by distillation, then preparative GLC on SE-30 column (Experimental), and finally again by distillation. The resulting 1D_1-benzylalcohol was pure when analyzed by GLC on an 8 ft column of 10% Carbowax 20 M on chromosorb at 130° and showed $[\alpha]_D^{25}$ (−)-0·095° (neat) and not $[\alpha]_D^{22}$ (+)-0·33° (*c*, 10 in chloroform) as reported previously. The mass spectrum showed 91·3 ± 1·9% of one deuterium. Since the 1*S*-1D_1-alcohol prepared by yeast reduction of 1D-benzaldehyde[14] had an $[\alpha]_D^{24}$ (+)1·58 (neat), it follows that the product has the I*R* configuration.

EXPERIMENTAL

The tetrahydrofuran, diglyme and borontrifluoride etherate were purified as previously described.[15] The α-pinenes used in this investigation were 98% pure and showed $[\alpha]_D^{25}$ (−)46·0° and (+)46·2° (neat, 1 = 1) corresponding to 91·0 and 91·4% optical purities respectively. The $NaBH_4$ (>98% pure) was purchased from Fisher Scientific Company and the $NaBD_4$ from Metal Hybrides Inc., Beverly, Mass. The soln of diborane in THF was prepared as before.[15] Commerical samples of ketones, and of benzaldehyde (min 98% pure by GLC) were used. Preparative GLC was carried out at 100–160° on an F & M Model 720 Instrument using a 2·5 m column (6 mm i.d.) of 20% TCEP or 5% SE-30 on chromosorb; helium was used as the carrier gas. The optical rotations were measured using a Hilger Mk-III polarimeter.

Procedures for the reduction of ketones

Procedure A. A 100 ml round-bottomed flask equipped with a side-arm capped with a rubber septum, and a magnetic stirring bar was flamed in a flow of dry N_2 and cooled. $NaBH_4$ (37·5 mmole, 1·43 g), or $NaBD_4$ (1·57 g), α-pinene (110 mmole, 14·96 g), purified diglyme (70 ml) *or* THF (80 ml) were placed in the flask and cooled to 0°. To the stirred mixture, purified BF_3-etherate (50 mmole, 6·3 ml) was added from a hypodermic syringe during 15 min, and the mixture was stirred at 0–3° for 5–6 hr. The ketone (50 mmole) was then added from a hypodermic syringe during 15 min, and stirring was continued for 17–22 hr at 0–3°. In the case of methyl-t-butyl ketone, the reaction time was extended for an additional 12 hr at room temp. The excess hydride was decomposed with water, and the generated H_2 was measured. Judging from the volume of H_2, the reductions were respectively 72, 77, and 90% complete for methyl-t-butyl, ethyl-isopropyl, and methylisopropyl ketones. However GLC analysis of the worked-up mixtures indicated the presence of 6·6, 4·9 and 3·5 mmoles of ketone respectively. To the organoborane 3N NaOH (20 ml), and 30% H_2O_2 (20 ml) were added in this order, and the reaction was stirred at 40° for 1·5 hr.

In experiments where diglyme was used as solvent, the reaction mixture was extracted with ether (4 × 40 ml), the extract was washed once with a cold dil NaCl aq, and dried over $MgSO_4$. The ether was removed by distillation through a 90 cm packed column, the residual liquid was distilled at atm press. The fraction corresponding to the alcohol was collected and purified twice by GLC and distilled.

When THF was used as solvent, the THF was separated, and the aqueous soln was extracted several times with small amounts of ether. The THF and ether solns were combined, washed twice with a sat NaCl aq, and dried over Na_2SO_4. Most of the solvent was then removed by distillation through a 90 cm packed column, and the residual material was distilled through a 15 cm packed column at atm press. The fraction corresponding to the alcohol was collected, and purified twice by preparative GLC. The product from benzaldehyde reduction was distilled and the fraction b.p. 93–98°/10–12 mm containing 1-D_1-benzyl alcohol and isopinocampheol was purified by preparative GLC.

Procedure B. The apparatus was the same as used in Procedure A. The flask was cooled in ice, and a soln of diborane in THF (50 mmole in BH_3, 42·6 ml) was admitted from a hypodermic syringe. To the stirred soln, α-pinene (110 mmole, 17·42 ml) was added during 20 min, and the stirring continued for 5–7 hr at 0–3°. The ketone (50 mmole) was added in the course of 20 min from a hypodermic syringe, and then the mixture was stirred at 0–3° for 20 hr. The excess hydride was decomposed with water. Judging from the volume of H_2 evolved, the reductions of methyl-ethyl and methyl-isopropyl ketones were more than 90% complete. The alkaline H_2O_2 oxidation, isolation, and purification of the product were carried out as in Procedure A.

Assignment of configuration to the alcohols by Horeau's method[9]

To a soln of the alcohol (1 mmole) in dry pyridine (3 ml) α-phenylbutyric anhydride (2 mmole) was added, and the mixture was kept at room temp for 24 hr. Water (1 ml) and benzene (1 ml) were added, and after 1 hr at r.t. the excess acid was titrated with 1·0N NaOH (phenolphtalein). The isolated amounts of excess acid suggested that in all cases the esterifications were complete. The slightly alkaline soln was extracted with $CHCl_3$ (4 × 15 ml), and the extracts were discarded. The aqueous layer was acidified with conc HCl, and extracted with 3 × 20 ml $CHCl_3$. The $CHCl_3$ extract was washed twice with dil NaCl aq, dried over Na_2SO_4, and evaporated to furnish α-phenylbutyric acid (450–460 mg). The optical rotations of the acids were measured in 1 dm tubes as 35–45% $CHCl_3$ solns. The results are given in Table 1.

1-D_2-*isobutanol.* Neoctylisobutyrate was prepared in 91% yield by the esterification of neooctanol (Eastman Chemical Products (Inc.)) with isobutyric acid. The ester b.p. 64–66°/15–20 mm was homogeneous by GLC.

The ester (40 g, 200 mmole) was added slowly to a cooled and stirred suspension of $LiAlD_4$ (4·2 g, 100 mmole) in dry ether (400 ml). The reaction mixture was stirred under reflux for 19 hr and was terminated with dil HCl (1:1). The ether layer was separated and the aqueous layer was extracted with small amounts of ether. The ether solns were combined and washed with small amounts of brine and dried over Na_2SO_4. The soln was concentrated through a 90 cm packed column and the concentrate was then fractionally distilled on a 30 cm packed column to furnish 1-D_2-isobutanol, b.p. 105–106°/750 mm (95% yield). Analysis of this sample by GLC indicated the presence of a small amount of ether as impurity.

1-D-*isobutyraldehyde.* The 1-D_2-isobutanol prepared above (7·4 g, 100 mmole) was added to a stirred slurry of lead tetraacetate (44·3 g, 100 mmole) in dry pyridine (300 ml). After 28 hr the clear reaction mixture was distilled through a 15 cm packed column and the fraction boiling up to 112°/750 mm was collected. This fraction was refractionated to furnish 1-D-isobutyraldehyde b.p. 62–64°/700 mm (2·48 g). Analysis of the aldehyde (GLC) showed the absence of 1-D_2-isobutanol. The mass spectrum of the 2,4-dinitrophenylhydrazone indicated 98·4% D_1.

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