required 24 hr for completion. After evaporation of the solvent *in vacuo*, the residue was dissolved in chloroform, which was subsequently washed with a saturated sodium bicarbonate solution. The chloroform layer was washed with water, dried, and evaporated. The oily residue (0.31 g) was crystallized from methylene chloride–diisopropyl ether, yielding 0.1 g of damsin (**9**), mp 106–107°. The material was identical with authentic damsin by melting point, mixture melting point, thin layer chromatography on silica gel G, and infrared and nmr spectra.

Determination of the Configuration at C-3 and C-4 in 4 by Horeau's Method.[8,9] **A. Esterification of 4.**—Racemic α-phenylbutyric anhydride (464.4 mg, 1.5 mmoles) and 133.3 mg of ambrosiol (0.5 mmoles) were dissolved in 5 ml of pyridine. After this stood at room temperature overnight, 1 ml of water was added to hydrolyze the excess anhydride. After 2 hr about 20 ml of water was added, and the aqueous solution was extracted twice with ethyl acetate. The ethyl acetate extract was washed with water, with a 5% sodium bicarbonate solution (three 10-ml portions), again with water, and finally with 3 *N* HCl. The ethyl acetate solution was dried in the usual manner and then concentrated *in vacuo* to a constant-weight residue, 271 mg. An nmr spectrum of the residue indicated that **4** was totally esterified. The sodium bicarbonate extract obtained above was washed with chloroform before being acidified with excess 3 *N* HCl. A chloroform extract of the acidic solution, worked up in the usual manner, yielded a residue which was dried to constant weight: 298.3 mg of pure α-phenylbutyric acid. The purity was established by nmr spectroscopy. The acid was dissolved in 10 ml of benzene and the specific rotation was determined: $[\alpha]^{24}D$ +17.1°.

B. Esterification of 3-Monoacetylambrosiol (**6**).—Racemic α-phenylbutyric anhydride (178.0 mg, 0.574 mmole) and 86.6 mg (0.281 mmole) of 3-monoacetylambrosiol were dissolved in 2.5 ml of pyridine, and the mixture was allowed to stand overnight at room temperature. The reaction was worked up as described above for ambrosiol. The nmr spectrum of the ethyl acetate fraction (103.4 mg) indicated that the product was totally esterified. The sodium bicarbonate extract yielded 145.1 mg of α-phenylbutyric acid, $[\alpha]^{24}D$ +11.4°. For a 100% optical yield, the recovered acid would have shown $[\alpha]D$ 32.2°, that is, one-third of the specific rotation of pure acid, ±96.5°.[8] The 1/3 factor reflects the fact that in this experiment, of the 3 moles of acid theoretically recovered (relative to 1 mole of **6**), 2 moles are derived from the hydrolysis of the excess racemic anhydride. Therefore, the optical yield is 35% [(11.4/32.2) × 100] in dextrorotatory acid.

C. Calculation of Optical Yield from the C-3 Hydroxyl Group in 4.—In the esterification of **4**, 1.5 mmoles of α-phenylbutyric acid was treated with 0.5 mmole of ambrosiol. One can easily calculate that, of the 2 moles of acid theoretically recovered (relative to 0.5 mole of **4**), one was derived from the hydrolysis of excess racemic anhydride. If both hydroxyl groups in **4** are esterified completely stereoselectively by the same optically active acyl group, then a specific rotation of 48.25° is expected. If the C-3 hydroxyl group were esterified nonstereoselectively, then a specific rotation for the recovered acid should be about +8.5° since the C-4 hydroxyl group reacted in **6** stereoselectively with a 35% optical yield. Since the experimental specific rotation is +17.1°, the C-3 hydroxyl group must have also given a dextrorotatory acid in about 35% optical yield.

Acknowledgments.—T. J. M. thanks the Robert A. Welch Foundation for financial support (Grant F-130); H. B. K. and H. E. M. acknowledge a NATO grant (1965) and an National Institutes of Health predoctoral fellowship (Grant 5T1- GM 789), respectively. We thank Dr. W. Herz, Florida State University, for authentic samples of damsin and parthenin.

Terpenes. II. The Stereochemistry and Absolute Configurations of the Thujylamines and Some Related Compounds[1]

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The absolute configurations of the isomeric thujylamines, (−)-thujylamine (Ia), (−)-neothujylamine (IIa), (+)-isothujylamine (IIIa), and (+)-neoisothujylamine (IVa), characterized as shown in Table I, were deduced on the basis of their preparation from the related thujyl alcohols and thujones. As reported in a preliminary communication and here described and discussed in more detail, the degradation of (−)-umbellulone (VII) to (+)-(*S*)-α-methyl-α-isopropylsuccinic acid (VIII) establishes the absolute configurations of the ring-junction carbon atoms in the thujyl alcohols, thujones, and thujylamines. In the amines, the configurational assignments for the amino and methyl groups depend on the assignments recently established for the hydroxyl and methyl groups in the alcohols and ketones.

In connection with an interest in optically active amines,[1c] our attention was directed toward the establishment of the absolute configurations of the isomeric thujylamines (Ia–IVa, Chart I), formed in the Leuckart reaction on (−)-thujone (V)[3] or by reduction of the oximes of (−)-thujone[4] or (+)-isothujone (VI).[3b,4,5] These amines provide a set of model compounds for study of the optical rotatory dispersion and circular dichroism of amine derivatives.[1c,6] In addition, in view of the extension of the investigation of cations of the proposed "trishomocyclopropenyl" type[7] to the deamination of *cis*- and *trans*-3-bicyclo[3.1.0]-hexylamine,[8] the determination of the absolute configurations of the thujylamines seemed especially important. These amines provide a series of optically active compounds, the deamination of which might afford valuable information concerning the steric and electronic nature of the intermediate cations. This information would augment and extend that already available in a recent report[9] concerning the acetolysis

(1) (a) Taken largely from the Ph.D. Thesis of E. H. M., Vanderbilt University, Jan 1966, and presented in part at the Southeast–Southwest Regional Meeting of the American Chemical Society, Memphis, Tenn., Dec 1965; Abstracts of Papers, p 47. (b) Paper I: H. E. Smith and A. W. Gordon, *J. Am. Chem. Soc.*, **84**, 2840 (1962). (c) This is also paper VI in the series entitled Optically Active Amines. Paper V: H. E. Smith and R. Records, *Tetrahedron*, in press.

(2) (a) National Defense Education Act Fellow, 1961–1964. (b) To whom inquiries should be sent. (c) National Defense Education Act Fellow, 1959–1962.

(3) (a) O. Wallach, *Ann.*, **272**, 99 (1893); (b) H. L. Dickison and A. W. Ingersoll, *J. Am. Chem. Soc.*, **61**, 2477 (1939).

(4) A. G. Short and J. Read, *J. Chem. Soc.*, 2016 (1938).

(5) (a) F. W. Semmler, *Ber.*, **25**, 3343 (1892); (b) O. Wallach, *Ann.*, **286**, 90 (1895); (c) L. Tschugaeff, *Ber.*, **34**, 2276 (1901).

(6) C. Djerassi, *Proc. Chem. Soc.*, 314 (1964).

(7) (a) S. Winstein, P. Bruck, P. Radlick, and R. Baker, *J. Am. Chem. Soc.*, **86**, 1867 (1964), and earlier papers referred to therein; (b) E. J. Corey and H. Uda, *ibid.*, **85**, 1788 (1963).

(8) E. J. Corey and R. L. Dawson, *ibid.*, **85**, 1782 (1963).

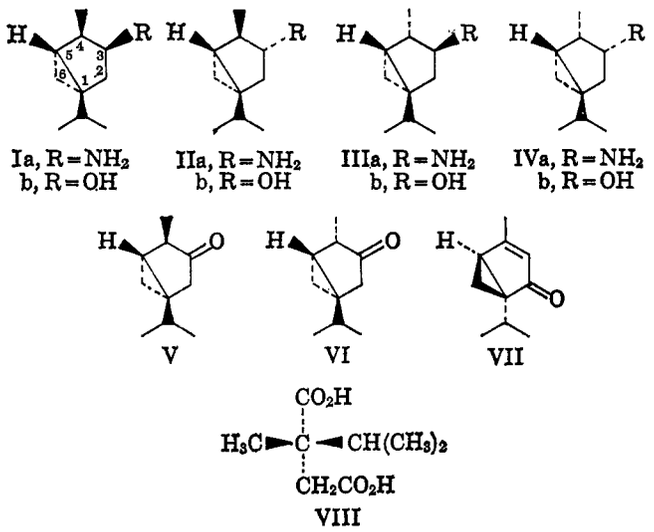
(9) T. Norin, *Tetrahedron Letters*, 37 (1964).

TABLE I
THE THUJYLAMINES

Compound	Present name	Short and Read[a] Name	Short and Read[a] $\alpha^{12-13}D$[b]	Dickison and Ingersoll[c] Name	Dickison and Ingersoll[c] $\alpha^{25}D$[b]
Ia	(−)-Thujylamine	*l*-Thujylamine	−24.32	(−)-Iso-α-thujylamine (D)	−22.07
IIa	(−)-Neothujylamine			(−)-α-Thujylamine (C)	−14.15
IIIa	(+)-Isothujylamine	*d*-Isothujylamine	+94.82	(+)-Iso-β-thujylamine (B)	+94.94
IVa	(+)-Neoisothujylamine			(+)-β-Thujylamine (A)	+27.80

[a] Reference 4. [b] Rotation in degrees for 1 dm without solvent. [c] Reference 3b; in parentheses are the letter designations also used by Dickison and Ingersoll.

CHART I



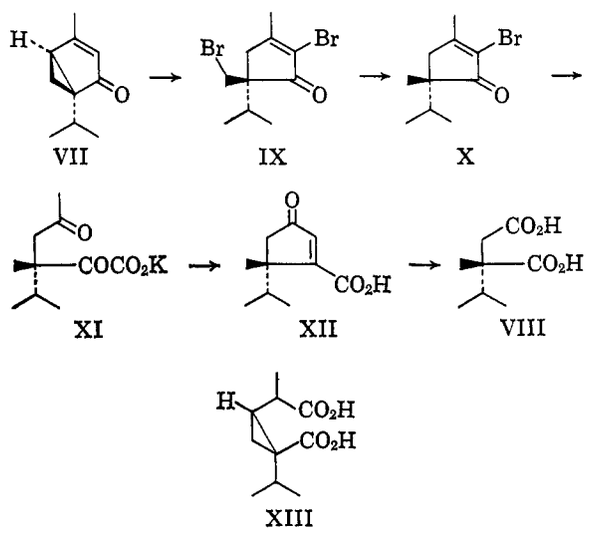
of the *p*-toluenesulfonates prepared from the isomeric thujyl alcohols (Ib–IVb).[10]

We now wish to report evidence which fixes the absolute configuration of each of the thujylamines. For each amine, the rotatory power, the name given by previous investigators,[3b,4] and the name which is now consistent with that applied to the related thujyl alcohol of corresponding configuration[10] are listed in Table I.[11] We also wish to describe and to discuss in more detail the degradation, reported in a preliminary communication,[1b] of (−)-umbellulone (VII) to (+)-(*S*)-α-methyl-α-isopropylsuccinic acid (VIII), which confirms other work[13] fixing the absolute configurations at C-1 and the dependent asymmetric center at C-5 of (−)-umbellulone and the thujones, thujyl alcohols, and thujylamines.

Results and Discussion

Configurations at C-1 and C-5.—For the establishment of the configurations of I–VII at C-1, the reaction of (−)-umbellulone (VII) with bromine in carbon tetrachloride was utilized (Chart II). As first reported by Lees,[14] when the crude product from this reaction is distilled, hydrogen bromide is evolved and one product is (+)-umbellulone dibromide (IX), which on reduction with zinc in acetic acid gives (−)-bromodihydroumbellulone (X). The structure of each of these latter two bromides was deduced by Eastman and Oken,[15] who oxidized X with buffered aqueous potassium permanganate and, after an intramolecular aldol condensation reaction of the salt XI, isolated (−)-(*S*)-5-isopropyl-5-methyl-3-oxo-1-cyclopentene-1-carboxylic acid (XII). Finally, vigorous oxidation of XII with potassium permanganate followed by nitric acid afforded α-methyl-α-isopropylsuccinic acid. The rotatory power of this latter acid, however, was not recorded.[16]

CHART II



For our purpose, the conversion of (−)-umbellulone to XII as outlined in Chart II was repeated. However, since the oxidation of XII as previously reported[15] gave such a low yield (5%) of the succinic acid, a different oxidative procedure was employed. Thus, ozonolysis of XII in ethyl acetate at −78° and treatment of the ozonide with hot, 30% aqueous hydrogen peroxide gave (+)-(*S*)-α-methyl-α-isopropylsuccinic acid

(10) M. S. Bergqvist and T. Norin, *Arkiv Kemi*, **22**, 137 (1964).

(11) The names used to distinguish the thujyl alcohols, (−)-thujyl alcohol (Ib), (−)-neothujyl alcohol (IIb), (+)-isothujyl alcohol (IIIb), and (+)-neoisothujyl alcohol (IVb), and the thujones, (−)-thujone (V) and (+)-isothujone (VI), do not conform to the suggestions made in connection with a rational nomenclature for the menthols and carvomenthols.[12] In the latter system, the prefix iso is reserved for those isomers in which the alkyl groups are *cis* to each other, and the prefix neo for isomers in which the functional group, a hydroxyl group or by inference an amino group, is *cis* to the adjacent alkyl group. However, since the names for the thujyl alcohols and the thujones are of long standing and are associated with well-characterized substances, less confusion would arise by naming the related thujylamines so as to be consistent with the alcohols and ketones rather than to conform with the menthol system.

(12) S. H. Schroeter and E. L. Eliel, *J. Org. Chem.*, **30**, 1 (1965).

(13) (a) H. M. Walborsky, T. Sugita, M. Ohno, and Y. Inouye, *J. Am. Chem. Soc.*, **82**, 5255 (1960); (b) T. Norin, *Acta Chem. Scand.*, **16**, 640 (1962); (c) J. D. Edwards, Jr., and I. Ichikawa, *J. Org. Chem.*, **29**, 503 (1964).

(14) F. H. Lees, *J. Chem. Soc.*, **85**, 639 (1904).

(15) R. H. Eastman and A. Oken, *J. Am. Chem. Soc.*, **75**, 1029 (1953).

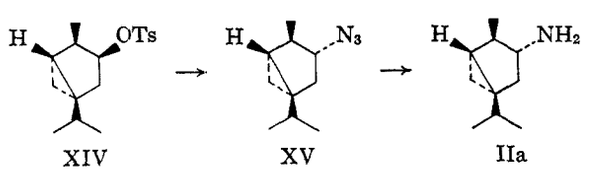
(16) Although the mechanism by which VII is converted to IX remains obscure, a number of possibilities have been discussed: A. Oken, Ph.D. Dissertation, Stanford University, 1952; J. C. Selover, Ph.D. Dissertation, Stanford University, 1953; P. de Mayo, "The Chemistry of Natural Products," Vol. II, K. W. Bently, Ed., Interscience Publishers, Inc., New York, N. Y., 1959, p 110; J. F. King and P. de Mayo, "Molecular Rearrangements," Part II, P. de Mayo, Ed., Interscience Publishers, New York, N. Y., 1964, p 807.

(VIII), a compound of established absolute configuration.[17]

This conversion thus establishes the absolute configuration of (−)-umbellulone as shown in VII. In addition, since previous conversions of (−)-umbellulone and (−)-thujone (V) to (+)- and (−)-homothujadicarboxylic acid (XIII), respectively,[18] have shown these ketones to be enantiomeric at C-1, the degradation also definitely fixes the absolute configurations at C-1 and C-5 for (−)-thujone and (+)-isothujone (VI), the latter obtained by treatment of the former with ethanolic sodium ethoxide,[19] and for the thujyl alcohols (Ib–IVb) and thujylamines (Ia–IVa) derived from these ketones.

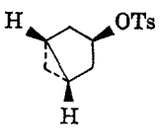
Configurations at C-3 and C-4.—In the amines, for the deduction of the configurations at C-3 and C-4 relative to those at C-1 and C-5, advantage was taken of the configurational assignments at C-4 for the thujones[10,13a] and at C-3 and C-4 for the thujyl alcohols[10] and the fact that, in the sodium–ethanol reduction of the oxime of (+)-isothujone,[20] the major product (83.7% of the amine product with 92% of the oxime converted to amines) is the amine now named (+)-isothujylamine (IIIa).[3b] Since of the two thujones, on the basis of their equilibration in ethanolic sodium ethoxide [33% (−)-thujone (V), 67% (+)-isothujone (VI)],[19] (+)-isothujone is the more thermodynamically stable, it is a good assumption that during the reduction epimerization at C-4 had not occurred to any great extent.[21] If this is assumed, (+)-isothujylamine must have the configuration IIIa in which the nonbonded interaction of the 3-amino group with the 4-methyl group is at a minimum and that with the cyclopropyl methylene group is absent.[12,21,22]

In order to establish the identity of one amine derived from (−)-thujone, the *p*-toluenesulfonate ester XIV was prepared from (−)-thujyl alcohol (Ib) and was treated with methanolic lithium azide.[23] Lithium aluminum hydride reduction of the resulting azido compound XV (not isolated) gave as the only detectable amine product, albeit in low over-all yield (13%), the amine now named (−)-neothujylamine (IIa).

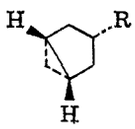


XIV XV IIa

Since *trans*-3-bicyclo[3.1.0]hexyl *p*-toluenesulfonate (XVI) has been shown with sodium acetate in acetic acid to give the acetate XVIIa with complete inversion at C-3,[24] and with sodium azide in dimethyl sulfoxide to give, after reduction with lithium aluminum hydride, the *cis*-amine XVIIb with over 94% stereospecificity,[8] there is no reason to suspect that the ester XIV does not react in a similar way. On the basis of this inversion, (−)-neothujylamine must correspond to the configuration IIa.

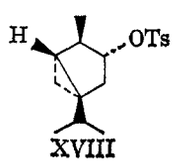


XVI

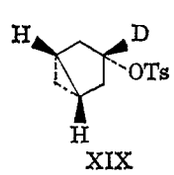


XVIIa, R = $OCOCH_3$
b, R = NH_2

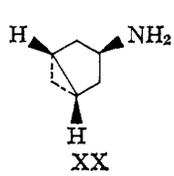
The latter assignment is strengthened by the fact that the epimeric *p*-toluenesulfonate ester XVIII prepared from (−)-neothujyl alcohol (IIb), under similar conditions with lithium azide in methanol and reduction of the intermediate azido compound, afforded racemic neothujylamine as the only detectable amine product. This was not totally unexpected in view of recent reports that the acetolysis of *cis*-3-bicyclo[3.1.0]hexyl *p*-toluenesulfonate-3-*d* (XIX) gives almost exclusively the *cis*-acetate XVIIa with the deuterium equally distributed over the 1-, 3-, and 5-positions[24] and that acetolysis of the ester XVIII gives racemic neothujyl acetate, the configuration being retained at C-3.[9]



XVIII



XIX



XX

As has been discussed in connection with the acetolysis of XVI and XIX[24] and of XIV and XVIII[9] and the deamination of XVIIb and XX,[8] the reaction of XVIII with lithium azide in methanol must proceed by way of a set of rapidly equilibrating classical (XXI) or "essentially classical"[8] cations or a symmetrical, nonclassical cation of the "trishomocyclopropenyl" type (XXII),[24] or by way of a combination of these classical and nonclassical intermediates (Chart III).[9] Also, in accord with the acetolysis experiments with XVIII,[9] it is to be noted that in the reaction of XVIII with lithium azide only those amines, (+)- and (−)-neothujylamine, which arise from attack of the azide ion at the least substituted cationic positions were found. In addition, perhaps reflecting the enhanced rate of ionization of XVIII when compared with *cis*-3-bicyclo[3.1.0]hexyl *p*-toluenesulfonate (XIX)[9] or a difference in the solvent[25] or both of these factors acting together, the reaction of XVIII with lithium azide in methanol proceeds with complete retention of configuration at C-3 while the reaction of *cis*-3-bicyclo[3.1.0]hexyl *p*-toluenesulfonate with sodium azide in dimethyl sulfoxide affords, after reduction with lithium aluminum hydride, the *trans*-amine XX with 98% stereospecificity.[8]

For correlation of the configurations of the remaining two amines, one of which was considered to be the thermodynamically less stable epimer of (+)-isothujylamine (IIIa), an epimerization reaction was sought by which under equilibrating conditions one of the

(17) (a) J. Porath, *Arkiv Kemi*, **1**, 385 (1949); (b) F. Freudenberg and W. Lwowski, *Ann.*, **587**, 213 (1954).

(18) F. W. Semmler, *Ber.*, **36**, 4367 (1903); **40**, 5017 (1907).

(19) R. H. Eastman and A. V. Winn, *J. Am. Chem. Soc.*, **82**, 5908 (1960).

(20) Earlier, (−)-thujone and (+)-isothujone were named, respectively, α- and β-thujone,[3b,5c] Short and Read[4] first using the names *l*-thujone and *d*-isothujone. The name (+)-isothujone presently referring to VI is not to be confused with another compound, also called in the earlier literature isothujone,[5b] 4-isopropyl-2,3-dimethyl-2-cyclopenten-1-one, formed by the action of mineral acid on (−)-thujone.[5b,19]

(21) In a similar reduction of either (−)-thujone or (+)-isothujone, the major product is (+)-isothujyl alcohol (IIIb).[10]

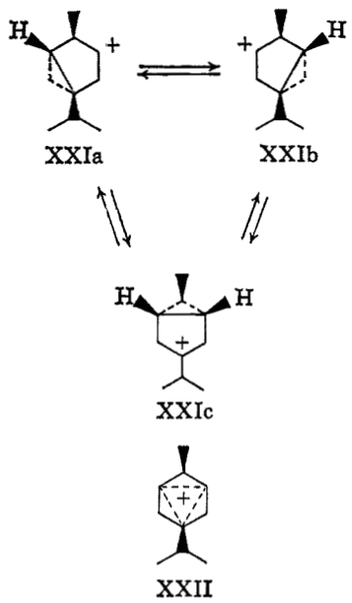
(22) J. A. Mills and W. Klyne, *Prog. Stereochem.*, **1**, 177 (1954).

(23) (a) R. Huisgen and I. Ugi, *Chem. Ber.*, **90**, 2914 (1957); (b) D. H. R. Barton and L. R. Morgan, Jr., *J. Chem. Soc.*, 622 (1962).

(24) S. Winstein and J. Sonnenberg, *J. Am. Chem. Soc.*, **83**, 3235, 3244 (1961).

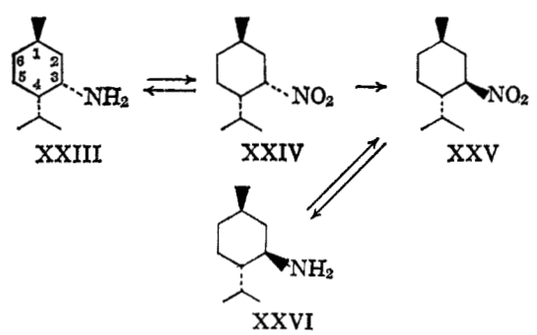
(25) S. G. Smith, A. H. Fainberg, and S. Winstein, *ibid.*, **83**, 618 (1961).

CHART III



remaining amines could be converted to IIIa. In this connection, a model system employing (+)-neomenthylamine (XXIII)[22,26] was examined (see Chart IV).

CHART IV

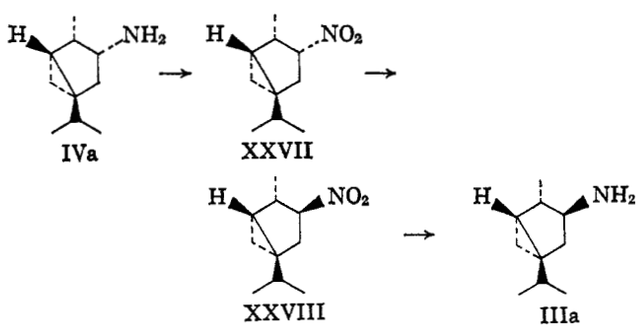


As previously described for 2-aminobutane,[27] oxidation of XXIII with peracetic acid afforded (+)-(1*R*,3*S*,4*S*)-3-nitro-*p*-menthane (XXIV), which on treatment with a catalytic amount of sodium bicarbonate in ethanol[28] was epimerized to (−)-(1*R*,3*R*,4*S*)-3-nitro-*p*-menthane (XXV). Reduction of this latter compound with iron powder in acetic acid[29] gave (−)-menthylamine (XXVI)[26] as the only detectable amine product. With optically active nitro compounds other more convenient reduction methods lead to racemic or epimeric amines.[29] It was demonstrated, however, that both the oxidation and reduction reactions employed here proceed without epimerization at C-3 when XXVI was oxidized to XXV, and XXIV was reduced to XXIII, both reactions proceeding without detectable isomerization.

By the same sequence of reactions, the amine now called (+)-neoisothujylamine (IVa) was oxidized to (+)-(1*S*,3*R*,4*S*)-3-nitrothujane (XXVII) which was epimerized to (+)-(1*S*,3*S*,4*S*)-3-nitrothujane (XXVIII). Without purification of the latter compound, reduction afforded (+)-isothujylamine (IIIa).

Since both the starting amine IVa and the amine product IIIa (see Chart V) thus have the same configuration at C-4 and are different from the amine IIa prepared from (−)-thujone by way of the *p*-toluenesulfonate ester of (−)-thujyl alcohol (Ib), and since the space requirement for the amino group is about the same as that for the nitro group,[30] this latter conversion justifies the earlier conclusion that the major product from the sodium–ethanol reduction of the oxime of (+)-isothujone is the more conformationally stable amine IIIa with the same configuration at C-4 as (+)-isothujone. On this basis (+)-neoisothujylamine is assigned configuration IVa, and by elimination, configuration Ia must represent the amine now named (−)-thujylamine.

CHART V



Experimental Section[31]

(−)-(*S*)-5-Isopropyl-5-methyl-3-oxo-1-cyclopentene-1-carboxylic Acid (XII) from (−)-Umbellulone (VII).—The conversion of VII[32] to XII was accomplished as reported previously.[14,15] The boiling points or melting points and specific rotations for VII, (+)-umbellulone dibromide (IX), (−)-bromodihydroumbellulone (X), and XII, along with those previously reported,[14,15] are recorded in Table II.

TABLE II

INTERMEDIATES IN THE DEGRADATION OF (−)-UMBELLULONE

Compound	Bp (mm) or mp, °C	$[\alpha]^{22-25}$D, deg	Ref
VII	99–100 (15)	−39.4 (neat)	15
	52 (0.9)	−40.1 (neat)	*a*
IX	119–119.5	+6.4 (*c* 2.1, $CHCl_3$)	14
	118–119	+6.8 (*c* 2, $CHCl_3$)	15
	119–121	+6.9 (*c* 2.0, $CHCl_3$)	*a*
X	58–59	−70.1 (*c* 1.7, $CHCl_3$)	14
	57–59	−58 (*c* 6.7, EtOH)	15
	58–60	−60 (*c* 1.5, abs EtOH)	*a*
XII	194–195.5	*b*	15
	194–196	−11 (*c* 3.2, 95% EtOH)	*a*

[a] This work. [b] Not reported.

(26) J. Read, *Chem. Rev.*, **7**, 1 (1930).
(27) W. D. Emmons, *J. Am. Chem. Soc.*, **79**, 5528 (1957).
(28) H. E. Zimmerman and T. E. Nevins, *ibid.*, **79**, 6559 (1957).
(29) N. Kornblum and L. Fishbein, *ibid.*, **77**, 6266 (1955); W. F. Trager, F. F. Vincenzi, and A. C. Huitric, *J. Org. Chem.*, **27**, 3006 (1962).
(30) E. L. Eliel, E. W. Della, and T. H. Williams, *Tetrahedron Letters*, 831 (1963); H. Feltkamp and N. C. Franklin, *J. Am. Chem. Soc.*, **87**, 1616 (1965); H. Feltkamp, N. C. Franklin, K. D. Thomas, and W. Brügel, *Ann.*, **683**, 64 (1965).
(31) Melting points were taken in capillary tubes or as otherwise noted on a Kofler hot stage and are corrected. Boiling points are not corrected. Infrared absorption spectra were obtained from KBr pellets, unless noted otherwise, using a Perkin-Elmer Model 137B or a Beckman Model IR10 spectrophotometer. Optical rotations were measured with a visual polarimeter and 1-dm tubes unless noted otherwise. Microanalyses were done by Galbraith Laboratories, Inc., Knoxville, Tenn. Evaporations of solvent were done using an efficient fractionating column, the last portion of solvent being removed at reduced pressure.
(32) We are grateful to Professor Richard H. Eastman, Stanford University, for a generous gift of (−)-umbellulone.

(+)-(*S*)-α-**Methyl-α-isopropylsuccinic Acid (VIII).**—A mixture of dry oxygen–ozone, produced in a standard corona discharge ozonator, was passed into a solution of 0.240 g (1.32 mmoles) of (−)-(*S*)-5-isopropyl-5-methyl-3-oxo-1-cyclopentene-1-carboxylic acid (XII) in 40 ml of ethyl acetate at −78° until a blue color, indicating an excess of ozone, persisted. The reaction mixture was then added dropwise to 25 ml of hot, 30% aqueous hydrogen peroxide, and this mixture was heated until all of the ethyl acetate had evaporated. The solution was made alkaline with sodium hydroxide and extracted with ether, then acidified with concentrated hydrochloric acid and again extracted with ether. The latter ether extract was dried over sodium sulfate and evaporated. The residue was dissolved in benzene and, on evaporation of the benzene, there was obtained 0.134 g of VIII (59%), mp 132–133°, which after three recrystallizations from cyclohexane–benzene and sublimation at 100° (0.1 mm) had mp 133–134°, $[\alpha]^{21}D$ +16° (*c* 2.9, 95% ethanol) [lit.[17a] mp 126.5–127°, $[\alpha]^{25}D$ +19° (*c* 1.57, ethanol)].

Anal. Calcd for $C_8H_{14}O_4$: C, 55.16; H, 8.10; neut equiv, 87. Found: C, 54.97, 55.00; H, 8.14, 8.21; neut equiv, 86.

The infrared spectrum of this substance was identical with that of authentic VIII,[33] mp 128–130°, but different in small detail from that of authentic (±)-α-methyl-α-isopropylsuccinic acid,[33] mp 154–155°.

(−)-**Thujone** (V).—Fractional distillation of Cedar Leaf Oil Extra[34] gave V, bp 85° (17 mm), $n^{25}D$ 1.4496, $[\alpha]^{24}D$ −16° (neat) [lit.[4] bp 74.5° (9 mm), $n^{25}D$ 1.4490, d^{25}_4 0.9109, $\alpha^{18}D$ −19.94° (1 dm, neat)].

(−)-**Thujyl Alcohol (Ib) and (−)-Neothujyl Alcohol (IIb).**—To 13 g (0.34 mole) of lithium aluminum hydride in 1.4 l. of ether was added with stirring 17.0 g (0.112 mole) of (−)-thujone, and the mixture was boiled for 6 hr. To the cooled mixture was added 10 ml of water and then 1 l. of 20% aqueous potassium sodium tartrate to facilitate extraction[35] of the alcohols into hexane. After extraction, the hexane solutions were washed with water, combined, dried over magnesium sulfate, and evaporated. The residue, 17.0 g, was fractionally distilled. As a series of early fractions there was obtained 9.4 g of IIb (54%), bp 85° (4.1 mm), mp 13–19°, $n^{25}D$ 1.4614–1.4623, $[\alpha]^{25}D$ −8.0 to −9.7° (*c* 2–3, 95% ethanol) [lit.[36] mp 22–23°, $[\alpha]^{20}D$ −8.84° (*c* 1.3, ethanol); lit.[10] mp 24–25°, $[\alpha]D$ −8° (*c* 1.9, ethanol)]. Later fractions contained 2.6 g of Ib (15%), bp 85° (4.1 mm), which crystallized in the receivers. The fractions were combined, and, after recrystallization from pentane, Ib had mp 67–68° and $[\alpha]^{25}D$ −22° (*c* 1.0, 95% ethanol) [lit.[4] mp 66–67°, $[\alpha]^{15}D$ −22.5° (*c* 1, ethanol); lit.[10] mp 66–68°, $[\alpha]D$ −24° (*c* 2.3, ethanol)].

(−)-**Thujyl *p*-Toluenesulfonate (XIV).**—A solution of 0.38 g (2.5 mmoles) of (−)-thujyl alcohol and 0.48 g (2.5 mmoles) of *p*-toluenesulfonyl chloride in 1 ml of dry pyridine was allowed to stand at room temperature for 18 hr. The white solid which remained after addition of 25 ml of water and decantation of the liquid was repeatedly washed with water, dried at reduced pressure, and recrystallized from petroleum ether (bp 40–57°). There was thus obtained 0.50 g of XIV (65%) as white needles, mp 55–56° (Kofler), $[\alpha]^{25}D$ −14° (*c* 3.0, chloroform) [previously observed[37] mp 56–57°, $[\alpha]D$ −16° (*c* 2.3, chloroform)].

(−)-**Neothujylamine (IIa) from (−)-Thujyl *p*-Toluenesulfonate (XIV).**—A solution of 0.610 g (1.98 mmoles) of XIV in 75 ml of 0.92 *M* methanolic lithium azide, prepared from sodium azide and lithium chloride,[23a] was allowed to stand at room temperature for 3 days and then boiled for 18 hr. After evaporation of 35 ml of the solvent, the solution was diluted with 150 ml of water and extracted with ether. The ether solutions were washed with water, combined, dried over sodium sulfate, and then evaporated to 50 ml. This solution was then added to 2 g of lithium aluminum hydride in 100 ml of ether, and the mixture was stirred for 16 hr at room temperature. To the mixture was added 300 ml of 20% aqueous sodium potassium tartrate,[35] the ether layer was separated, and the aqueous layer was extracted with additional portions of ether. The ether solutions were washed with water, combined, and dried over potassium hydroxide. After evaporation of the ether, treatment of the residual oil with 0.087 g (6.9 mmoles) of oxalic acid dihydrate in 1.5 ml of water resulted in the precipitation of 0.052 g of the (−)-neothujylamine normal oxalate (13% based on XIV), mp 203–207° dec (Kofler) (lit.[3b] mp 200–201°), which is too insoluble in water or other solvents for polarimetric measurements. The infrared spectrum of this substance was identical with that of authentic (−)-neothujylamine normal oxalate,[38] mp 204–206° dec (Kofler).

To 0.048 g (0.12 mmole) of the normal oxalate salt, isolated as outlined above, in 2 ml of 15% aqueous sodium hydroxide was added with shaking 0.100 g (0.72 mmole) of benzoyl chloride. The solid which separated was collected by filtration, and on recrystallization from methanol–water there was obtained 0.035 g of (−)-N-benzoylneothujylamine (56%), mp 92–94° (Kofler), $[\alpha]^{25}D$ −14° (*c* 1.5, methanol) [lit.[3b] mp 94.5°, $[\alpha]^{25}D$ −12.16° (methanol)]. The infrared spectrum of this substance was identical with that of authentic (−)-N-benzoylneothujylamine,[38] mp 93–95°, $[\alpha]^{25}D$ −13° (*c* 2.0, methanol), and showed no melting point depression when mixed (1:1) with the authentic sample.

When treated with an excess of benzoyl chloride in aqueous alkali, the mother liquors from the initial precipitation of the oxalate salt gave, as the only product, an additional 0.014 g of (−)-N-benzoylneothujylamine, mp 92–94° (Kofler), isolated as a residue by evaporation of a benzene extract of the reaction mixture.

(−)-**Neothujyl *p*-Toluenesulfonate (XVIII).**—As described for the epimeric alcohol, reaction of 5.55 g (36.0 mmoles) of (−)-neothujyl alcohol with *p*-toluenesulfonyl chloride in pyridine afforded, after one recrystallization from petroleum ether (bp 40–57°), 4.32 g of XVIII (39%), mp 56–59° (Kofler), $[\alpha]^{25}D$ −12° (*c* 2.0, chloroform) [previously observed[37] mp 58–59°, $[\alpha]D$ −12° (*c* 1.9, chloroform)]. As has been previously noted,[37] the ester decomposes when stored at room temperature.

(±)-**Neothujylamine from (−)-Neothujyl *p*-Toluenesulfonate (XVIII).**—A solution of 3.09 g (10.1 mmoles) of XVIII in 200 ml of 0.92 *M* methanolic lithium azide was boiled for 18 hr. As described above, the intermediate azido compound was isolated as an ethereal solution and reduced with lithium aluminum hydride. The total amine product, obtained as a residual oil, was treated with dilute nitric acid. Evaporation of this solution gave 1.26 g of a solid residue which on recrystallization from water afforded 1.03 g of (±)-neothujylamine nitrate (48% based on XVIII), mp 142–145°, $[\alpha]^{25}D$ ±0.3° (*c* 3.0, water). The properties of this salt were unchanged on recrystallization from water. Evaporation of the first recrystallization mother liquors gave 0.23 g of salt which was also optically inactive.

As outlined above, treatment of 0.216 g (1.00 mmole) of the recrystallized nitrate salt in aqueous alkali with an excess of benzoyl chloride and isolation of the total product by sublimation at 80–85° (0.02 mm) gave 0.225 g of (±)-N-benzoylneothujylamine (89%), mp 92–95°, $[\alpha]^{25}D$ ±0.3° (*c* 3.0, methanol).

The proton chemical shifts relative to tetramethylsilane observed in the 60-Mc/sec nmr spectrum (Varian Model A-60[39]) of the racemic amide (17% in carbon tetrachloride) were identical with those observed for authentic (−)-N-benzoylneothujylamine.[38] The infrared spectrum (5% in carbon tetrachloride) of the racemic amide was also identical with that of the same authentic sample.

(−)-**Menthone.**—Oxidation of (−)-menthol, $[\alpha]^{25}D$ −50° (*c* 1.2, absolute ethanol, 2 dm), as previously described[40] gave (−)-menthone, bp 88–90° (16 mm), $n^{25}D$ 1.4495, d^{20}_4 0.887, $[\alpha]^{25}D$ −28.3° (neat) [lit.[41] d^{19}_4 0.896, $[\alpha]^{19}D$ −29.10° (neat)].

(+)-**Neomenthylamine (XXIII) from (−)-Menthone.**—By a somewhat revised procedure for the Leuckart reaction,[42] 200 g (1.30 moles) of (−)-menthone was heated with 358 g (7.95 moles) of formamide and 33 ml of 98% formic acid. The reaction vessel was fitted with a 3-ft Vigreux fractionating column

(33) We are grateful to Professor Arne Fredga, University of Uppsala, Uppsala, Sweden, for a generous gift of this compound.

(34) Isolated from *Thuja occidentalis* L. by the seller, Fritzsche Brothers, Inc., New York, N. Y.

(35) F. I. Carrol, J. D. White, and M. E. Wall, *J. Org. Chem.*, **28**, 1236 (1963).

(36) A. G. Short and J. Read, *J. Chem. Soc.*, 1040 (1939).

(37) Private communication from Professor Torbjörn Norin, Royal Institute of Technology, Stockholm, Sweden, for which we are very grateful.

(38) We are very grateful to Professor Arthur W. Ingersoll, Vanderbilt University, for a generous gift of this compound.

(39) We acknowledge the generosity of the National Science Foundation for a grant (GP-1683) to the Department of Chemistry for the purchase of this instrument.

(40) L. T. Sandborn, "Organic Syntheses," Coll. Vol. I, 2nd ed, A. H. Blatt, Ed., John Wiley and Sons, Inc., New York, N. Y., 1947, p 340.

(41) R. H. Pickard and W. O. Littlebury, *J. Chem. Soc.*, **101**, 109 (1912).

(42) A. W. Ingersoll and H. D. DeWitt, *J. Am. Chem. Soc.*, **73**, 3360 (1951).

surmounted by a controllable take-off head with reflux condenser. The mixture was maintained at 165–180° for 16 hr by periodically removing water at the head as necessary. Unreacted ketone was separated from the distillate and returned to the reaction mixture. More formic acid (50 ml total) was added periodically through the condenser as solid ammonium carbonate collected in the condenser.

After cooling, the crude mixture of the N-formyl derivatives of the menthylamines which separated as a layer was extracted into benzene, and the benzene solution was washed with water and dried over magnesium sulfate. Removal of the benzene and distillation of the residue gave 215 g of the mixed N-formyl derivatives as a viscous oil, bp 135–140° (0.3 mm). As described previously,[43] when the oil was refrigerated for 15 hr in contact with 75 ml of dry ether, crude (+)-N-formylneomenthylamine was obtained as a white oily solid, mp 90–100°. Recrystallization of this solid from ether gave 103 g of (+)-N-formylneomenthylamine (44%) as clear, colorless rhomboids, mp 116–118°, $[\alpha]^{25}D$ +53° (*c* 1.1, chloroform) [lit.[43] mp 117–118°, $[\alpha]^{15}D$ +53.8° (*c* 1.76, chloroform)].

The pure N-formyl derivative was hydrolyzed by boiling with 5 *N* hydrochloric acid, and the amine was liberated by addition of sodium hydroxide and extracted into ether. The ether extract was dried over potassium hydroxide and evaporated. Distillation of the residue gave 78 g of XXIII (84% based on the N-formyl derivative), bp 95–97° (27.5 mm), $n^{25}D$ 1.4568, d^{20}_4 0.854, $[\alpha]^{25}D$ +15.5° (neat) [lit.[44] $n^{25}D$ 1.4614, d^{25}_4 0.8551, $[\alpha]^{25}D$ +15.12° (neat)].

(−)-Menthylamine (XXVI) from (−)-Menthone.—As previously described for substituted acetophenones,[45] oximation of 32.4 g (0.210 mole) of (−)-menthone was performed in hot, aqueous ethanol made neutral by adding appropriate amounts of hydroxylamine hydrochloride and sodium hydroxide. The layer of oxime which was obtained on dilution of the crude reaction mixture with water was extracted into hexane. After the latter solution was washed with water and dried over magnesium sulfate, the solvent was evaporated. Distillation of the residue gave 22.9 g of oxime (65%), bp 133–135° (15 mm), which solidified on cooling.

Without further purification, reduction of the oxime in boiling absolute ethanol with sodium gave, after the usual isolation procedure, 18.0 g of crude XXVI (86%), bp 87° (15 mm), d^{20}_4 0.846, $[\alpha]^{25}D$ −36.8° (neat). The amine was converted to the hydrochloride salt, and serial recrystallization of the latter from water gave 11.1 g of pure (−)-menthylamine hydrochloride (50% based on oxime) as white needles, $[\alpha]^{25}D$ −36° (*c* 1.5, water) [lit.[46] $[\alpha]^{25}D$ −36.3° (7%, water) to −36.6° (5%, water)]. The hydrochloride salt was treated with aqueous alkali, and the amine was isolated in the usual way. The (−)-menthylamine had bp 84° (11 mm) and $[\alpha]^{25}D$ −37° (*c* 2.0, chloroform) [lit.[44] bp 81–82° (12 mm), $[\alpha]^{25}D$ −38.2° (*c* 4, chloroform).

(+)-(1*R*,3*S*,4*S*)-3-Nitro-*p*-menthane (XXIV) from (+)-Neomenthylamine (XXIII).—With vigorous stirring, 10.5 ml (0.390 mole) of 90% hydrogen peroxide[47] was added dropwise, fairly rapidly, to 50 ml of ethylene chloride at 0°. Then, following the addition of 2 drops of concentrated sulfuric acid, 47.1 g (0.461 mole) of acetic anhydride was added to the cold solution during 30 min. After the latter solution had been stirred for 30 min at 0° and then 30 min at room temperature, it was diluted with 30 ml of ethylene chloride and heated rapidly to boiling. At this temperature, a solution of 15.0 g (96.5 mmoles) of XXIII in 10 ml of ethylene chloride was added dropwise during 10 min. The mixture was boiled for an additional 2.5 hr, cooled, washed with two 80-ml portions of 1:1 concentrated ammonium hydroxide–water, and then washed thoroughly with water. The ethylene chloride layer was finally dried over magnesium sulfate, and the solvent was evaporated. Fractional distillation of the residue gave 9.85 g of XXIV (56%) as a pale yellow liquid, bp 72° (0.12 mm), $n^{25}D$ 1.4624, $[\alpha]^{25}D$ +36° (*c* 1.1, methanol), $[\alpha]^{25}D$ +32° (*c* 1.5, hexane).

Anal. Calcd for $C_{10}H_{19}NO_2$: C, 64.83; H, 10.34; N, 7.56. Found: C, 64.29; H, 10.52; N, 7.46.

(+)-Neomenthylamine (XXIII) from (+)-(1*R*,3*S*,4*S*)-3-Nitro-*p*-menthane (XXIV).—A mixture of 2.8 g (0.050 g-atom) of hydrogen-reduced iron powder, 1.5 g (8.1 mmoles) of XXIV, and 15 ml of glacial acetic acid was stirred at room temperature for 4 hr. Then, after addition of 200 ml of water and 5 ml of concentrated sulfuric acid, any volatile, nonbasic material was removed by steam distillation. Finally, the basic product was isolated by addition of an excess of sodium hydroxide, steam distillation, and extraction of this steam distillate with four 100-ml portions of hexane. The combined hexane solutions were dried over potassium hydroxide, and evaporation of the hexane gave 0.51 g of a residual oil. This oil was added to a 10% excess of salicylaldehyde in boiling methanol. Heating the solution for 30 min, removal of the solvent, and sublimation of the residue at 80° (0.02 mm) gave 0.64 g of (+)-N-salicylideneneomenthylamine (32% based on XXIV), mp 95–98°, $[\alpha]^{25}D$ +59° (*c* 1.0, methanol), $[\alpha]^{25}D$ +31° (*c* 1.6, chloroform) [lit.[43] mp 99–100°, $[\alpha]^{15}D$ +30.0° (*c* 1.5, chloroform)]. The infrared spectrum of this substance was identical with that of authentic (+)-N-salicylideneneomenthylamine, mp 94–96°, $[\alpha]^{25}D$ +57° (*c* 0.7, methanol), $[\alpha]^{25}D$ +33° (*c* 2.0, chloroform), prepared from pure XXIII.

(−)-(1*R*,3*R*,4*S*)-3-Nitro-*p*-menthane (XXV) from (−)-Menthylamine (XXVI).—Oxidation of 7.16 g (46.2 mmoles) of XXVI according to the procedure described above gave, after fractional distillation, 5.46 g of nearly pure XXV as a pale yellow oil, bp 93–94° (3 mm), $[\alpha]^{25}D$ −61° (*c* 1.0, methanol). On standing for 3 weeks, the oil crystallized as white needles. Recrystallization from methanol followed by sublimation at 40° (0.5 mm) afforded 5.11 g of XXV (60%), mp 48–49°, $[\alpha]^{25}D$ −67° (*c* 1.0, methanol).

Anal. Calcd for $C_{10}H_{19}NO_2$: C, 64.83; H, 10.34; N, 7.56. Found: C, 65.10; H, 10.35; N, 7.28.

(−)-(1*R*,3*R*,4*S*)-3-Nitro-*p*-menthane (XXV) from (+)-(1*R*,3*S*,4*S*)-3-Nitro-*p*-menthane (XXIV).—A solution of 3.00 g (16.2 mmoles) of XXIV in 350 ml of 95% ethanol saturated with sodium bicarbonate (4 mg/100 ml) was boiled for 15 hr. After reduction of the volume of ethanol and addition of water, the mixture was extracted with five 50-ml portions of hexane; the combined hexane solutions were dried over magnesium sulfate. Evaporation of the hexane and distillation of the residue gave 2.6 g of nearly pure XXV (70%) as a pale yellow liquid, bp 64–66° (0.4 mm), $[\alpha]^{25}D$ −61° (*c* 1.0, methanol).

Anal. Calcd for $C_{10}H_{19}NO_2$: C, 64.83; H, 10.34; N, 7.56. Found: C, 65.37; H, 10.29; N, 7.15.

Seeding of this liquid induced crystallization, and recrystallization of this material from methanol gave pure XXV, mp 47–49°, $[\alpha]^{25}D$ −67° (*c* 1.0, methanol). The infrared spectrum of this substance was identical with that of authentic XXV, prepared by oxidation of XXVI.

(−)-Menthylamine (XXVI) from (−)-(1*R*,3*R*,4*S*)-3-Nitro-*p*-menthane (XXV).—Reduction of 1.79 g (9.68 mmoles) of XXV with iron powder in glacial acetic acid as described above gave 0.69 g of a crude amine product, bp 95–98° (29 mm). Addition of this material to an excess of salicylaldehyde in boiling methanol, removal of the solvent, and sublimation of the residue at 50° (0.01 mm) gave 1.02 g of (−)-N-salicylidenementhylamine (42% based on XXV), mp 53–57°, $[\alpha]^{25}D$ −131° (*c* 1.0, 95% ethanol), $[\alpha]^{25}D$ −115° (*c* 1.0, chloroform) [lit.[48] mp 57–58°, $[\alpha]D$ −119.2° (chloroform)]. The infrared spectrum of this substance was identical with that of authentic (−)-N-salicylidenementhylamine, mp 56–58°, $[\alpha]^{20}D$ −119° (*c* 1.0, chloroform), prepared from pure XXVI.

(+)-Neoisothujylamine (IVa) was obtained by the usual decomposition procedure from the *p*-toluenesulfonate salt,[38] mp 191–193°, $[\alpha]^{25}D$ +26° (*c* 0.6, water, 2 dm) [lit.[3b] mp 194.7°, $[\alpha]^{25}D$ +27.91° (water)]. After distillation, the amine had bp 80–81° (14.5 mm), $[\alpha]^{25}D$ +53° (*c* 2.5, 95% ethanol) [lit.[3b] bp 77.0° (12 mm), $[\alpha]^{25}D$ +51.27° (*c* 3, ethanol)].

(+)-(1*S*,3*R*,4*S*)-3-Nitrothujane (XXVII) from (+)-Neoisothujylamine (IVa).—Oxidation of 8.01 g (52.4 mmoles) of IVa according to the procedure described above for XXIV gave, after fractional distillation, 3.75 g of somewhat impure XXVII (39%) as a yellow oil, bp 54–56° (0.5 mm), $[\alpha]^{25}D$ +48° (*c* 1.0, methanol). Distillation was accompanied by some decomposition.

Anal. Calcd for $C_{10}H_{17}NO_2$: C, 65.54; H, 9.35; N, 7.64. Found: C, 64.16; H, 9.40; N, 6.90.

(43) J. Read and G. J. Robertson, *J. Chem. Soc.*, 2209 (1926).

(44) J. Read and R. A. Storey, *ibid.*, 2761 (1930).

(45) D. E. Pearson and J. D. Bruton, *J. Org. Chem.*, **19**, 957 (1954).

(46) A. C. Cope and E. M. Acton, *J. Am. Chem. Soc.*, **80**, 355 (1958); E. S. Rothman and A. R. Day, *ibid.*, **76**, 111 (1954).

(47) We are grateful to the FMC Corp., Inorganic Chemicals Division, for a generous gift of this reagent.

(48) J. Read, A. M. R. Cook, and M. I. Shannon, *J. Chem. Soc.*, 2223 (1926).

(+)-Isothujylamine (IIIa) from (+)-(1*S*,3*R*,4*S*)-3-Nitrothujane (XXVII).—A solution of 1.80 g (9.82 mmoles) of XXVII in 200 ml of 95% ethanol saturated with sodium bicarbonate was boiled for 8 hr. After partial removal of the ethanol, addition of water, extraction with hexane, drying, and evaporation of the hexane, there was obtained 1.15 g of (+)-(1*S*,3*S*,4*S*)-3-nitrothujane (XXVIII) (64%) as a residual oil, $[\alpha]^{25}D$ +96° (*c* 2.5, methanol). Without further purification, 1.06 g (5.78 mmoles) of this oil was reduced with iron powder in glacial acetic acid, and there was obtained 0.61 g of a crude amine product. Addition of this oil to an equivalent amount of 0.016 *M* aqueous nitric acid gave a precipitate. Recrystallization of this precipitate from water gave 0.52 g of (+)-isothujylamine nitrate (60% based on crude amine), mp 171–173° dec, $[\alpha]^{25}D$ +71° (*c* 0.8, water) [lit.[3b] mp 176.9°, $[\alpha]^{25}D$ +70.48° (water)]. The infrared spectrum of this substance was identical with that of authentic (+)-isothujylamine nitrate,[38] mp 172–173° dec, $[\alpha]^{25}D$ +72° (*c* 1.0, water).

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Terpenes. III. The Nuclear Magnetic Resonance Spectra and Absolute Configurations of the Thujylamines[1]

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The nmr spectra at 60 and 100 Mc/sec were measured for (+)-isothujylamine and (+)-neoisothujylamine, for the N-*p*-nitrobenzoyl derivative of (−)-thujylamine, and for the N-benzoyl derivatives of (−)-neothujylamine, (+)-isothujylamine, and (+)-neoisothujylamine. The absolute configurations at the ring-junction carbon atoms being known with certainty, interpretation of these spectra confirms for the amino and methyl groups the configurational assignments recently deduced on the basis of the preparation of the amines from the related thujyl alcohols and thujones. Since these assignments previously depended explicitly on the configurational assignments for the hydroxyl and methyl groups in the alcohols and ketones, this present work, when taken together with the chemical evidence, also confirms the corresponding configurational assignments in the thujyl alcohols and thujones.

In the preceding paper in this series,[1b] the absolute configurations of the four isomeric thujylamines (Ia–IVa, Chart I)[3] were deduced on the basis of their preparation from the related thujyl alcohols (Ib–IVb)[4] and thujones (V and VI),[4] and, as shown in Table I, a name consistent with that applied to the related thujyl alcohol[4] was given to each amine.

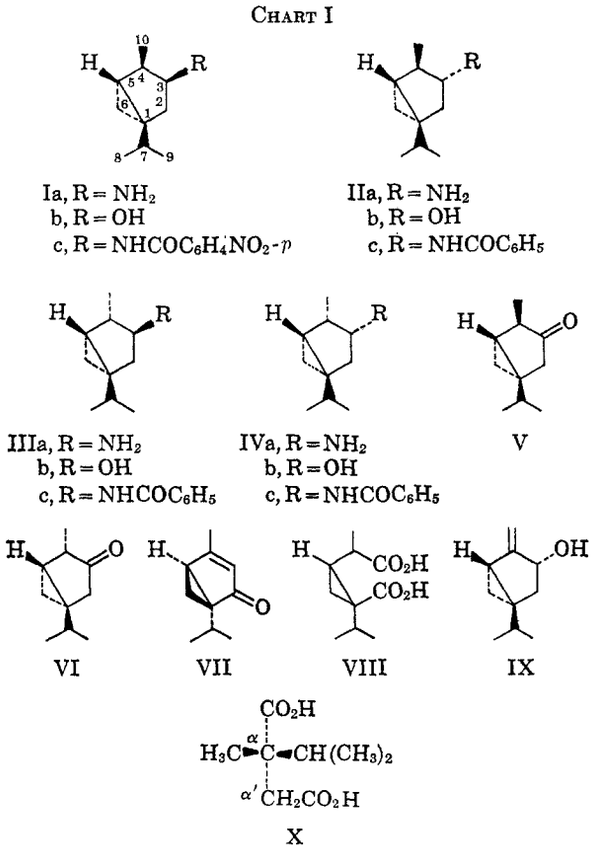
TABLE I
THE THUJYLAMINES

Compound	Name	$\alpha^{25}D$[a]
Ia	(−)-Thujylamine	−22.07
IIa	(−)-Neothujylamine	−14.15
IIIa	(+)-Isothujylamine	+94.94
IVa	(+)-Neoisothujylamine	+27.80

[a] Rotation in degrees for 1 dm without solvent.

In these amines, the configurations at C-1 and at the dependent asymmetric center at C-5 follow from those at C-1 and C-5 for (−)-thujone (V) and (+)-isothujone (VI), these assignments first being deduced on the basis of the asymmetric synthesis of (−)-*cis*-umbellularic acid,[5] a degradation product of (−)-umbellulone (VII).[6] This latter terpene was shown previously to be enantiomorphic at C-1 and C-5 with (−)-thujone by the conversions of (−)-umbellulone and (−)-thujone to (+)- and (−)-homothujadicarboxylic acid (VIII), respec-

CHART I



(1) (a) Presented at the Southeast–Southwest Regional Meeting of the American Chemical Society, Memphis, Tenn., Dec 1965; Abstracts of Papers, p 50. (b) Paper II: E. H. Massey, H. E. Smith, and A. W. Gordon, *J. Org. Chem.*, **31**, 684 (1966). (c) This is also paper VII in the series entitled Optically Active Amines. Paper VI is ref 1b.

(2) National Defense Education Act Fellow, 1961–1964.

(3) H. L. Dickison and A. W. Ingersoll, *J. Am. Chem. Soc.*, **61**, 2477 (1939).

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