olido)-2-keto-5-acetoxytetrahydrofuran,²⁴ then sodium borohydride reduction, gave trans-1,3dibenzyl - 5 - hydroxymethylimidazolid - 2 - one-4-carboxylic acid, m.p. 160–161.5° (found: C, 66.46; H, 6.42; N, 8.14). Treatment of the latter with sodium in liquid ammonia, then with hot mineral acid, led to formation of threo-2,3-diamino-4-hydroxybutyric acid, which was converted into V, m.p. 237–240° (found: C, 37.32; H, 5.54), by treatment with cyanogen bromide. III and V could not be differentiated by paper chromatography in three different systems. The structure of streptolidine (I) is thus 4-(1-hydroxy-2-aminoethyl)-2-aminoimidazoline-5-carboxylic acid.

$$HO_2C \xrightarrow{HN V} CH - CH_2NH_2$$

 $HN V OH NH_2$
 VH_2

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(24) A gift from Hoffmann-La Roche, Inc. NOVES LABORATORY OF CHEMISTRY UNIVERSITY OF ILLINOIS URBANA, ILLINOIS

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BIMOLECULAR REACTIONS IN CARBONIUM ION REARRANGEMENTS

Sir;

Primary carbonium ions, arising from intramolecular rearrangements of secondary and tertiary ones, frequently are postulated as intermediates in *liquid phase* isomerizations of paraffins and related compounds. Calculations¹ indicate that at

$$R - \underbrace{C}_{+} - CH_2 - R \underset{R}{\longrightarrow} R \xrightarrow{R} C - \underbrace{CH_2}_{+}$$
(1)

least 22 kcal./mole of activation energy are needed for rearrangements of secondary to primary carbonium ions, and 33 kcal./mole for rearrangements of tertiary to primary. We considered such energies large enough to warrant examination of alternate mechanistic paths, not involving primary carbonium ions. Specifically, rearrangements via *bimolecular* reactions (2) appeared attractive.

$$R-CH-CH_{2}-R \xrightarrow{} R-CH=CH-R + H^{+}$$

$$R-CH=CH-R + R'^{+} \xrightarrow{} R$$

$$R-CH-CH-R \xrightarrow{} R$$

$$R \xrightarrow{} CH-CH-R' \xrightarrow{} R$$

$$R \xrightarrow{} C+CH_{2}-R' \xrightarrow{} R$$

$$R \xrightarrow{} C=CH_{2} + \overrightarrow{R}' \qquad (2)$$

It was demonstrated² that isotopic scrambling of C-2 \rightleftharpoons C-3 of 2-methyl-2-chlorobutane-2-C¹⁴ with aluminum chloride does not proceed twice as fast as the scrambling of C-1 \rightleftharpoons C-4 of 2-methyl-

(1) A. G. Evans, "The Reactions of Organic Halides in Solution," The Manchester University Press, Manchester, England, 1946, p. 15.

(2) J. D. Roberts, R. E. McMahon and J. H. Hine, J. Am. Chem. Soc., 72, 4237 (1950). 2-chlorobutane-1-C¹⁴ as anticipated if (3) was the only path of isotopic equilibration. Instead, the rate of scrambling of C-2 \rightleftharpoons C-3 versus C-1 \rightleftharpoons C-4 was 1.55. The data necessitated the inter-

$$c \xrightarrow{c} c \xrightarrow{c}$$

pretation that 87% of the rearrangement occurs via (3) and 13% via (4), since (4) effects C-1 \rightleftharpoons C-4 equilibration, but not C-2 \rightleftharpoons C-3.

However, the data are also explicable on the basis of bimolecular reactions, without intervention of primary carbonium ions (neopentyl)



Reaction (5), as far as its effect on isotopic equilibration is concerned, is identical with (4). Differentiation between (5) and (4) becomes obvious upon consideration of the implication of (5). If both the cation and the olefin are labeled the recovered *t*-amyl chloride should contain dilabeled species.

Another source of rearrangement and dilabeled species besides (5) is (6).



Reaction (6), unlike (5), leads to dilabeled species from either the C-1 or C-2 labeled chloride (shown

above for the C-2 labeled compound), and its effect on isotopic equilibration is identical with that of (3).

2-Methyl-2-chlorobutane-1-C¹³ (1.00 g.) was treated with aluminum chloride (0.049 g.) for 5 min. according to ref. 2. The recovered volatile fraction (52%) was shown by v.p.c. to contain 62.8% *t*-amyl chloride, 21.6% *t*-butyl chloride, 7.4% 2-methyl-2-chloropentane, 2.0% 3-methyl-3chloropentane, 4.1% 2-methyl-3-chlorobutane, 0.9% isopentane and 0.6% methylpentanes. The corresponding reaction of the C-2 labeled compound gave identical results. The *t*-amyl chlorides were collected through a Beckman Megachrom and analyzed with a Consolidated Model 21-103C Mass Spectrometer. The pertinent mass spectrometric data are summarized.

MASS SPECTRAL ANALYSIS OF *t*-AMYL CHLORIDES: ISOTOPIC COMPOSITION (% MOLECULES)

	Before reaction		-After react	tion
t-Amyl chloride-1-C ¹³	C_5H_{11} +	$C_5H_{11}^{+}$	C ₄ H ₈ Ci ^{+a}	$C_3H_6Cl^{+a}$
unlabeled	57.0	61.0	31	30.0
monolabeled	43.0	35.5	66	68.2
dilabeled	0.0	3.5	3	1.8
t-Amyl chloride-2-C13				
unlabeled	42.3	46.9	0.0	47.8
monolabeled	57.7	48.8	94	52.2
dilabeled	0.0	4,3	6	0.0

^a Isotropic composition computed on the basis of labeled molecules only (contribution of unlabeled *t*-amyl chloride removed).

These data, corroborated and supplemented by proton n.m.r., can be summarized



We wish to make several comments: (1) The data constitute cogent arguments for the contribution of *bimolecular paths* to liquid phase isomerizations. (2) Since isotope-position rearrangement has reached equilibrium, reliable quantitative conclusions concerning the per cent. contributions of bimolecular paths (5) and (6), and unimolecular

(3) Values in parentheses are from the C4 and C3 fragments. Very little C¹³, if any, appears in carbons other than those designated.

paths to the over-all rearrangement cannot be drawn. An *upper limit* of 20% contribution by (5), (6), and their analogs to C-1 \rightleftharpoons C-4 scrambling, and 14% contribution by (6) and its analogs to C-2 \rightleftharpoons C-4 scrambling may be calculated from the data. (3) We have no way of evaluating the contribution of (7), the analog of (3), and in this respect the over-all contribution of bimolecular reactions to isomerization could be higher than the values given above.



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DISTRIBUTION OF RADIOACTIVITY IN MORPHINE FROM BIOSYNTHESIS WITH CARBON-14 DIOXIDE* Sir:

Three groups of workers^{1,2,3} independently fed ¹⁴C-labeled tyrosine to plants of *Papaver somniferum* and observed the formation of radioactive opium alkaloids. In two cases^{1a,2} the isolated morphine (a hydrophenanthrene alkaloid) and in two cases the isolated papaverine^{1b} and narcotoline³ (benzylisoquinoline alkaloids) were degraded, and in each case the activity was reported as equally divided between the two halves of the molecule, long considered to be derivable from two molecules of tyrosine or an equivalent.⁴

Although the equality of labeling in the two halves was stressed as much as the fact of incorporation, this becomes the "theoretical" distribution only if the alkaloid is formed by the direct combination of two identical molecules or if nonidentical molecules combine and the structure formed or subsequent intermediates become symmetrical, as in the example.

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(2) E. Lette, J. Am. Chem. Soc., 81, 3948 (1959).

(3) G. Kleinschmidt and K. Mothes, Z. Naturforsch., 14b, 52 (1959).
(4) E. Winterstein and G. Trier, "Die Alkaloide," Borntraeger Press, Berlin, 1910, p. 307.