order $k_{int}^{0+0} > k_{int}^{0+-} > k_{int}^{-+-}$ is in agreement with this mechanism since increasing the electron-withdrawing and the resonance-stabilizing capacities of the substituents attached to the α-carbon causes a corresponding increase in the rate of interconversion. In acid solutions the mechanism of the racemization reaction of amino acids has been suggested to proceed by enolization, promoted by the formation of small amounts of the conjugate acid of the α-carboxylic acid group.[14] The results obtained here support this mechanism; the racemization reaction of aspartic acid becomes proportional to $[H^+]$ for acid concentrations greater than 1 *M*.

The results for aspartic acid suggest that for monocarboxylic amino acids (abbreviated as AA) the rate of interconversion between pH 1 and 13 should be described by the equation

$$k_{int}[AA]_T = k_{int}^{+0}[AA^{+0}][OH^-] + k_{int}^{+-}[AA^{+-}][OH^-] \quad (3)$$

The term $k_{int}^{0-}[AA^{0-}][OH^-]$ might be significant in highly basic solutions. The values of k_{int} determined for L-valine at 135° between pH 1 and 8 are summarized in Table I. Based on the aspartic acid results, the dominant term in eq 3 near neutral pH would be expected to be $k_{int}^{+0}[AA^{+0}][OH^-]$. This term is independent of pH between pH 4 and 8, which is in agreement with the observed pH dependence for k_{int} of valine in this pH region. These results indicate that in the pH range 5–8, pH has little effect on the racemization rates of the amino acids. Therefore, at neutral pH the relative order for the racemization rates of the various amino acids should depend largely upon the electron-withdrawing capacity of the R substituent. The rates of interconversion of the D and L enantiomers of phenylalanine and alanine and the rate of conversion of isoleucine to alloisoleucine have been measured at pH 7.6 between 91 and 135°.[2] Comparing these values at 135° with those for aspartic acid and valine at the same pH and temperature gives $k_{int}^{iso}:k_{int}^{val}:k_{int}^{ala}:k_{int}^{phe}:k_{int}^{asp}$ = 1.0:0.8:2.4:4.4:8.6, which is in agreement with the order predicted from the σ^* values of the various R substituents.[15] In fossil shells[3] and sediments[16] $k_{int}^{ala}/k_{int}^{val}$ = 2–3, which is consistent with the rates in aqueous solution at pH 7.6. However, $k_{int}^{phe}/k_{int}^{val}$ = 1–2, which indicates that in natural environments, factors other than the electron-withdrawing capacity of the R substituents may be important in determining the rates of racemization for certain amino acids.

Table I. Values of k_{int} for Valine at 135.5° between pH 1 and 8

$pH_{135.5°}$	k_{int}, sec^{-1}
0.89	6.9×10^{-8}
3.51	3.9×10^{-7}
5.00	4.0×10^{-7}
6.10	4.2×10^{-7}
6.90	4.2×10^{-7}
7.48	4.1×10^{-7}
7.82	4.1×10^{-7}
8.25	4.1×10^{-7}

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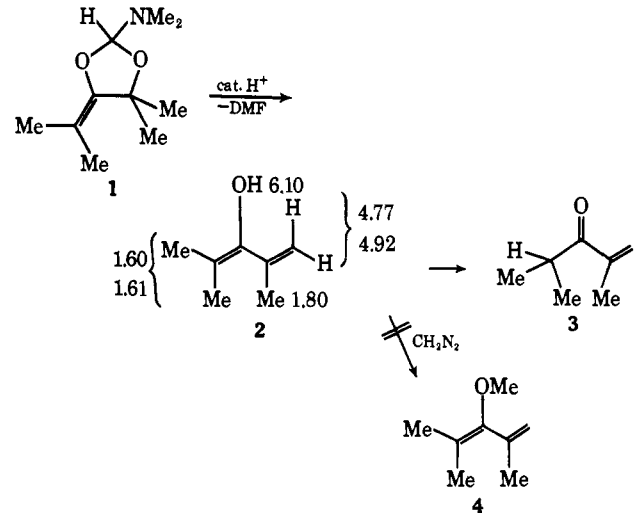
(14) J. M. Manning, *J. Amer. Chem. Soc.*, **92**, 7449 (1970).
(15) M. Charton, *J. Org. Chem.*, **29**, 1222 (1964).
(16) K. A. Kvenvolden, E. Peterson, and F. S. Brown, *Science*, **169**, 1079 (1970).

2,4-Dimethyl-1,3-pentadien-3-ol, a Simple Aliphatic Enol

Sir:

Simple aliphatic enols are unstable relative to the keto form, *i.e.*, rearrangement into the thermodynamically preferred isomer is generally quantitative and irreversible.[1] Whether one might be able to observe such an enol as a fleeting intermediate before equilibrium is reached is a question which appears to have been overlooked almost completely.

2-Dimethylamino-4-methylene-1,3-dioxolanes which have been prepared recently for the first time[2] are highly reactive heterocyclics and the most stable representative is the tetramethylated species **1**. When



1 was rigorously purified and stored neat or in dry dimethylformamide in the absence of light and oxygen, it remained unchanged for 3 weeks at room temperature. In contrast, a 2 *M* solution of **1** in CCl_4 (AnalaR) in the presence of 0.006 *M* benzoic acid proved to be unstable and was transformed overnight into dimethylformamide and isopropenyl isopropyl ketone[3] (**3**). When the same rearrangement was induced by less

(1) For example, diisopropyl ketone has been estimated to yield 0.0037% enol at equilibrium; *cf.* A. Gero, *J. Org. Chem.*, **19**, 1960 (1954). However, more recent work suggests [N. L. Allinger, L. W. Chow, and R. A. Ford, *ibid.*, **32**, 1994 (1967); see also J. E. Dubois and G. Barbier, *Bull. Soc. Chim. Fr.*, 682 (1965); R. P. Bell and P. W. Smith, *J. Chem. Soc.*, 241 (1966)] that this figure is still too high. For a recent review on keto–enol equilibria, see: S. Forsén and M. Nilsson, "The Chemistry of the Carbonyl Group," Vol. 2, J. Zabicky, Ed., Interscience, New York, N. Y., 1970, p 157 ff.
(2) H. M. R. Hoffmann, K. E. Clemens, E. A. Schmidt, and R. H. Smithers, *J. Amer. Chem. Soc.*, in press.
(3) H. O. House and G. A. Frank, *J. Org. Chem.*, 30, 2948 (1965).

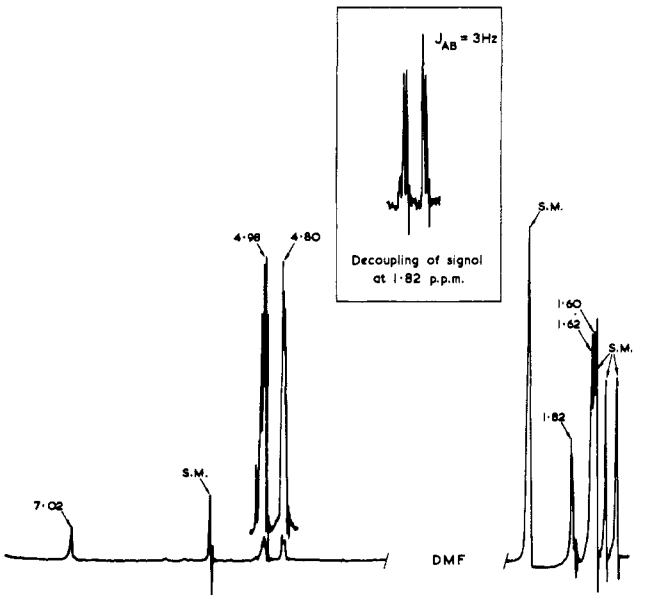
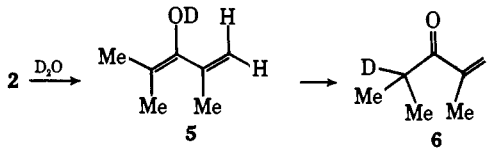


Figure 1. Nmr spectrum (δ^{TMS}) of 2,4-dimethyl-1,3-pentadien-3-ol (2) in dimethylformamide (S. M. = starting material 1).

benzoic acid (0.003 *M*), it became clear that ketone 3 arose from an intermediate, the concentration of which reached a maximum (>0.5 *M*) after *ca.* 15 hr at 25°. At this point and during the preceding 6 hr the ratio of intermediate–ketone 3 amounted to *ca.* 4:1, and the formation of ketone was complete after *ca.* 30 hr at 25°. The nmr spectrum [$\delta^{TMS}_{CCl_4}$ 1.61 (s, 3 H), 1.60 (s, 3 H), 1.80 (br, s, 3 H), 4.77 (1 H) and 4.92 (1 H) (AB quartet with further fine structure which could be removed cleanly by decoupling the signal at 1.80 ppm), 6.10 (s, 1 H)] and the ir spectrum [intense broad bond at 3390 cm^{-1}; OH stretching] suggested the intermediate to be 2,4-dimethyl-1,3-pentadien-3-ol (2).

The most reasonable chemical proof for this enol was thought to be its transformation into the enol ether 4 by methylation with diazomethane in diethyl ether. However, several attempts to obtain 4 by this route were not successful. Apparently, the enolic proton is not acidic enough to allow O-methylation and it is instructive that the chemical shift of the OH proton of enol 2 (δ 6.10 ppm) is closer to that of ordinary alcohols (*e.g.*, methanol ($\delta^{TMS}_{CCl_4}$ 4.00)) than to conventional enols (acetylacetone, 15 ppm).

Nevertheless, the enolic proton of 2 could be exchanged rapidly and quantitatively by brief shaking of the solution of 2 in CCl_4 with an excess of D_2O. The deuterioenol 5 so produced rearranged into the



deuterioketone 6, which was isolated (mass spectrum *m/e* 113.0948; calcd for $C_7H_{11}OD$, 113.0951). Significantly, while 2 rearranged into 3 within 15 hr in CCl_4, the rearrangement of the deuterioenol 5 proceeded more slowly and required *ca.* 250 hr. Independently, the enol 2 was generated in dimethylformamide from a 2 *M* solution of the precursor 1 in the presence of 0.003 *M* benzoic acid (*cf.* Figure 1). In this instance the concentration of the enol reached its maximum after *ca.* 50 hr and formation of the ketone 3 was complete after 120 hr.

We conclude that thermodynamically unstable enols[4] can be handled perhaps more easily than has been hitherto assumed, especially if as in the present instance the double bond is fully alkylated and delocalized further by conjugation. It also seems advantageous to generate the enol in a solvent such as dimethylformamide which in being polar and aprotic stabilizes the enol *via* hydrogen bonding without supplying any protons itself, which would catalyze the rearrangement into the ketone.

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(4) I. A. Kaye, M. Fieser, and L. F. Fieser (*J. Amer. Chem. Soc.*, 77, 5936 (1955)) have suggested the formation of a fairly stable enol derived from α-amyrin in which the OH group is attached to a nonhydrogenatable double bond. This observation, which appears to have escaped all further compilation, can only be retrieved on careful scrutiny of the experimental part (*cf.* 3β,12-dihydroxy-Δ^{12}-ursene on p 5938). Nevertheless, this work has apparently been confirmed by Professor D. Arigoni and his collaborators. We thank Professor Arigoni for this information.

A referee has drawn our attention to the transient formation of the enol (or enolate ion) of α-ketoisovaleric acid (*cf.* R. Steinberger and F. H. Westheimer, *ibid.*, 73, 429 (1951)); however, in this instance the enolic double bond is conjugated with a carboxyl group.

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On the Mechanism of Intermolecular Aromatic Substitution by Arylnitrenes

Sir:

We wish to report studies on the mechanism of intermolecular aromatic substitution of activated substrates by electrophilic nitrenes.[1] Ethoxycarbonyl-[2] and cyanonitrene[3] react with benzene to give both N-substituted azepines and anilines, the latter probably arising from the former either thermally or through acid catalysis. With sulfonylnitrenes formation of the *N*-sulfonylazepine is the kinetically controlled process while the *N*-sulfonylanilines are products of thermodynamic control.[4] Intramolecular cyclizations of some *o*-azidodiphenylmethanes give fused seven-membered ring compounds.[5] We now report examples in which benzene and substituted benzenes containing weak electron-donating substituents undergo intermolecular substitution by an arylnitrene, and the trapping of some *N*-arylazepines.

Since the *N*-arylazepines anticipated from a kinetically controlled addition of ArN to Ar'H were not ex-

(1) R. A. Abramovitch and E. F. V. Scriven, *Chem. Commun.*, 787 (1970).
(2) W. Lwowski, T. J. Maricich, and T. W. Mattingly, Jr., *J. Amer. Chem. Soc.*, 85, 1200 (1963); R. J. Cotter and W. F. Beach, *J. Org. Chem.*, 29, 751 (1964); K. Hafner and C. König, *Angew. Chem.*, 75, 89 (1963).
(3) F. D. Marsh and H. E. Simmons, *J. Amer. Chem. Soc.*, 87, 3529 (1965).
(4) R. A. Abramovitch and V. Uma, *Chem. Commun.*, 797 (1968).
(5) L. Krbechek and H. Takimoto, *J. Org. Chem.*, 33, 4286 (1968); G. R. Cliff and G. Jones, *Chem. Commun.*, 1705 (1970).