the relative intensities of the ester (1730 cm.$^{-1}$) and carboxylate (1565 cm.$^{-1}$) absorptions with synthetic mixtures of poly-(vinyl acetate) and poly-(sodium acrylate).

Anal. Found: N, 6.85 (0.24 mole of imidazole per 100 g. of polymer).

Hydrolysis of Terpolymer.—To a solution of 0.5 g. of the terpolymer prepared above in 200 ml. of 50% aqueous methanol was added 2.0 g. (0.04 mole) of potassium hydroxide. The solution was refluxed, with stirring, for 5 hours, stirred at room temperature overnight, neutralized with 2 *N* hydrochloric acid, dialyzed against tap water for 24 hours, and lyophilized, giving 0.4 g. of a fluffy, white solid; $[\eta]$ 3.33 in 0.2 *N* potassium bromide. The infrared spectrum (Nujol) showed hydroxyl and carboxylate absorptions and was very similar to the spectrum of the hydrolyzed terpolymer prepared from vinyl acetate, methyl acrylate and 4-vinylimidazole.

Anal. Found: N, 5.63 (0.20 mole of imidazole per 100 g. of polymer).

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE 39, MASS.]

A New Method for the Conversion of Glycidic Esters to Aldehydes and Ketones

BY E. P. BLANCHARD, JR., AND G. BÜCHI

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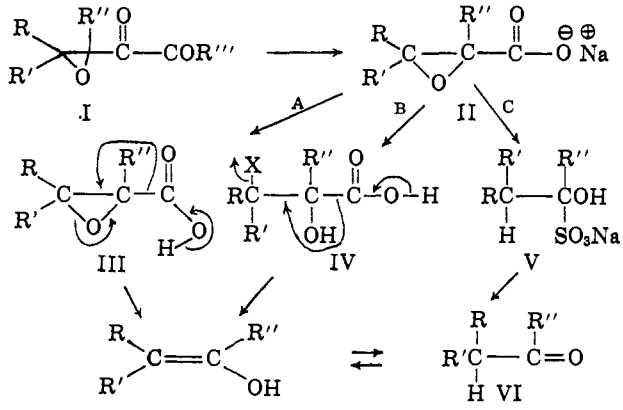
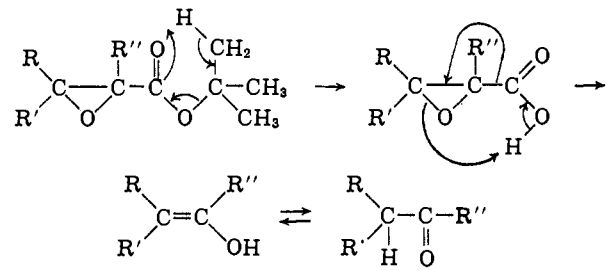
Pyrolysis of *tert*-butyl glycidic esters is shown to be a useful method for the preparation of aldehydes and ketones, particularly those containing acid sensitive substituents. Seven examples serve to illustrate the utility of this procedure.

One of the more useful transformations of glycidic esters concerns their conversion to aldehydes and ketones. Three methods for effecting this change have been in fairly general use. The first step in each of these methods is the saponification of the glycidic ester I to the corresponding alkali glycidate II, a reaction which is best achieved by the procedure of Claisen.[1] Hydrolysis with *aqueous* alkali results in the appearance of carbonyl compounds presumably formed by "retro-aldol cleavage" of initially produced α,β-dihydroxy-ester.[2] Path A represents the most commonly used sequence for effecting decarboxylation. The alkali glycidate II is transformed to the glycidic acid III which is pyrolyzed. Path B is based on the observation of Darzens[3] that addition of hydrogen chloride or hydrogen bromide to glycidic acids produces α-hydroxy-β-halocarboxylic acids. Later investigators utilized this reaction and treated the α-hydroxy-β-halo-acid (IV) with alkali. Decarboxylation with concomitant loss of hydrogen halide furnishes the desired aldehydes or ketones (VI) in fair to good yields.[4,5] Path C[5] consists of heating the alkali glycidate II with a saturated aqueous solution of sodium bisulfite. This mild, presumably acid-catalyzed decarboxylation, is followed by formation of the sodium bisulfite adduct



V of the aldehyde and certain ketones, thus protecting the desired products from further transformations.

In each of these methods an intermediate is exposed to an acidic medium at one stage. For certain syntheses it is advantageous to effect the conversion without recourse to acidic reagents. A procedure which meets this requirement is the direct pyrolysis of *t*-butyl glycidic esters to isobutylene, carbon dioxide and the desired carbonyl compounds. Examination of the pertinent literature revealed that Johnson and his



co-workers[5] had already attempted such a pyrolysis without success, but in deference to current journal practice did not report experimental conditions. Fortunately, at the time we learned about this earlier study we had already pyrolyzed *t*-butyl β-methyl-β-(3-methylene-4-methylamyl)-glycidate (XIII) to 2,6-dimethyl-3-methyleneheptanal-1 (XXII) in 56% yield. A product analysis by gas liquid partition chromatography indicated the absence of double bond isomers, while a sample of this aldehyde prepared by the "bisulfite procedure" (method C) was grossly contaminated with substances whose infrared spectra indicated absence of a methylene group. Isomerization undoubtedly had occurred during prolonged heating in the presence of the acidic sodium bisulfite. Encouraged by the successful pyrolysis just mentioned we decided to investigate the thermal decomposition of other *t*-butyl glycidic esters and the results are presented in this report.

Seven *t*-butyl glycidic esters listed in Table I were prepared by condensation of the appropriate ketone with either *t*-butyl chloroacetate or *t*-butyl α-chloropropionate following the reliable procedure of Johnson, *et al.*[5] In agreement with earlier observations, the infrared spectra of all esters exhibited two bands in the carbonyl region.[2,6] Five of these glycidic esters can exist in diastereomeric forms and the products actually isolated may well have represented mixtures of such isomers. The esters listed in Table I were then pyro-

(1) L. Claisen, *Ber.*, **38**, 693 (1905).

(2) H. O. House, J. W. Blaker and D. A. Madden, *J. Am. Chem. Soc.*, **80**, 6386 (1958).

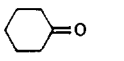
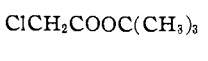
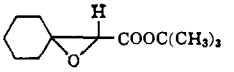
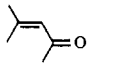
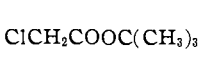
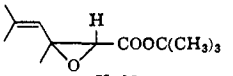
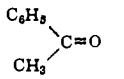
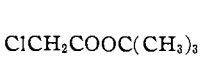
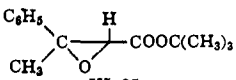
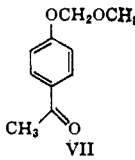
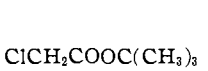
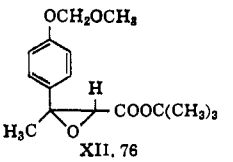
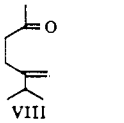
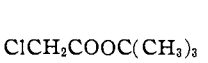
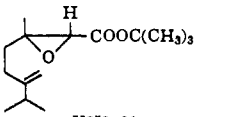
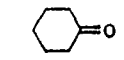
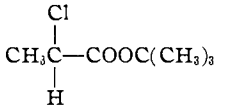
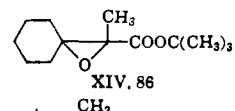
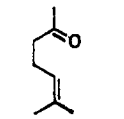
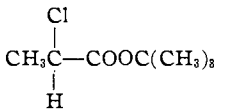
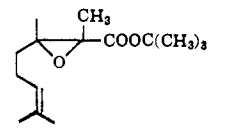
(3) G. Darzens, *Compt. rend.*, **150**, 1243 (1910). The preparation and reactions of glycidic esters were reviewed by M. S. Newman and B. J. Magerlein, *Org. Reactions*, **5**, 413 (1949), and by O. Bayer, Houben-Weyl, "Methoden der Organischen Chemie," Vol. VII, G. Thieme Verlag, Stuttgart, 1954, p. 326. A critical discussion of the mechanism of the Darzens synthesis was presented by M. Ballester, *Chem. Rev.*, **55**, 283 (1955).

(4) W. A. Yarnall and E. S. Wallis, *J. Org. Chem.*, **4**, 270 (1939).

(5) W. S. Johnson, J. C. Belew, L. J. Chinn and R. A. Hunt, *J. Am. Chem. Soc.*, **75**, 4995 (1953).

(6) H. O. House and J. W. Blaker, *ibid.*, **80**, 6389 (1958).

TABLE I

Ketone	Haloester	Glycidic ester yield, %[a]
		 IX, 94
		 X, 82
		 XI, 95
 VII		 XII, 76
 VIII		 XIII, 91
		 XIV, 86
		 XV, 79

[a] Yields reported are based on starting ketone.

lyzed by single passage through a nitrogen-swept tube packed with glass helices which was heated externally to 350–360°. The pyrolysates were washed with aqueous sodium carbonate solution and distilled and the purity of the products was determined by gas–liquid partition chromatography.

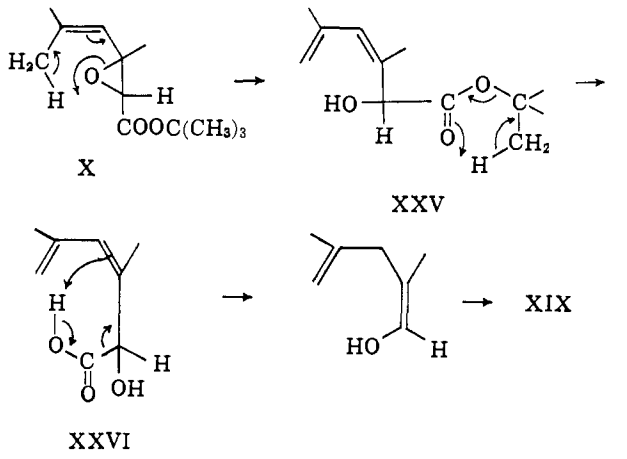
From the yields listed in Table II it can be inferred that the pyrolysis of *t*-butyl glycidic esters is indeed a useful synthetic method of apparently fairly general utility. The preparation of the aldehydoacetal XXI illustrates the superiority of the method for the preparation of highly acid sensitive substances.

The formation of three isomeric (catalytic reduction of all isomers afforded only 2,4-dimethylpentanol-1) 2,4-dimethylpentenals (XVII, XVIII and XIX) in the pyrolysis of *t*-butyl β-methyl-β-isopropylideneglycidate (X) showed that the method is not suited for synthesis of aldehydes or ketones from conjugated carbonyl compounds. Particularly, the formation of 2,4-dimethylpenten-4-al-1 (XIX) in 20% yield (30% of the product) was rather surprising. The infrared spectrum of the ester X revealed only very weak absorption at 890 cm.$^{-1}$ due to a methylene group, and it consequently seemed unlikely that the ester already contained 20% of the isomer with terminal double bond. A *tentative* mechanistic rationalization of this finding involves thermal rearrangement of the epoxide X to the hydroxy-ester XXV, ester pyrolysis and decarboxylation of the resulting β,γ-unsaturated acid XXVI.

The transformation of the glycidate X to the hydroxy-ester XXV is analogous to the thermal rearrangement of allyl ethers.[7]

Acknowledgment.—We are indebted to Firmenich and Cie, Geneva, for financial support.

(7) W. J. Bailey and R. A. Malzahn, Abstracts of the 136th National Meeting of the American Chemical Society, Atlantic City, N. J., September 13–18, 1959, p. 69-P.

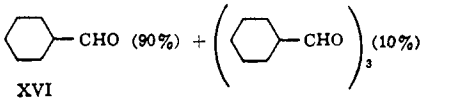
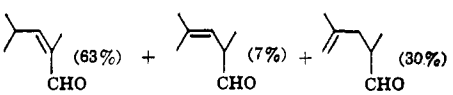
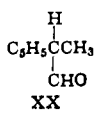
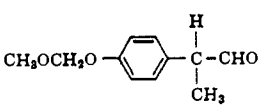
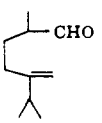
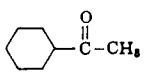
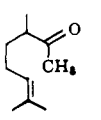


X XXV XIX XXVI

Experimental

Analyses by Dr. S. M. Nagy and associates, Massachusetts Institute of Technology; Microanalytical Laboratory and Scandinavian Microanalytical Laboratory, Copenhagen, Denmark. Melting points and boiling points are uncorrected. Infrared spectra were measured on a Perkin–Elmer recording spectrophotometer, model 21, with sodium chloride prisms. The listings of infrared bands include only those which are relevant to the structural arguments. The activity of the adsorbents used for chromatography was determined by the adsorption of dyes according to the procedure of Brockmann.[8] Gas–liquid partition chromatograms were obtained with 0.6 × 215 cm. columns packed with 30% by weight suspensions of Dow Corning silicone oil no. 550 or Dow tetraethylene glycol saturated with silver nitrate on 48–100 mesh firebrick support. The fractions, eluted with helium, were detected with a thermal conductivity cell.

TABLE II

Ester	Yield, %	Product composition
IX	45	 XVI
X	67	 XVII XVIII XIX
XI	63	 XX
XII	59	 XXI
XIII	56	 XXII
XIV	48	 XXIII
XV	73	 XXIV

(8) H. Brockmann and H. Schodder, *Ber.*, **74**, 73 (1945).

Materials.—The commercially available ketones used in the preparation of the glycidic esters were distilled and had the physical properties: cyclohexanone, b.p. 66.5° (36 mm.), $n^{25}D$ 1.4482; acetophenone, b.p. 78–79° (8 mm.), $n^{25}D$ 1.5317; mesityl oxide, b.p. 128° (757 mm.), $n^{25}D$ 1.4409 [93.5% 4-methylpenten-3-one-2 and 6.5% 4-methylenepentanone-2 as determined from peak areas by g.l.p.c. (silicone oil)]; methylheptenone, b.p. 168° (760 mm.), $n^{25}D$ 1.4398. Chloroacetyl chloride, α-chloropropionic acid and *p*-hydroxyacetophenone (Eastman Kodak Co. White Label) were used without purification.

***t*-Butyl Chloroacetate.**—*t*-Butyl chloroacetate was available in 67.5% yield from *t*-butyl alcohol (131 g., 1.77 moles) and chloroacetyl chloride (200 g., 1.77 moles) by the procedure of Baker.[9] The product had b.p. 47.5–49.5° (9.5–10 mm.), $n^{25}D$ 1.4211 (lit.[5] $n^{25}D$ 1.4204–1.4210).

***t*-Butyl α-Chloropropionate.**—*t*-Butyl α-chloropropionate was available in 82% yield from α-chloropropionic acid (116.7 g., 1.02 moles) and isobutylene (235 g., 4.2 moles) by the procedure of Johnson and co-workers.[5] The product had b.p. 44.5–47.0° (8 mm.), $n^{25}D$ 1.4165 (lit.[5] $n^{25}D$ 1.4163).

***t*-Butyl 1,α,β-epoxycyclohexylideneacetate (IX)** was prepared in essentially the same manner as described by Johnson and coworkers.[5] To 14.7 g. (0.15 mole) of cyclohexanone and 23.2 g. (0.155 mole) of *t*-butyl chloroacetate stirred under nitrogen at 10–15° was added potassium *t*-butoxide (6.275 g. of potassium dissolved in 120 ml. of *t*-butyl alcohol over a period of 0.75 hr.). This mixture was stirred for an additional 1.5 hr. during which time the temperature was allowed to rise to 25°. The *t*-butyl alcohol was removed by evaporation under reduced pressure at room temperature, the residue was taken up in 50 ml. of ether, extracted with water and then three times with saturated salt solution. After drying, the ether phase was filtered and the solvent evaporated through an 18 in. Vigreux column. The residue was distilled through a Holzman column to give 30.06 g. (94.5%) of ester, b.p. 86.5–88.0° (1.1 mm.), $n^{25}D$ 1.4533–1.4535 (lit.[5] $n^{25}D$ 1.4528–1.4530).

***t*-Butyl β-methyl-β-(2-methyl-1-propenyl)-glycidate (X)** was available in 81.9% yield from mesityl oxide (14.7 g., 0.15 mole), *t*-butyl chloroacetate (23.2 g., 0.155 mole) and potassium *t*-butoxide (0.161 mole) by the procedure described above; b.p. 64.5–66.0° (0.75 mm.), $n^{25}D$ 1.4405–1.4413.

Anal. Calcd. for $C_{12}H_{20}O_3$: C, 67.89; H, 9.50. Found: C, 68.28; H, 9.77.

***t*-Butyl β-methyl-2-phenylglycidate (XI)** was synthesized in 95% yield from acetophenone (18.0 g., 0.15 mole), *t*-butyl chloroacetate (23.2 g., 0.155 mole) and potassium *t*-butoxide (0.161 mole) by the procedure described; b.p. 95–103° (0.75 mm.), $n^{25}D$ 1.4908–1.4913.

Anal. Calcd. for $C_{14}H_{18}O_3$: C, 71.77; H, 7.74. Found: C, 71.90; H, 8.00.

4-Acetylphenyl Methoxymethyl Ether (VII).—*p*-Hydroxyacetophenone (32.6 g., 0.24 mole) was dissolved in 300 ml. of dry toluene containing 25 ml. of absolute ethanol and the solution stirred under nitrogen. Sodium hydride (6 g., 0.25 mole) was added and the slurry warmed to *ca.* 50° until hydrogen evolution had ceased (1 hr.). Ethanol was removed by distillation and to the cooled residue was added 19.4 g. (0.24 mole) of freshly distilled chloromethyl methyl ether and the mixture was stirred for 3 hr. Additional chloromethyl methyl ether (4 g.) was then added and stirring continued for 0.5 hr. The toluene solution was extracted twice with 100-ml. portions of 5% potassium hydroxide solution and finally with cold water. After drying, the toluene was evaporated under reduced pressure and the residue was distilled through a Holzman column to give 31.5 g. (73%) of VII, b.p. 93.5–103° (0.35 mm.), $n^{25}D$ 1.5346.

Anal. Calcd. for $C_{10}H_{12}O_3$: C, 66.67; H, 6.67. Found: C, 66.39; H, 6.69.

***t*-Butyl glycidate XII** was prepared in 76% yield from 4-acetylphenyl methoxymethyl ether (30.6 g., 0.170 mole), *t*-butyl chloroacetate (26.35 g., 0.176 mole) and potassium *t*-butoxide (0.180 mole). Attempts to distil this ester resulted in decomposition (see pyrolysis experiment). The crude product (49.2 g., 0.168 mole) was eluted from 150 g. of alumina (Act. I) with ether to give 38.1 g. (76%) of XX as a viscous oil.

***t*-Butyl α-Methyl-α,β-epoxycyclohexylideneacetate (XIV).**—Obtained in 84.3% yield from cyclohexanone (14.7 g., 0.15 mole), *t*-butyl α-chloropropionate (25.6 g., 0.155 mole) and potassium *t*-butoxide (0.161 mole), the material had b.p. 71.5–72.5° (0.2–0.15 mm.), $n^{25}D$ 1.4508–1.4512 (lit.[5] $n^{25}D$ 1.4508).

***t*-Butyl α-methyl-β-methyl-β-(4-methyl-3-pentenyl)-glycidate (XV)** was synthesized in 79.5% yield from methylheptenone (17.64 g., 0.14 mole), *t*-butyl α-chloropropionate (23.9 g., 0.145 mole) and potassium *t*-butoxide (0.150 mole); b.p. 97.5–99.0° (0.8 mm.), $n^{25}D$ 1.4463–1.4465.

Anal. Calcd. for $C_{15}H_{26}O_3$: C, 70.83; H, 10.30. Found: C, 70.89; H, 9.99.

2-Methyl-3-methyleneheptanone-6 (VIII) was prepared in 41% yield from thujone *via* thujoketo acid according to the procedure of Werner and Bogert.[10] The product isolated had b.p. 80–80.5° (20 mm.), $n^{25}D$ 1.4358 (lit.[10] b.p. 183–188°, $n^{25}D$ 1.4430).

***t*-Butyl β-methyl-β-(3-methylene-4-methylamyl)-glycidate (XIII)** was prepared in 91% yield from 2-methyl-3-methyleneheptanone-6 (37.9 g., 0.27 mole), *t*-butyl chloroacetate (42.3 g., 0.28 mole) and potassium *t*-butoxide (11.4 g., 0.292 mole of potassium dissolved in 200 ml. of *t*-butyl alcohol) by the procedure described. The ester had b.p. 92–94° (0.5 mm.), $n^{25}D$ 1.4475.

Anal. Calcd. for $C_{15}H_{26}O_3$: C, 70.83; H, 10.30. Found: C, 70.69; H, 9.97.

Pyrolysis Apparatus and Procedure.—The pyrolysis apparatus was that described previously[11] except that the pyrolysis tube was filled completely with 1/8 or 3/16 in. Pyrex helices. The glycidic esters were pyrolyzed at a rate of 6 drops/min.; flow of nitrogen, 5 ml./min.; temperature 350–360°. Pyrolysates were taken up in ether, extracted with aqueous sodium carbonate solution, and the ethereal solutions were dried over anhydrous magnesium sulfate, filtered and evaporated. The residues were subsequently distilled to give the desired aldehyde or ketone. No attempt was made to improve yields by subjecting distillation residues to a second pyrolysis.

Cyclohexane Carboxaldehyde (XVI).—*t*-Butyl 1,α,β-epoxycyclohexylideneacetate (21.2 g., 0.1 mole) was pyrolyzed to give 4.55 g. (40.6%) of XVI, b.p. 78.5–80.0° (57 mm.), $n^{25}D$ 1.4485, forming an orange 2,4-dinitrophenylhydrazone, m.p. 173–174° (lit.[5] 173–173.8°). Also formed in the pyrolysis was 531 mg. (4.7%) of 2,4,6-tricyclohexyl-1,3,5-trioxane which crystallized in colorless needles from chloroform; m.p. 203–204° (lit.[12] 202–203°).

2,4-Dimethylpentenals (XVII, XVIII, XIX).[13]—*t*-Butyl β-methyl-β-(2-methyl-1-propenyl)-glycidate (21.2 g., 0.10 mole) was pyrolyzed to give 7.50 g. (67%) of a mixture of isomeric aldehydes, b.p. 135–139° (760 mm.), which was separated into two fractions by g.l.p.c. (silicone oil).

The infrared spectrum (CS_2) of the first fraction (37%) had bands at 1725, 2700 cm.$^{-1}$ (unconjugated aldehyde); 890, 1650, 3080 cm.$^{-1}$ (terminal methylene group); 825, 1650 cm.$^{-1}$ (trisubstituted double bond). Gas chromatography (tetraethylene glycol–silver nitrate) showed this fraction to be a mixture of 2,4-dimethylpenten-3-al-1 (XVIII) (19%) and of 2,4-dimethylpenten-4-al-1 (XIX) (81%). Structure assignment was based on relative intensities of the 825 and 890 cm.$^{-1}$ bands in the infrared spectrum.

The infrared spectrum (CS_2) of the second fraction (63%) had bands at 1680 and 2700 cm.$^{-1}$ (conjugated aldehyde), as anticipated for 2,4-dimethylpenten-2-al-1 (XVII).

2,4-Dimethylpentanol-1.—A mixture of XVII, XVIII and XIX (410 mg., 3.6 mmoles) was reduced catalytically in ethanol solution over a platinum-on-charcoal catalyst. After filtration and evaporation, the residue (275 mg.) was analyzed by g.l.p.c. (silicone oil) and found to consist of a single substance. The distilled alcohol had $n^{25}D$ 1.4206 (lit.[14] $n^{25}D$ 1.427) and formed a 3-nitrophthalate which crystallized in white plates from toluene: m.p. 154–155° (lit.[14] 154–155°).

α-Phenylpropionaldehyde (XX).—*t*-Butyl β-methyl-β-phenylglycidate (23.4 g., 0.1 mole) was pyrolyzed to give 8.62 g. (62.8%) of XX, b.p. 86.5° (12–9.5 mm.), $n^{25}D$ 1.5141–1.5170, forming a 2,4-dinitrophenylhydrazone, m.p. 134–135° (lit.[15] m.p. 135°).

Aldehydo-acetal XXI. (A).—Pyrolysis of the *t*-butyl glycidate XII in the usual manner led to accumulation of polymeric material in the pyrolysis tube. By increasing the temperature to 470° and the rate of addition to 30 drops/min. it was possible to obtain 5.29 g. (59%) of XXI, b.p. 88–95° (0.3 mm.), from 13.6 g. (0.046 mole) of XII.

(B).—During an attempt to distil the glycidic ester XII (24.5 g., 0.083 mole) decomposition was observed to occur already at 140°. Pyrolysis in this fashion (160° and 4 mm.) gave 10.32 g. (64%) of crude XXI, b.p. up to 132° (4 mm.). Redistillation of the pyrolysate afforded 6.13 g. (35%) of XXI, b.p. 81–84° (0.1 mm.). An analytical sample was obtained by fractionation through a spinning band column (0.6 × 46 cm.). The colorless product, b.p. 64–65° (0.03 mm.), $n^{25}D$ 1.5122, formed a semicarbazone, m.p. 122–123° after recrystallization from aqueous ethanol. The infrared spectrum (CS_2) showed bands at 1727

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(10) J. Werner and M. Bogert, *J. Org. Chem.*, **3**, 578 (1938).

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(14) T. Chu and C. S. Marvel, *J. Am. Chem. Soc.*, **53**, 4449 (1931).

(15) C. H. F. Allen and J. Van Allen, "Organic Syntheses," Coll. Vol. III, John Wiley and Sons, Inc., New York, N. Y., 1955, p. 734.

and 2720 cm.$^{-1}$ (unconjugated aldehyde) and 1005 cm.$^{-1}$ (methoxymethyl).

Anal. Calcd. for $C_{11}H_{14}O_3$: C, 68.02; H, 7.27. Found: C, 68.31; H, 7.28.

Hexahydroacetophenone XXIII.—*t*-Butyl α-methyl-α,β-epoxycyclohexylideneacetate (22.6 g., 0.1 mole) was pyrolyzed[16] to give 6.13 g. (48.4%) of XXIII, b.p. 75–77° (23 mm.), $n^{25}D$ 1.4500–1.4502 (lit.[5] $n^{25}D$ 1.4462). It formed a 2,4-dinitrophenylhydrazone, m.p. 138.5–140° (lit.[17] m.p. 140°).

(16) In a single experiment, which could not be reproduced, the pyrolysis of *t*-butyl α-methyl-α,β-epoxycyclohexylideneacetate gave as the major product 1-hydroxy-1-acetylcyclohexane. Reaction parameters which led to this abnormal reaction are being investigated.

(17) R. L. Shriner and R. C. Fuson, "The Systematic Identification of Organic Compounds," Fourth Edition, John Wiley and Sons, Inc., New York, N. Y., 1956, p. 316.

3,7-Dimethylocten-6-one-2 (XXIV).—*t*-Butyl α-methyl-β-methyl-β-(4-methyl-3-pentenyl)-glycidate (25.4 g., 0.1 mole) on pyrolysis yielded 11.32 g. (73.5%) of XXIV, b.p. 90–93 (18 mm.), $n^{25}D$ 1.4448 [lit. b.p. 88–90° (14 mm.),[18] $n^{20}D$ 1.4434[18]; b.p. 87° (13 mm.),[19] $n^{15.2}D$ 1.446[19]].

2,6-Dimethyl-3-methyleneheptanal-7 (XXII).—*t*-Butyl β-methyl-β-(3-methylene-4-methylamyl)-glycidate (35.87 g., 0.141 mole) was pyrolyzed to give 12.11 g. (55.7%) of XXII, b.p. 78–82° (14.5–15.0 mm.), $n^{25}D$ 1.4390–1.4408; infrared spectrum (CS_2): 885, 1640 and 3100 cm.$^{-1}$ (>C=CH_2); 1720, 2700 cm.$^{-1}$ (—C(H)=O).

Anal. Calcd. for $C_{10}H_{18}O$: C, 77.86; H, 11.76. Found: C, 77.49; H, 11.53.

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[CONTRIBUTION FROM THE THOMPSON CHEMICAL LABORATORY, WILLIAMS COLLEGE, WILLIAMSTOWN, MASS.]

The Rearrangement of Pyridine N-Oxide with Acetic Anhydride: Kinetics and Mechanism

BY J. HODGE MARKGRAF,[1] HAMILTON B. BROWN, JR.,[2] SCOTT C. MOHR[2] AND RICHARD G. PETERSON

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The thermal rearrangement of pyridine N-oxide with excess acetic anhydride to form 2-acetoxypyridine has been studied kinetically at a series of temperatures over the range 100–130°. A procedure was developed in which aqueous solutions of the hydrolyzed reaction mixture were analyzed spectrophotometrically; the accuracy of this method was within 1%. Four possible reaction courses were considered: intramolecular, intermolecular, ion pair and free radical. Kinetic expressions were derived for the first three processes. A series of runs over a tenfold change in concentration was conducted at each temperature. All runs, which were followed to at least 60% completion, exhibited pseudo-first-order kinetics. Additional runs with added salts were conducted. The intramolecular rearrangement of a free cation was excluded by the kinetic data. The free radical mechanism was excluded by the absence of gaseous decomposition products commensurate with such a process. No reliable distinction was possible between pathways involving free ions and ion pairs. Activation parameters were calculated.

Introduction

Katada[3] first reported that pyridine N-oxide in acetic anhydride rearranged thermally to yield 2-acetoxypyridine. Analogous reactions have been observed with other heterocyclic N-oxides. It has been in the picoline series,[4] however, that the mechanism of this type of rearrangement has received the most thorough inspection. Traynelis and Martello postulated the anhydrobase I[5,6] as the key intermediate in the rearrangement of 2-picoline N-oxide with acetic anhydride. The conversion of I to product, 2-pyridylmethyl acetate, was best explained by an intramolecular path, although no distinction was possible among concerted, ion pair or radical pair processes. More recently Oae, Kitao and Kitaoka[7] have studied the same rearrangement using acetic anhydride of which all three oxygens were equally enriched by oxygen-18. Their results, which definitely excluded intermolecular and free radical chain[8] processes, further substantiated an intramolecular pathway in which the two oxygen atoms of I became equilibrated by a radical pair process within the solvent cage.

I

The mechanism of the corresponding rearrangement of pyridine N-oxide has not received comparable attention. In this case there is no possibility for the generation of a species such as I. The preferred route to 2-acetoxypyridine, therefore, may well differ *a priori* from the route to 2-pyridylmethyl acetate. Hence intramolecular, intermolecular, ion pair and free radical chain pathways must be considered. The object of the work reported here was to distinguish by kinetic methods among the above possible processes.

Experimental[9]

Materials.—Pyridine N-oxide was prepared by the method of Ochiai.[10] The product was distilled *in vacuo* under nitrogen: b.p. 128–129° (7 mm.) (lit.[10] b.p. 138–140° at 15 mm.); picrate m.p. 182.5–182.8° (lit.[11] m.p. 179.5°). The white crystalline product was stored in the dark under nitrogen; neither discoloration nor hydration occurred over a period of months.

2-Pyridone was prepared by the method of Adams and Schrecker[12] from 2-aminopyridine. The product was recrystallized from benzene; m.p. 105–107° (lit.[13] m.p. 106°).

Acetic anhydride (J. T. Baker, analyzed reagent, assay 99.2%) was used without further purification. Butyric anhydride was redistilled through a short column; a middle fraction, b.p. 92.0–92.2° (15.5 mm.), was used.

(1) To whom inquiries should be addressed.

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