

absorbed 60.0 ml. (S.T.P.) of hydrogen (91% of theory) in 24 minutes.

**Ozonization.**—A solution of 2 g. of acid III in 100 ml. of redistilled carbon tetrachloride was cooled with an ice-salt cooling mixture while a mixture of oxygen and ozone of unknown concentration was passed through it. After 16 hours it was found that the oxygen-ozone mixture passing through the solution liberated iodine from a potassium iodide solution at the same rate as the oxygen-ozone mixture coming directly from the ozone generator. The carbon tetrachloride solution was then mixed with a 50% solution of acetic acid and zinc dust was added in parts. After the completion of the addition the solution was refluxed for one hour, the organic layer separated and the aqueous layer extracted with several portions of ether which were combined with the carbon tetrachloride solution and dried over magnesium sulfate. The solvents were removed by distillation and the residue treated with 2,4-dinitrophenylhydrazine to yield 0.5 g. of a yellow 2,4-dinitrophenylhydrazone. After two recrystallizations from alcohol it melted at 64–65° and did not depress the melting point of the 2,4-dinitrophenylhydrazone from ethyl *n*-amyl ketone.

Ethyl *n*-amyl ketone was prepared in 77% yields by the

method of Newman and Smith.<sup>10</sup> Its 2,4-dinitrophenylhydrazone melted at 64–65°. *Anal.* Calcd. for C<sub>14</sub>H<sub>20</sub>O<sub>4</sub>N<sub>4</sub>: C, 54.5; H, 6.5; N, 18.2. Found: C, 54.8; H, 6.3; N, 18.2.

**The Reaction of the Addition Product of I to the Acid II with Acetyl Chloride.**—A solution of 3.5 g. (0.025 mole) of acid II in dry ether was added to a solution of 0.076 mole of I in ether. The solution was cooled in an ice-bath and 5.9 g. (0.075 mole) of freshly distilled acetyl chloride was added in parts. When the addition was about two thirds completed, the solution turned to a yellowish-green color and separated into two layers. Attempts to crystallize the addition product by cooling to Dry Ice temperature failed. It was therefore refluxed for one hour with a 10% solution of sodium hydroxide, the aqueous solution acidified with hydrochloric acid and extracted with several portions of ether, the ether solution dried with magnesium sulfate, and filtered. The filtrate was distilled at 2-mm. collecting four fractions, up to 107°, 107 to 112°, 112 to 116°, and 116 to 119°. None of the fractions yielded iodoform when treated with a 10% solution of sodium hydroxide and iodine-potassium iodide solution.

(10) M. S. Newman and A. S. Smith, *J. Org. Chem.*, **13**, 592 (1948).

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, COLORADO A. AND M. COLLEGE]

## The Reaction of *p*-Methoxystyrene Oxide with Phenol<sup>1</sup>

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The preparation of *p*-methoxystyrene bromohydrin by solvolysis of *p*-methoxystyrene dibromide provided an easy synthesis of *p*-methoxystyrene oxide. Reaction of the oxide with phenoxide ion gave the primary alcohol, but no secondary alcohol, and products of nuclear alkylation. The acid-catalyzed reaction of the oxide with phenol led almost exclusively to nuclear attack. These results further support the postulate of a unimolecular route to the primary alcohol in the ring-opening reactions of styrene oxides.

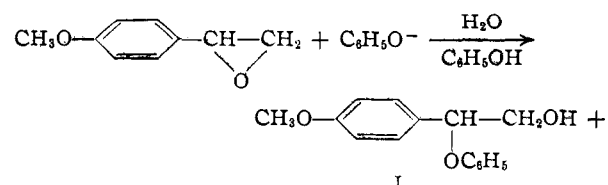
The effect of substituents in substituted styrene oxides on the direction of ring opening has been investigated recently<sup>2,3</sup> in order to gain a better understanding of the mechanism of the reaction. Electron-attracting groups, as exemplified by the nitro group, favor the formation of the secondary alcohol in the reaction of the substituted styrene oxide with phenoxide ion, contrary to prediction based on inductive effects by which nitro groups would tend to lower the electron density on the  $\alpha$ -carbon atom. On the other hand, if attack at the  $\alpha$ -carbon involved a unimolecular ring opening, then the nitro group might well inhibit the formation of the primary alcohol<sup>3</sup> and yet facilitate a bimolecular route to the secondary alcohol.<sup>4</sup> A study of the ring-opening reactions of *p*-methoxystyrene oxide is an obvious source of supplementarily helpful data.

At least one attempt to make *p*-methoxystyrene oxide has been reported.<sup>5</sup> Olefin oxides similarly activated have been found to be rather susceptible to thermal isomerization even when distilled at pressures down to around 1 mm.<sup>6</sup> Therefore, the

first objective in the present work was to prepare *p*-methoxystyrene oxide in a sufficiently pure state without distillation or other heat treatment. Ordinarily the conversion of a bromohydrin to the corresponding oxide is rapid and quantitative. With this in mind, pure *p*-methoxystyrene bromohydrin was sought as a desirable precursor.

Among the methods investigated was the solvolysis of *p*-methoxystyrene dibromide to the bromohydrin as reported by Tutin, Caton and Hann.<sup>7</sup> Eventually an acceptable modification of their procedure was developed which led to the bromohydrin in good yield and of analytical purity. The oxide was produced when the solvolysis was conducted in the presence of sodium hydroxide.

The reaction of *p*-methoxystyrene oxide with phenoxide ion was carried out at the same temperature and with the same concentration of components as was used with styrene oxide<sup>8</sup> and the nitrostyrene oxides.<sup>2,3</sup> As shown in the equation



(1) Scientific Series Paper No. 373 of the Experiment Station.

(2) C. O. Guss and H. G. Mautner, *J. Org. Chem.*, **16**, 887 (1951).

(3) C. O. Guss, *ibid.*, in press.

(4) G. Baddeley and G. M. Bennett, *J. Chem. Soc.*, 1819 (1935).

(5) E. D. Bergmann and M. Sulzbacher, *J. Org. Chem.*, **16**, 84 (1951).

(6) S. Winstein, T. L. Jacobs, R. B. Henderson, J. H. Robson and B. F. Day, *ibid.*, **11**, 157 (1946); G. P. Mueller and R. May, *THIS JOURNAL*, **71**, 3313 (1949).

(7) F. Tutin, F. W. Caton and A. C. O. Hann, *J. Chem. Soc.*, **95**, 2113 (1909).

(8) C. O. Guss, *THIS JOURNAL*, **71**, 3460 (1949).



latter solution dried over anhydrous sodium sulfate. Removal of the ether under reduced pressure gave 3.9 g. (86.6%) of *p*-methoxystyrene oxide as a pale yellow oil,  $n_D^{20}$  1.5400  $\pm$  0.0025. *p*-Methoxystyrene oxide, as prepared here, melted to a clear liquid at  $20 \pm 2^\circ$ . It was not stable, the refractive index and melting point increasing steadily until a solid material, presumably a polymer, resulted. When placed in a refrigerator in the solid state, the deterioration of the oxide may have been delayed, but it was not prevented.

One preparation of the oxide was analyzed after being held for several hours under vacuum to remove the last traces of solvent.

*Anal.* Calcd. for  $C_9H_{10}O_2$ : C, 71.98; H, 6.71. Found: C, 70.89; H, 6.70.

When the oxide was heated with water, with or without the addition of a catalytic amount of hydrochloric acid, the glycol was formed, m.p.  $81-82^\circ$ .<sup>20</sup>

**The Reaction of *p*-Methoxystyrene Oxide with Phenoxide Ion.**—To freshly prepared *p*-methoxystyrene oxide (3.45 g., 0.023 mole) was added, in one portion, a solution of phenol (6.5 g., 0.069 mole), sodium hydroxide (0.9 g., 0.225 mole) and water (3.5 cc.), which was at the temperature of a boiling water-bath. There appeared to be an immediate exothermic reaction. The one-phase mixture was at once placed in a boiling water-bath for 30 minutes, then poured into iced 4% sodium hydroxide. The insoluble portion was extracted with ether, dried over anhydrous potassium carbonate, and the ether evaporated to give 3.8 g. (67.9%) as a yellow oil that solidified on standing. Recrystallization from heptane was accomplished by allowing a less soluble oil to separate from the hot solution and then cooling the supernatant solution in a separate flask. By repeating this process with the oil, 2.6 g. (46.4%), m.p.  $70-72^\circ$ , of the primary alcohol (I), 2-(4-methoxyphenyl)-2-phenylethanol was isolated. The analytical sample melted at  $71-72^\circ$ .

*Anal.* Calcd. for  $C_{15}H_{16}O_2$ : C, 73.75; H, 6.60. Found: C, 73.76; H, 6.77.

The *p*-nitrobenzoate,<sup>21</sup> from dilute ethanol as faintly yellow needles, melted at  $100-101^\circ$ .

*Anal.* Calcd. for  $C_{22}H_{19}NO_4$ : C, 67.17; H, 4.87. Found: C, 66.88; H, 5.14.

In a repetition of this experiment a 70.0% yield of alkali-insoluble material and a 43.3% yield of I was obtained. In both runs the residue from the crystallization of I was a viscous to brittle tan resin. Use of the bromohydrin instead of the oxide gave similar results. When dioxane was used instead of water, the yield of alkali-insoluble material was 51.7% and of I, 36.2%, with no evidence for the presence of the isomeric secondary alcohol.

The alkali-soluble material was isolated by acidification and extraction with ether. To the 5.8 g. of oil obtained in this manner from the run just described in detail was added phthalic anhydride (3.0 g.), dioxane (15 cc.) and pyridine (3 cc.). After 48 hours at room temperature this solution was dissolved in ether, washed with dilute hydrochloric acid and water, and then extracted with four 25-cc. portions of 4% sodium bicarbonate. Sodium hydroxide (1.0 g.) in water (20 cc.) was added to the combined bicarbonate extract, which was then refluxed one-half hour. An insoluble material was isolated as a nearly colorless oil, 0.6 g., which solidified slowly when cooled, m.p.  $38-42^\circ$ . This was purified by recrystallization from ethanol-water to m.p.  $45-46^\circ$ . The assigned structure, 3-(4-methoxyphenyl)-2,3-dihydrobenzofuran (IV), is based on the mode of formation and the analysis.

*Anal.* Calcd. for  $C_{15}H_{14}O_2$ : C, 79.62; H, 6.24. Found: C, 79.84; H, 6.42.

Addition of Dry Ice to the alkaline liquid from the hydrolysis and cyclization reaction effected the separation of 0.5 g. of an oil. A solid (III), m.p.  $150-151^\circ$ , was obtained in small amount from this oil by crystallization from benzene-heptane. This material showed no depression in melting point when mixed with the substance of the same melting point isolated from the acid-catalyzed reaction of the oxide with phenol.

**The Acid-catalyzed Reaction of *p*-Methoxystyrene Oxide with Phenol.**—A mixture of phenol (9.4 g., 0.1 mole) and *p*-

toluenesulfonic acid monohydrate (0.1 g.) was held at  $40-45^\circ$  with cooling while *p*-methoxystyrene oxide (3.75 g., 0.025 mole) was added in 15 minutes. The viscous, dark red solution was allowed to stand 15 minutes, then poured into water (150 cc.) containing sodium hydroxide (5 g.). A solid was filtered off, washed and dried; 0.7 g. Recrystallization from heptane gave 0.4 g., m.p.  $150-190^\circ$ . This was apparently a mixture of products from the self-condensation of the oxide, perhaps dimers such as dioxanes<sup>9</sup> or polymerized *p*-methoxyphenylacetaldehyde.

*Anal.* Calcd. for  $C_{18}H_{20}O_4$ : C, 71.98; H, 6.71. Found: C, 72.11; H, 6.76.

The alkaline filtrate from the isolation of the foregoing was acidified to precipitate a solid, 4.2 g., m.p.  $115-140^\circ$ . This solid (4 g.) in benzene (100 cc.) containing *p*-toluenesulfonic acid monohydrate (0.1 g.) was heated at reflux for 3 hours in order to effect the cyclization of any of the phenol-alcohol (II) to the furan (IV). The reaction mixture, in ether, was then extracted with dilute sodium hydroxide. There was isolated 0.4 g. of alkali-insoluble material, which was probably the furan (IV) although attempts to crystallize the oil failed. The alkali-soluble fraction, 3.2 g., m.p.  $130-145^\circ$ , was recrystallized from benzene-ethanol to yield 1.1 g., m.p.  $150-151^\circ$ , the remainder melting at  $135-148^\circ$ . The material melting at  $150-151^\circ$ , also obtained from the reaction of the oxide with phenoxide ion, was considered to be 2-(4-methoxyphenyl)-2-(4-hydroxyphenyl)-ethanol (III).

*Anal.* Calcd. for  $C_{15}H_{16}O_3$ : C, 73.75; H, 6.60. Found: C, 73.77; H, 6.86.

**Preparation of 2-(4-Methoxyphenyl)-2-phenylethanol (I).**—Sodium (0.46 g., 0.02 mole) was added to a solution of phenol (3.76 g., 0.04 mole) in dioxane (5 cc.). After all of the sodium had reacted, the solution was heated to the temperature of a boiling water-bath, and to it was added ethyl  $\alpha$ -chloro-*p*-methoxyphenylacetate<sup>14</sup> (4.57 g., 0.02 mole) in dioxane (5 cc.). After 3.5 hours the reaction mixture was poured into water and extracted with ether. The material recovered from the ether solution was distilled; 2.45 g., b.p.  $190-210^\circ$  (3 mm.). The impure ester was hydrolyzed in dilute sodium hydroxide and the product recrystallized from heptane to obtain  $\alpha$ -phenoxy-*p*-methoxyphenylacetic acid, m.p.  $108-109^\circ$ .

*Anal.* Calcd. for  $C_{15}H_{14}O_4$ : C, 69.76; H, 5.46. Found: C, 70.07; H, 5.69.

This acid (0.2 g.) in ether was reduced with lithium aluminum hydride in 15 minutes to obtain the alcohol (I), 0.15 g. crude, which, when recrystallized from heptane, melted at  $71-72^\circ$  alone or when mixed with the alcohol (I) from the reaction of *p*-methoxystyrene oxide with phenoxide ion.

**Preparation of 1-(4-Methoxyphenyl)-2-phenylethanol.**—*p*-Methoxyphenyl chloride<sup>22</sup> (9.2 g., 0.05 mole) was added to a solution of sodium phenoxide (0.05 mole) in water (25 cc.) and the mixture heated on a water-bath for 30 minutes. The dispersion was cooled and diluted to give a tan solid, 11.0 g., m.p.  $45-55^\circ$ . Two recrystallizations from dilute ethanol (Nuchar) gave white leaves, 4.3 g. (35.5%), m.p.  $66-67^\circ$ . *p*-Anisyl phenoxyethyl ketone has been prepared by Stoermer and Atenstädt<sup>23</sup> by a different method and found to melt at  $67^\circ$ . The oxime, as prepared here, melted at  $107-108^\circ$  (lit.<sup>23</sup> m.p.  $105^\circ$ ). A preparation of the 2,4-dinitrophenylhydrazones<sup>24</sup> gave orange needles, from ethyl acetate, m.p.  $178.5-179.5^\circ$ .

*Anal.* Calcd. for  $C_{21}H_{18}N_4O_6$ : C, 59.71; H, 4.29. Found: C, 59.47; H, 4.50.

Reduction of the ketone (2.42 g., 0.01 mole) in isopropyl alcohol (50 cc.) with a 1 molar solution (15 cc.) of aluminum isopropoxide in isopropyl alcohol yielded 2.20 g. (90.9%), m.p.  $50-60^\circ$ . One recrystallization from heptane gave the pure 1-(4-methoxyphenyl)-2-phenylethanol, m.p.  $63.5-64.5^\circ$ .

*Anal.* Calcd. for  $C_{15}H_{16}O_2$ : C, 73.75; H, 6.60. Found: C, 73.92; H, 6.70.

The *p*-nitrobenzoate,<sup>21</sup> from dilute ethanol as faintly yellow needles, melted at  $87-88^\circ$ .

*Anal.* Calcd. for  $C_{22}H_{19}NO_4$ : C, 67.17; H, 4.87. Found: C, 67.08; H, 4.99.

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