

TABLE I  
MELTING POINTS OF THE PHENANTHRENE CARBOXYLIC ACIDS AND METHYL ESTERS

Isomer	Acid		Methyl Esters	
	Found	Lit.	Found	Lit.
1	234.7–235.2	228–233 <sup>4-7</sup>	55.0–55.7	57 <sup>4</sup>
2	267.8–268.5	254–260. <sup>3, 9, 10</sup>	96.7–98.2	96.0–96.5 <sup>9</sup>
3	278.5–280.0	269–272 <sup>8, 9, 19</sup>	95.1–95.6	94.5–95.0 <sup>9</sup>
4	174.5–175.5	170–174. <sup>5, 10, 11, 20</sup>	83.0–84.0	84.8–85.5 <sup>20</sup>
9	259.2–260.0	246–256 <sup>8, 13-18</sup>	116.2–116.8	115.5–116.0 <sup>9, 17</sup>

Anal. Calcd. for  $C_{15}H_{10}O_2$ : C, 81.1; H, 4.5; neut. equiv. 222. Found: C, 81.1; H, 4.5; neutralization equiv. 223.

*1,1'-Bicyclohexenyl*. The conjugated diene was prepared by dehydrating 195 g. of 1,1'-dihydroxy-1,1'-dicyclohexyl<sup>27</sup> over 19 g. of anhydrous copper sulfate at 130–150°. As the diene formed it distilled from the mixture; yield 177 g. (96%). After purification by washing with dilute sodium bicarbonate and fractional distillation the diene weighed 122 g. (77%), b.p. 87° (0.84 mm.),  $n_D^{25}$  1.5349.

*1,2,3,4,5,6,7,8,9,9a,10,10a-Dodecahydrophenanthrene-9-carboxylic acid*. Acrylic acid (25 g.), 1,1'-bicyclohexenyl (27 g.), and 100 ml. of 95% ethanol were refluxed for 24 hr. On cooling, 24.3 g. (52%) of snow-white crystals precipitated, m.p. 168–170°.

Anal. Calcd. for  $C_{15}H_{22}O_2$ : Neut. equiv. 234. Found: 233.

A second crop of crystals (14 g.) had a lower melting point and is believed to have been contaminated with the ethylester.

*Phenanthrene-9-carboxylic acid*. The dodecahydrophenanthrene-9-acid. (16.1 g.) and powdered sulfur (13.2 g.)

(27) E. E. Gruber and R. Adams, *J. Am. Chem. Soc.* **57**, 2555 (1935).

were heated for 3 hr. at 150–210°. The product was dissolved in 5% sodium carbonate solution. After filtration, the acid was recovered by acidification of the filtrate. Ten grams of the crude acid was converted to the methyl ester with diazomethane. The ester was fractionally distilled through a Piros-Glover spinning band column (b.p. 162° at 0.22 mm.). Repeated recrystallization from methanol of the best distillation fractions yielded 1.6 g. (16%) of ester, m.p. 116.2–116.8°.

Anal. Calcd. for  $C_{15}H_{12}O_2$ : Saponification equiv. 236. Found: 232. Saponification of the ester with 0.4N potassium hydroxide in diethylene glycol and three recrystallizations from ethanol gave colorless needles, m.p. 259.2–260.0°.

Anal. Calcd. for  $C_{15}H_{10}O_2$ : C, 81.1; H, 4.5; neut. equiv. 222. Found: C, 81.9; H, 4.5; neut. equiv. 221.

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The synthesis of the phenanthrene-1-carboxylic acid by Gerald Yarnell is gratefully acknowledged.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, DUKE UNIVERSITY]

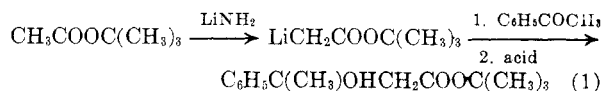
## Synthesis of $\beta$ -Hydroxy Esters from Ethyl Acetate and Ketones or Aldehydes by Means of Lithium Amide. Some Results with Other Esters<sup>1</sup>

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Ethyl acetate was condensed with various ketones or aldehydes including certain  $\alpha,\beta$ -unsaturated ketones or aldehydes by means of two equivalents of lithium amide in liquid ammonia to form the corresponding  $\beta$ -hydroxy esters. In general the yields were good. This method is considered more convenient than that involving the Reformatsky reaction. The products were saponified and/or dehydrated to give derivatives. The condensations of certain other esters with ketones or aldehydes were effected with one or two equivalents of lithium amide.

It has been previously shown<sup>2</sup> that lithio *t*-butyl acetate, prepared from molecular equivalents of the ester and lithium amide in liquid ammonia, can be condensed satisfactorily with various ketones or aldehydes in ether to form the  $\beta$ -hydroxy esters. For example, this aldol type of condensation was realized with the lithio ester and acetophenone in 76% yield (Equation 1).



It has similarly been observed<sup>3</sup> that even ethyl acetate can be condensed satisfactorily with acetophenone,<sup>3</sup> cyclohexanone,<sup>3</sup> or fluorenone<sup>4</sup> provided an extra equivalent of lithium amide is employed.

(1) Supported by the Office of Ordnance Research, U. S. Army.

(2) C. R. Hauser and W. H. Puterbaugh, *J. Am. Chem. Soc.*, **73**, 2972 (1951); *J. Am. Chem. Soc.*, **75**, 1068 (1953).

(3) C. R. Hauser and J. K. Lindsay, *J. Am. Chem. Soc.*, **77**, 1050 (1955).

(4) C. R. Hauser and D. Lednicer, *J. Org. Chem.*, **22**, 1248 (1957).

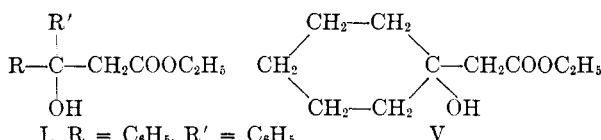
TABLE I

$\beta$ -HYDROXY ESTERS FROM ETHYL ACETATE WITH KETONES OR ALDEHYDES BY MEANS OF TWO EQUIVALENTS OF LITHIUM AMIDE IN LIQUID AMMONIA

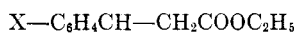
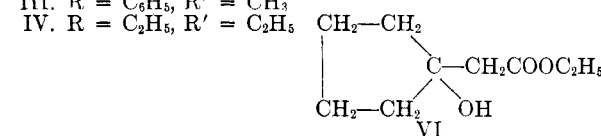
Ketone or Aldehyde	$\beta$ -Hydroxy Ester	Yield, %	M.P. or B.P.		
			Found	Reported	Mm.
Benzophenone	Ethyl $\beta$ -hydroxy- $\beta$ , $\beta$ -diphenylpropionate (I)	84	M.p. 85–86 <sup>a</sup>	87 <sup>b</sup>	
4-Methyl benzophenone	Ethyl $\beta$ -hydroxy- $\beta$ -tolyl- $\beta$ -phenylpropionate (II)	88	M.p. 56–57 <sup>a</sup>	<sup>c</sup>	
Acetophenone	Ethyl $\beta$ -hydroxy- $\beta$ -phenylbutyrate (III)	66	146–148	15	146–147
3-Pentanone	Ethyl $\beta$ -hydroxy- $\beta$ , $\beta$ -diethylpropionate (IV)	65	99–102	13–14	<sup>e</sup>
Cyclohexanone	Ethyl 1-hydroxycyclohexylacetate (V)	69	124–126	18	124–126
Cyclopentanone	Ethyl 1-hydroxycyclopentylacetate (VI)	31	99–102	9	105–107
Benzaldehyde	Ethyl $\beta$ -hydroxy- $\beta$ -phenylpropionate (VII)	37	154–156	12	151–154
Anisaldehyde	Ethyl $\beta$ -hydroxy- $\beta$ -anisylpropionate (VIII)	28	182–186	17	<sup>c</sup>
Benzalacetone	Ethyl $\beta$ -hydroxy- $\beta$ -styrylbutyrate (IX)	65	188–191	20	192
Benzalacetophenone	Ethyl $\beta$ -hydroxy- $\beta$ -phenyl- $\beta$ -styrylpropionate (X)	93	M.p. 74–75 <sup>a</sup>	<sup>c</sup>	
Cinnamaldehyde	5-Phenylpentadienoic acid (XI) <sup>j</sup>	20 <sup>k</sup>	M.p. 165–166 <sup>l</sup>	165 <sup>m</sup>	

<sup>a</sup> Recrystallized from ethanol. <sup>b</sup> H. Rupe and E. Busolt, *Ber.*, **40**, 4537 (1907). <sup>c</sup> See Experimental. <sup>d</sup> S. Lindenbaum, *Ber.*, **50**, 1270 (1917). <sup>e</sup> Product reported by G. A. R. Kon and K. S. Nargund, *J. Chem. Soc.*, 2461 (1932), and by S. Reformatsky, *J. prakt. Chem.*, **54**, 469 (1896), but no b.p. was given. <sup>f</sup> O. Wallach, *Ann.*, **347**, 328 (1906). <sup>g</sup> O. Wallach, *Ann.*, **323**, 159 (1902). <sup>h</sup> C. R. Hauser and D. S. Breslow, *Org. Syntheses*, **21**, 51 (1951). <sup>i</sup> E. P. Kohler and G. L. Heritage, *Am. Chem. J.*, **43**, 484 (1910). <sup>j</sup> Crude ester decomposed upon attempted purification and was therefore saponified and isolated as the  $\alpha$ , $\beta$ -unsaturated acid. <sup>k</sup> Yield based on starting cinnamaldehyde. <sup>l</sup> Recrystallized from benzene. <sup>m</sup> J. J. Sudborough and J. M. Gittens, *J. Chem. Soc.*, **95**, 315 (1909).

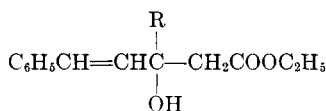
It has now been found that the latter method also is quite general. Thus, the several types of  $\beta$ -hydroxy esters I–XI were synthesized from ethyl acetate and the appropriate ketone or aldehyde by a modification of the earlier procedure. The yields and other data are summarized in Table I.



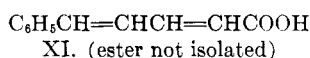
- I. R = C<sub>6</sub>H<sub>5</sub>, R' = C<sub>6</sub>H<sub>5</sub>  
 II. R = C<sub>6</sub>H<sub>5</sub>, R' = *p*-CH<sub>3</sub>C<sub>6</sub>H<sub>4</sub>  
 III. R = C<sub>6</sub>H<sub>5</sub>, R' = CH<sub>3</sub>  
 IV. R = C<sub>2</sub>H<sub>5</sub>, R' = C<sub>2</sub>H<sub>5</sub>



- VII. X = H  
 VIII. X = OCH<sub>3</sub>



- IX. R = CH<sub>3</sub>  
 X. R = C<sub>6</sub>H<sub>5</sub>



In the earlier procedure<sup>3</sup> the condensations were initiated in liquid ammonia, but completed in refluxing ether (two hours). In the present work the condensations were completed in liquid ammonia. The general procedure involved the addition of ethyl acetate to two molecular equivalents of lithium amide in liquid ammonia, followed after fifteen to twenty minutes by one equivalent of the ketone or aldehyde. After one hour the reaction mixture was neutralized with ammonium chloride.<sup>5</sup>

In certain condensations such milder reaction conditions appear to be required to avoid the dehydration of the  $\beta$ -hydroxy ester. Thus, whereas the  $\beta$ -hydroxy esters IV and VII were obtained in the condensations of ethyl acetate with diethyl ketone and benzaldehyde under the present conditions, only the dehydration product of IV and a mixture of the  $\beta$ -hydroxy ester VII and its dehydration product (determined spectrophotometrically) were isolated when the reaction mixture was refluxed in ether.

(5) No significant difference in the yield (81–84%) of  $\beta$ -hydroxy ester I was observed when the neutralization was carried out by adding solid ammonium chloride to the reaction mixture, by pouring the reaction mixture into a solution of ammonium chloride in liquid ammonia, or by replacing the ammonia by ether followed by acidification with cold dilute hydrochloric acid.

TABLE II  
 DERIVATIVES OF KNOWN  $\beta$ -HYDROXY ESTERS

$\beta$ -Hydroxy Ester	Treatment	Product	M.p. or b.p. °			
			Found	Mm.	Reported	Mm.
I	Saponification	$\beta$ -Hydroxy- $\beta,\beta$ -diphenylpropionic acid	M.p. 210-211 <sup>a</sup>		212 <sup>b</sup>	
I	Sapon., Dehyd. (Method A)	$\beta$ -Phenylcinnamic acid	M.p. 161-162 <sup>a</sup>		162 <sup>b</sup>	
III	Dehyd. (Method B)	Ethyl $\beta$ -methylcinnamate	146-149	17	146-148	17 <sup>c</sup>
III	Dehyd., Sapon.	$\beta$ -Methylcinnamic acid	M.p. 97-98 <sup>a</sup>		97-98 <sup>c</sup>	
IV	Dehyd. (Method B)	Ethyl $\beta,\beta$ -diethylacrylate	74-78	13	77	14 <sup>e</sup>
IV	Dehyd., Sapon.	$\beta,\beta$ -Diethylacrylic acid	128-131	23	129	23 <sup>e</sup>
V	Saponification	Cyclohexanolic acid	M.p. 63-64 <sup>f</sup>		62-64 <sup>g</sup>	
VI	Dehyd. (Method C)	Ethylcyclopentylideneacetate	82-84	11	82-84	11 <sup>g</sup>
VI	Dehyd., Sapon.	Cyclopentylideneacetic acid	M.p. 49-50 <sup>a</sup>		49-50 <sup>g</sup>	
VII	Saponification	Cinnamic acid	M.p. 132-133 <sup>h</sup>		133 <sup>i</sup>	
IX	Dehyd., Sapon. (Method D)	$\beta$ -Methyl- $\beta$ -styrylacrylic acid	M.p. 153-153.5 <sup>j</sup>		153 <sup>k</sup>	

<sup>a</sup> Recrystallized from 1:1 methanol-water. <sup>b</sup> H. Rupe and E. Busolt, *Ber.*, **40**, 4537 (1910). <sup>c</sup> S. Lindenbaum, *Ber.*, **50**, 1270 (1917). <sup>d</sup> Recrystallized from 60-90° petroleum ether. <sup>e</sup> G. A. R. Kon and K. S. Nargund, *J. Chem. Soc.*, 2461 (1932). <sup>f</sup> Recrystallized from 1:1 benzene-ligroin. <sup>g</sup> O. Wallach, *Ann.*, **347**, 328 (1906). <sup>h</sup> Recrystallized from benzene. <sup>i</sup> Heilbron, *Dictionary of Organic Compounds*, Vol. I, Oxford University Press, N. Y. (1953) p. 586. <sup>j</sup> Recrystallized from 1:1 ethanol-water. <sup>k</sup> E. P. Kohler and G. L. Heritage, *Am. Chem. J.*, **43**, 484 (1910).

It can be seen from Table I that the yields of  $\beta$ -hydroxy esters I-IV from typical aromatic and aliphatic ketones were good to excellent, those of  $\beta$ -hydroxy esters V and VI from the cyclic ketones fair to good, those of  $\beta$ -hydroxy esters VII and VIII from the aromatic aldehydes fair, and those of IX and X from the  $\alpha,\beta$ -unsaturated ketones good to excellent. The  $\beta$ -hydroxy ester from cinnamaldehyde was not isolated; it was converted to the  $\alpha,\beta$ -unsaturated acid XI in an overall yield of 20%.

These yields are in general comparable to those reported for the Reformatsky reactions, which have usually been employed for the synthesis of  $\beta$ -hydroxy esters. We believe the present method is more convenient than the latter process.

The known  $\beta$ -hydroxy esters were identified by conversion to appropriate derivatives through saponification and/or dehydration. The results are summarized in Table II. In general the yields of the derivatives were good to excellent (50-85%). The new  $\beta$ -hydroxy esters were identified similarly including analysis (see Experimental).

The condensation of ethyl acetate with the  $\alpha,\beta$ -unsaturated ketones or aldehydes was of special interest since 1,4- as well as 1,2- addition was conceivable. That the latter mode of addition occurred was indicated by the infrared absorption spectra which gave absorption at 2.7  $\mu$  for the hydroxyl group, which would not be present in the event of 1,4- addition.

The structure of the  $\beta$ -hydroxy ester IX was established by dehydration and saponification to form the corresponding  $\alpha,\beta$ -unsaturated acid (see Table II). Since attempts to convert  $\beta$ -hydroxy ester X to a suitable derivative were unsatisfactory, this structure must be considered only tentative. The structure of the  $\alpha,\beta$ -unsatu-

rated acid obtained through ethyl acetate and cinnamaldehyde was established as XI by comparison of the melting point and infrared spectrum with an authentic sample prepared from cinnamaldehyde and ethyl malonate, followed by dehydration, saponification, and decarboxylation.<sup>6</sup>

Attempts to condense ethyl acetate with *p*-nitroacetophenone or *p*-nitrobenzaldehyde employing two equivalents of lithium amide and using the inverse addition procedure were unsatisfactory, since only tars were produced or the starting nitro compounds were recovered. The Reformatsky reaction has likewise been reported unsuitable with nitro ketones or aldehydes.<sup>7</sup> However, *t*-butyl acetate has been condensed successfully with certain nitro ketones as aldehydes employing one equivalent of lithium amide.<sup>2</sup>

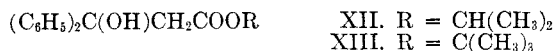
It should be mentioned that an attempt to condense ethyl acetate with benzophenone by means of one equivalent of lithium amide following the general procedure was unsuccessful, although this condensation was realized to form  $\beta$ -hydroxy ester I in 20% yield when a mixture of equivalents of the ester and ketone was added to one equivalent of the reagent. The similar addition of a mixture of the ester and ketone to two equivalents of the reagent produced the  $\beta$ -hydroxy ester I in 43% yield, which is considerably less than that (84%) obtained by the general procedure.

*Results with other esters.* Isopropyl acetate and *t*-butyl acetate were condensed with benzophenone by means of two equivalents of lithium amide by the general procedure to form  $\beta$ -hydroxy esters

(6) B. S. Bansal and K. C. Pandya, *J. Indian Chem. Soc.*, **24**, 443 (1947).

(7) R. L. Shriner, *Org. Reactions*, Vol. I, 2 (1942).

XII and XIII in yields of 80% and 87% respectively.



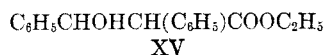
The condensation of *t*-butyl acetate with benzophenone was also effected by means of one equivalent of lithium amide in liquid ammonia following the general procedure to form  $\beta$ -hydroxy ester XIII in 71% yield. *t*-Butyl acetate has previously been condensed with various ketones or aldehydes by means of one equivalent of the reagent<sup>2</sup> but benzophenone was not then studied.

Ethyl propionate was condensed with benzophenone by means of two equivalents of lithium amide by the general procedure to form  $\beta$ -hydroxy ester XIV in 21% yield:



*t*-Butyl propionate has previously been condensed with acetone and acetophenone in yields of 53–58% by means of one equivalent of lithium amide.<sup>2</sup>

The present method failed to effect the condensation of ethyl phenylacetate with benzophenone under the usual conditions and, when forcing conditions were employed, the ester underwent self-condensation to produce ethyl  $\alpha,\gamma$ -diphenylacetoacetate (60%). Ethyl phenylacetate was recently<sup>2</sup> condensed with benzaldehyde by means of one equivalent of lithium amide to form  $\beta$ -hydroxy ester XV in 34% yield. The present method employing two equivalents of lithium amide gave only a 15% yield of this  $\beta$ -hydroxy ester:



#### EXPERIMENTAL<sup>8</sup>

*$\beta$ -Hydroxy esters from ethyl acetate and ketones or aldehydes by lithium amide. General procedure.* In a 1-l. three-necked round bottom flask, equipped with a ball-sealed stirrer, separatory funnel and condenser, was placed 400 ml. of commercial, anhydrous liquid ammonia. To the stirred liquid was added a small piece of lithium metal. After the appearance of the blue color (almost immediately) a few crystals of ferric nitrate were added, followed by small portions of lithium metal until a total of 0.42 mole had been added. After the blue color had been discharged and a grey suspension of lithium amide had formed (about 20 min.), a solution of 0.2 mole (17.6 g.) of ethyl acetate and 50 ml. of anhydrous ether was added during 1 min. After stirring for 20 min., 0.20 mole of the ketone or aldehyde was added during 1 min. At the end of 1 hr. stirring the reaction mixture was neutralized by adding 0.42 mole of solid ammonium chloride. The liquid ammonia was then driven off by means of a hot water bath while adding 200–300 ml. of ether. When the ammonia had been removed, 200 ml. of cold water was added. The ether layer was separated and washed with 1*N* sulfuric acid, saturated sodium bicarbonate solution, and then water, and combined with the ether extracts of the aqueous layers. The ether solution was dried over magnesium sulfate and the solvent was removed. The residue

was then either vacuum distilled, or recrystallized from the appropriate solvent. The results are summarized in Table I.

The known  $\beta$ -hydroxy esters formed were identified, in addition to boiling point or melting point, by the preparation of certain derivatives given in Table II.

*Derivatives of known  $\beta$ -hydroxy esters (Table II).* Saponifications, unless otherwise stated, were accomplished by refluxing the  $\beta$ -hydroxy esters with 20% aqueous sodium hydroxide for 3 hr. Dehydrations were effected by the methods listed below.

*Method A.* Dehydration was effected by refluxing a mixture of the acid, acetic anhydride, and sodium acetate for 3 hr. Water was then added and the acetic acid and anhydride were removed by distillation. The residue was dissolved in sodium carbonate solution, filtered and acidified to give the unsaturated acid.

*Method B.* The  $\beta$ -hydroxy ester was refluxed for 3–4 hr. with three volumes of benzene containing excess phosphorus oxychloride. Water was then added to the cooled mixture and the benzene layer was separated, dried over magnesium sulfate, and then distilled.

*Method C.* The  $\beta$ -hydroxy ester was heated at 130° for 60 min. with solid potassium bisulfate. The resulting mixture was vacuum distilled to yield the unsaturated ester.

*Method D.* The  $\beta$ -hydroxy ester was dehydrated by refluxing with 5*N* hydrochloric acid for 15 hr. The cooled solution was extracted by ether and the ether evaporated to a residue which was saponified by treatment with 3% methanolic potassium hydroxide for 20 hr. at room temperature.

*New  $\beta$ -hydroxy esters prepared by the general procedure.* *Ethyl- $\beta$ -hydroxy- $\beta$ -tolyl- $\beta$ -phenyl propionate (II).* The ether residue was stirred with 95% ethanol in an ice bath to form a white solid, which upon recrystallization two times from ethanol melted at 56–57°. The infrared spectrum showed weak hydroxyl absorption at 2.75  $\mu$  and ester carbonyl absorption at 5.82  $\mu$ .

*Anal.* Calcd. for  $\text{C}_{18}\text{H}_{20}\text{O}_3$ : C, 76.03; H, 7.09. Found: C, 75.73; H, 7.16.

A mixture of 5 g. of III was dehydrated using Method A (see below) and then saponified to yield 1.7 g. (41%) of  $\beta$ -tolyl cinnamic acid, m.p. 139–140° after recrystallization from ethanol water (lit.,<sup>9</sup> m.p. 140°).

*Ethyl- $\beta$ -hydroxy- $\beta,\beta$ -diethyl propionate (IV).* Distillation of the ether residue gave a colorless liquid b.p. 99–102° (13–14 mm.). The infrared spectrum showed strong hydroxyl absorptions at 2.7  $\mu$  and ester carbonyl absorption at 5.75  $\mu$ .

*Anal.* Calcd. for  $\text{C}_9\text{H}_{18}\text{O}_3$ : C, 62.39; H, 10.47. Found: C, 62.64; H, 10.90.

For derivatives see Table II.

*Ethyl- $\beta$ -hydroxy- $\beta$ -anisyl propionate (VIII).* Distillation of the ether residue gave 23 g. (28%) of viscous liquid b.p. 182–186° (17 mm.). Much dark red nondistillable residue remained after the distillation. The product showed hydroxyl absorption at 2.75  $\mu$  and the ester carbonyl absorption at 5.7  $\mu$  in the infrared.

*Anal.* Calcd. for  $\text{C}_{12}\text{H}_{16}\text{O}_3$ : C, 69.20; H, 7.74. Found: C, 69.31; H, 7.62.

Saponification of 8 g. of VI gave 5.5 g. (80% of  $\beta$ -anisyl acrylic acid, m.p. 172–173° (lit.,<sup>10</sup> m.p. 172–173°).

*Ethyl- $\beta$ -hydroxy- $\beta$ -phenyl- $\beta$ -styryl propionate (X).* Evaporation of the ether layer in the general procedure yielded a solid which was recrystallized from 95% ethanol to give X, m.p. 74–75° in 95% yield. The infrared shows weak hydroxyl absorption at 2.75  $\mu$  and ester carbonyl absorption at 5.72  $\mu$ .

*Anal.* Calcd. for  $\text{C}_{19}\text{H}_{20}\text{O}_3$ : C, 77.00; H, 6.80. Found: C, 77.34; H, 6.84.

Attempts to prepare derivatives of X by use of the methods described above all led to intractable materials.

*Simultaneous addition of ethyl acetate and benzophenone to*

(8) Analyses are by Galbraith Microanalytical Laboratories, Knoxville, Tenn.

(9) J. V. Braun, G. Manz, and E. Reinsch, *Ann.*, **468**, 291 (1929).

(10) E. Knoevenagel, *Ber.*, **31**, 2606 (1898).

*lithium amide.* Lithium amide was prepared from 1.4 g. (0.2 mole) of lithium in 400 ml. of liquid ammonia. After 20 min. stirring a mixture of 17.6 g. (0.2 mole) of ethyl acetate and 36.4 g. (0.2 mole) of benzophenone in 150 ml. of anhydrous ether was added. After stirring for 1 hr. the mixture was neutralized and worked up as in the general procedure. By fractional crystallization from ethanol with cooling there was obtained 11.0 g. (20%) of  $\beta$ -hydroxy ester I, m.p. 85–86°, and 21 g. (58%) of benzophenone, m.p. 45–46°.

The above procedure was repeated, except that 0.4 mole of lithium amide was employed rather than 0.2 mole. From the resulting reaction mixture was obtained 25.1 g. (46%) of  $\beta$ -hydroxy ester I, m.p. 84–85°, and 20.0 g. (55%) of recovered benzophenone m.p., 45–46°.

*Isopropyl- $\beta$ -hydroxy- $\beta,\beta$ -diphenyl propionate (XII).* The general procedure was followed using 1.7 g. (0.24 mole) of lithium, 12.5 g. (0.12 mole) of isopropyl acetate, and 21.6 g. (0.12 mole) of benzophenone. The ether residue was recrystallized from ethanol to yield 27.2 g. (80%) of the ester as colorless, rod-shaped crystals, m.p. 101–102°.

*Anal.* Calcd. for  $C_{18}H_{20}O_3$ : C, 76.03; H, 7.09. Found: C, 75.93; H, 7.03.

A 3.0 g. sample of XII was added to 10 ml. of ice cold concentrated sulfuric acid. After standing for 15 min., chipped ice was added and a viscous tan material separated. The material was treated with dilute sodium hydroxide solution and extracted by ether. The aqueous layer was separated and acidified to give 0.7 g. (53%) of  $\beta$ -phenyl cinnamic acid, m.p. 162–163° after recrystallization from a 1:1 methanol-water mixture (lit.,<sup>11</sup> m.p. 162°).

*t-Butyl- $\beta$ -hydroxy- $\beta,\beta$ -diphenyl propionate (XIII).* The general procedure was followed using 1.2 g. (0.34 mole) of lithium, 20 g. (0.17 mole) of *t*-butyl acetate, and 31.5 g. (0.17 mole) of benzophenone. Evaporation of the ether fraction yielded a solid which, upon recrystallization from 95%

ethanol gave 36.4 g. (87%) crystalline ester XII, m.p. 93–94° after recrystallization from ethanol (lit.,<sup>12</sup> m.p. 92–93°).

*Anal.* Calcd. for  $C_{19}H_{22}O_3$ : C, 76.47; H, 7.43. Found: C, 76.23; H, 7.54.

Repetition of the above reaction using one instead of two equivalents of lithium amide gave XII in 71% yield.

Dehydration was accomplished by adding 3 g. of XIII to 10 ml. of ice-cold concentrated sulfuric acid. After 15 min. the slurry was poured onto chipped ice to precipitate a yellow solid. The solid was dissolved in sodium hydroxide solution and the yellow coloration was removed by ether extraction. Acidification of the aqueous layer precipitated 1.9 g. (90%) of  $\beta$ -phenyl cinnamic acid, m.p. 161–162° after recrystallization from 1:1 methanol-water mixture (lit.,<sup>11</sup> m.p. 162°).

*Ethyl- $\beta$ -hydroxy- $\beta,\beta$ -diphenyl isobutyrate (XIV).* The general procedure was followed using 1.7 g. (0.24 mole) of lithium, 12.5 g. (0.12 mole) of ethyl propionate and 22.2 g. (0.12 mole) of benzophenone. The oily ether residue was cooled with stirring in an ice bath to give 7.3 g. (21%) of the ester, m.p. 98–99°.

*Anal.* Calcd. for  $C_{18}H_{20}O_3$ : C, 76.02; H, 7.09. Found: C, 76.03; H, 7.27.

*Ethyl- $\beta$ -hydroxy- $\alpha,\beta$ -diphenyl propionate (XV).* The general procedure was not used here, the reaction previously reported<sup>2</sup> being repeated exactly except that two equivalents of lithium amide were used rather than one. The reaction was carried out using 2.91 g. (0.42 mole) of lithium, 33 g. (0.2 mole) of ethyl phenyl acetate and 21.5 g. (0.2 mole) of benzaldehyde. Distillation of the ether residue gave 8 g. (15%) of ester b.p. 171–176° (3 mm.) (lit.,<sup>2</sup> b.p. 170–175° (2 mm.)).

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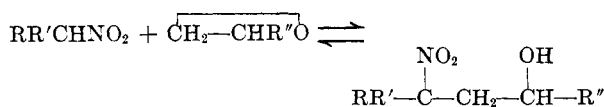
## Reactions of Nitroalkanes with Olefin Oxides

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Acidic mononitroalkanes react with olefin oxides in the presence of pyridine. The products depend upon the nature of the nitroalkane. Nitromethane gives a 1-(2-hydroxyalkyl)pyridinium nitrite and tars, while nitroethane yields 3,4,5-trimethylisoxazole, 1-(2-hydroxyalkyl)pyridinium nitrite, tars and a possible trace of nitroalcohol. Secondary nitroalkanes yield, depending on the steric requirements of the substituted groups, ketones, ketone oximes, 1-(2-hydroxyalkyl)pyridinium nitrite, ditertiary *vic*-dinitroalkane, 1,3-nitroalcohol and tars.

Condensation reactions of acidic mononitroalkanes are known to involve a nucleophilic attack of the corresponding nitronate anion upon an electron deficient center. As olefin oxides usually undergo ring opening by a nucleophilic displacement, one might expect nitroalkanes to condense with olefin oxides to yield as one possible product a 1,3-nitroalcohol:



(1) From the Ph.D. Thesis of Frank J. Donat.

The 1,3-nitroalcohols have not been previously described. In fact, the only reaction of nitroalkanes and olefin oxides appearing in the literature reports an oxime as the principal product.<sup>3a</sup> The role of the olefin oxide is further obscured by the known base-induced transformations of nitroalkanes to oximes.<sup>3b,3c,4,5</sup>

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(4) E. M. Nygaard, J. H. McCracken, and T. T. Noland U. S. Patent **2,370,185**.

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