

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE WASHINGTON SQUARE
COLLEGE OF NEW YORK UNIVERSITY]

A New Synthesis for Alkyl and Aryl Substituted Coumaranes

BY JOSEPH B. NIEDERL AND EDWARD A. STORCH¹

Theoretical Part

Various methods have been applied to the synthesis of coumarane (benzo-dihydrofuran)² and substituted coumaranes.³ Many of the methods reported for the preparation of alkyl and aryl substituted benzo-dihydrofurans do not appear to be completely satisfactory from the standpoint of yield, directness and generality. The process here described appears to be simpler and more direct; it furnishes comparatively good yields and seems to be more widely applicable, since it involves the condensation of an unsaturated alcohol with a phenol.

Alkylated Coumaranes.—Very briefly, the synthesis involves the condensation of allyl alcohol with phenol or cresols in the presence of a sulfuric-glacial acetic acid mixture. After heating the solution for five hours, water is added. The resulting polymer is decomposed pyrolytically. The alkyl substituted coumaranes are obtained along with small quantities of isopropenylphenol.

Allyl Alcohol-*p*-Cresol Condensation.—On depolymerization of the condensation product, a small quantity of an alkali soluble material was obtained along with the alkali-insoluble dimethylcoumarane. The former was identical with 4-methyl-2-isopropenyl phenol (III).⁴ The alkali-insoluble material was shown to be 2,4-dimethylcoumarane (IV) in that it agreed in properties with this product reported in the literature.⁵

The reaction mechanism suggested to explain the formation of the above products is similar to that offered to account for the isopropenylphenols arising from the condensations of allyl alcohol with phenols in the cold, under the influence of sulfuric acid. Fundamentally, it involves addition of the phenol to the double bond in the alcohol. Since the addition of anionoids to the ethylenic linkage cannot be a direct one, it is postulated that sulfuric acid first⁶ adds to the unsaturation and this is eliminated in

(1) From Part II of the thesis presented by Edward A. Storch to the Faculty of the Graduate School of New York University in candidacy for the degree of Doctor of Philosophy.

(2) Alexander, *Ber.*, **25**, 2409 (1892); Stoermer and co-workers, *ibid.*, **34**, 1810 (1901); **36**, 2873 (1903); Rindfus and co-workers, *THIS JOURNAL*, **41**, 665 (1919); **42**, 157 (1920).

(3) Fries and Moskopp, *Ann.*, **372**, 195 (1910); Stoermer, Chydenius and Schinn, *Ber.*, **57**, 72 (1924); Claisen and co-workers, *ibid.*, **58**, 275 (1925); **59**, 2344 (1926); German Patent 279,864 (1914); Schering-Kahlbaum, British Patents 273,684-273,686 (1926); 306,051 (1927); Canadian Patent 278,726; 278,727 (1928); German Patent 501,723 (1926); U. S. Patent 1,679,664 (1928); 1,901,824 (1933).

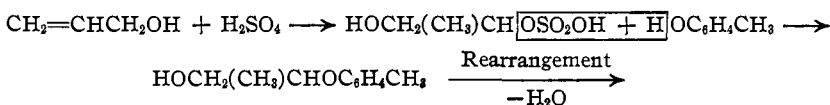
(4) (a) Fries and Fickewirth, *Ann.*, **362**, 46 (1908); (b) Guillaumin, *Bull. soc. chim.*, [4] **7**, 381 (1910); (c) Niederl and co-workers, *THIS JOURNAL*, **53**, 3390 (1931); **55**, 284 (1933).

(5) Schering-Kahlbaum, Jordan, German Patent, 501,723 (1926).

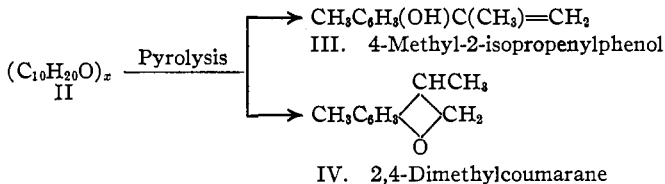
(6) Robinson-Wreschner, "Versuch einer Elektronentheorie organisch-chemischer Reaktionen," F. Enke, Stuttgart, 1932, pp. 14-17.

another sense, involving the phenolic group, to form an ether. Assuming alpha addition of the acid radical to have occurred (the structures of the final products rule out the possibility of beta addition), then the resulting ether would be β -(*p*-cresoxy)-propylene glycol (I).

Repulsion energy data compiled by Latimer⁷ and application of these principles by the authors to a specific case, the isopropenyl aryl ethers, would indicate that ethers of the type I⁸ possess a higher inner energy than the corresponding phenols and under the conditions of the present reaction readily undergo rearrangement. In the presence of sulfuric acid this transition is accompanied by the loss of water from the side chain. This loss may either precede or follow the rearrangement. In any case the resulting product, an alkali insoluble polymer with the empirical formula II, was isolated.



I. β -(*p*-Cresoxy)-propyleneglycol



On distillation under ordinary pressures (slight decomposition took place), depolymerization was effected and the 2,4-dimethylcoumarane (IV) was isolated along with a small quantity of 4-methyl-2-isopropenylphenol (III).

In the condensation of allyl alcohol with *p*-cresol in the presence of sulfuric acid in the cold (0°), the resulting polymer was soluble in alkali. On distillation, the chief product was shown to be 4-methyl-2-isopropenylphenol (III). Therefore it was assumed that the solid condensation product was a polymer of the latter. In the present reaction, carried out at higher temperatures, the polymer differed from the above in that it was insoluble in alkali and on distillation gave rise chiefly to the 2,4-dimethylcoumarane (IV).

Allyl Alcohol-*m*-Cresol Condensation.—This system gave rise to a condensation product which appeared to be a polymer similar to the one discussed above. On pyrolytic decomposition, there was isolated 2,5-dimethylcoumarane and a small quantity of a phenolic product. The latter corresponded with the 5-methyl-2-isopropenylphenol,⁴ while the former, the 2,5-dimethylcoumarane, was found to be identical with the product reported in the literature.⁵

(7) Latimer, *THIS JOURNAL*, **51**, 3185 (1929).

(8) Niederl and Storch, *ibid.*, **55**, 284 (1933).

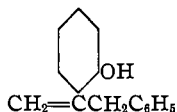
Allyl Alcohol-Phenol Condensation.—The reaction product was a polymer, which on distillation gave rise to a small quantity of a phenolic body and a greater yield of an alkali insoluble product which appeared to be 2-methylcoumarane. The alkali soluble product agreed in physical and chemical properties with *o*-isopropenylphenol,⁹ yielding a crystalline bromine derivative which was identical with the hexabromo compound reported previously.⁸

Allyl Alcohol-*o*-Cresol Condensation.—The polymer resulting from this reaction was decomposed to yield an alkali insoluble product which represented the greater portion of the yield. It appeared to be 2,6-dimethylcoumarane. A very small quantity of a phenolic product was observed which appeared to correspond with the 6-methyl-2-isopropenylphenol known in the literature.¹⁰

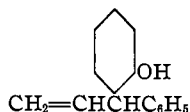
Arylated Coumaranes.—The work was extended to the aromatic series, involving the addition of various phenols to cinnamyl alcohol. In general the experimental procedure employed and the products isolated in the cinnamyl alcohol condensations resembled those obtained with allyl alcohol.

Cinnamyl Alcohol-Phenol Condensation.—The reaction of cinnamyl alcohol and phenol gave rise to a solid polymer which on distillation yielded chiefly an alkali-insoluble product. A small quantity of a phenolic body was observed in the distillate. The reaction appeared to be quite similar to the allyl alcohol-phenol condensations. Neither substance could be crystallized in a bath of solid carbon dioxide and acetone. Analyses of the products indicated that addition of the phenol to the unsaturation in the alcohol had taken place and that a molecule of water had been eliminated.

Assuming the reactions involving phenol formation to be identical with those leading to configuration IV (however, the possibility of beta addition to the ethylenic linkage must be considered as well as alpha addition), then the following structures might be suggested for the phenol isolated here.



V. 3-Phenyl-2-(2-hydroxy)phenylpropene-1
(Alpha addition)



VI. *o*-(α -Phenylallyl)phenol
(Beta addition)

The *o*-(α -phenyl allyl) phenol (VI) has been reported,¹¹ and possesses properties which differ from the phenol obtained in this research. It would appear, then, that the phenylisopropenylphenol (V) is the structure of the present product.

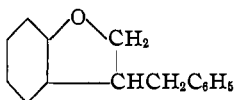
Further evidence for this structure may be obtained from a study of the alkali-insoluble heterocyclic compound. Assuming alpha addition of the

(9) (a) Béhal and Tiffeneau, *Bull. soc. chim.*, [4] 3, 315 (1908); (b) Hoering and Baum, German Patent 208,886 (1909); (c) Fries and Volk, *Ann.*, 379, 95 (1911).

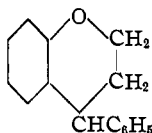
(10) Béhal and Tiffeneau, *Bull. soc. chim.*, [4] 3, 730 (1908).

(11) Claisen and Tietze, *Ber.*, 58, 275 (1925).

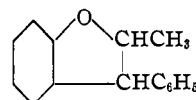
phenol to the unsaturation in the alcohol, the polymer would pyrolyze to yield 2-benzylcoumarane (VII). In like manner, had beta addition been favored, then the resulting polymer might give rise to either a 4-phenylchromane (VIII) or a 1-methyl-2-phenylcoumarane (IX).



VII. 2-Benzylcoumarane



VIII. 4-Phenylchromane

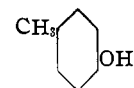


IX. 1-Methyl-2-phenylcoumarane

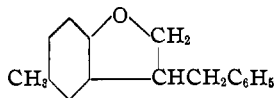
The latter two compounds have been prepared and characterized, the 4-phenylchromane (VIII) by Greenwood and Nierenstein,¹² and the 1-methyl-2-phenylcoumarane (IX) by Claisen and Tietze.¹¹ The compound obtained in this research did not agree with either of these and, therefore, appears to be the 2-benzylcoumarane (VII). Such a conclusion would indicate alpha addition of the phenol to the ethylenic linkage.

Cinnamyl Alcohol-*p*-Cresol Condensation.—On pyrolytic decomposition of the polymer resulting from the condensation of cinnamyl alcohol with *p*-cresol, two liquids, one phenolic in character (in small yield) and the other insoluble in alkali, were obtained. These products resembled in all respects the liquids isolated from the cinnamyl alcohol-phenol condensation.

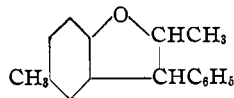
Presupposing alpha addition of the *p*-cresol to the ethylenic linkage in a manner similar to that previously described, then the phenolic product would be 3-phenyl-(2-hydroxy-5-methyl)-phenylpropene-1 (X) and the alkali-insoluble material would have the structure of 2-benzyl-4-methylcoumarane (XI). If beta addition had occurred, then the resulting phenolic product would be *o*-(α -phenylallyl)-*p*-cresol. This product has been reported in the literature¹¹ and differs in properties from the material obtained in this research. With respect to the major fraction obtained by distillation of the polymer, the coumarane structure, beta addition would lead to the formation of 1,4-dimethyl-2-phenylcoumarane (XII).



X. 3-Phenyl-(2-hydroxy-5-methyl)phenylpropene-1



XI. 4-Methyl-2-benzylcoumarane



XII. 1,4-Dimethyl-2-phenylcoumarane

A survey of the literature revealed that this product had not been previously prepared, but that it may be readily synthesized by the method of Claisen and Tietze.¹¹ The 1,4-dimethyl-2-phenylcoumarane (XII) was prepared and found to differ in physical and chemical properties from the

(12) Greenwood and Nierenstein, *J. Chem. Soc.*, **117**, 1594 (1920).

substance obtained in this research. The former yielded a crystalline pentabromo derivative melting at 249°, whereas the latter by the same procedure gave rise to 2,3,5,6-tetrabromo-*p*-cresol.¹³

Cinnamyl Alcohol-*m*-Cresol Condensation.—The condensations were extended to include the reaction of cinnamyl alcohol with *m*-cresol. The two products which were isolated were similar to those obtained in previous condensations. In view of the aforementioned proofs of structure and postulated reaction mechanisms the formation and configuration of the compounds isolated may be readily elucidated. The small quantity of phenolic material appeared to be a phenylisopropenyl-*m*-cresol and the major fraction, 2-benzyl-5-methylcoumarane.

Cinnamyl Alcohol-*o*-Cresol Condensation.—The reaction of cinnamyl alcohol with *o*-cresol was similar in all respects to the condensations previously discussed. The isolated products appeared to be a phenylisopropenyl-*o*-cresol, and 2-benzyl-6-methylcoumarane.

Experimental Part

The Condensation Method.¹⁴—To a solution of molar quantities of allyl (cinnamyl) alcohol and of the phenol (cresols) in 150 cc. of glacial acetic acid, a mixture of 10 cc. of concentrated sulfuric acid in 100 cc. of glacial acetic acid was added. The colorless solution was refluxed for five hours. During the course of the heating the reaction mixture took on a deep red coloration. After allowing to come to room temperature (preferably standing overnight), the solution was poured into excess cold water, the mixture being constantly stirred. With allyl alcohol condensations the reaction product appeared as a viscous oil, while with cinnamyl alcohol an amorphous precipitate was obtained. In any case the supernatant liquid was decanted. The polymerized condensation product was treated with 5% potassium hydroxide solution to remove any unreacted materials as well as traces of acid. It was washed repeatedly, first with hot water and then with cold water, until free from alkali. At this point the material was a solid. It was allowed to dry and then pulverized. The product distilled at ordinary pressure (very slight decomposition took place) as an orange-red liquid, a mixture of a phenol and coumarane. The distillate was collected over a range of 150–350°. The phenolic product, a small fraction of the total yield, was extracted from the mixture by means of a 20% potassium hydroxide solution and the coumarane layer separated. The coumarane, which represents the major portion of the yield (50–65% on the basis of the starting materials), was distilled under ordinary pressure. A small quantity of the phenolic product was obtained by acidification of the potassium hydroxide solution with concentrated hydrochloric acid. The colorless phenol was isolated by distillation of the oily layer under ordinary pressures.

Preparation of Bromine Derivatives.—These were prepared by treating the pure coumarane (or phenol) with an excess of bromine in the cold, without the use of a solvent. The whole was then allowed to stand until all the hydrogen bromide and excess bromine had evaporated. The dark mass was transferred to a porous tile and washed

(13) Bodroux, *Compt. rend.*, **126**, 1283 (1898); Zincke and Buff, *Ann.*, **341**, 327 (1905); Wiederhold, *Ann.*, **320**, 206 (1902); Auwers, *Ber.*, **66**, 464 (1902); Hantzsch and Scholtze, *Ber.*, **40**, 4882 (1907).

(14) Niederl and co-workers, *THIS JOURNAL*, **50**, 2230 (1928); **51**, 2426 (1929); **53**, 272, 806, 1928, 3390 (1931); **54**, 1063 (1932); **55**, 284, 2571, 3025 (1933); *Monatsh.*, **51**, 1028 (1929); **60**, 150 (1932); *Z. angew. Chem.*, **44**, 467 (1931); **46**, 396 (1933).

successively with small quantities of carbon tetrachloride to remove the tarry material and last traces of bromine. Recrystallizations were then effected from carbon tetrachloride.

Acknowledgment is made here to Miss Roslyn T. Roth of this Laboratory for performing the many quantitative micro-analytical determinations.

TABLE I
ALLYL ALCOHOL-PHENOL CONDENSATIONS

Compound	With ferric chloride in alcoholic solution		M. p., °C.	B. p., °C.	
	Products with Phenol				
1 <i>o</i> -Isopropenylphenol ^{8,9,10}	Brown		202-205 (60-62, 5 mm.)		
2 Hexabromo- <i>o</i> -isopropenylphenol ⁸			85-86		
3 2-Methylcoumarane			208-212		
Products with <i>p</i> -Cresol					
4 4-Methyl-2-isopropenylphenol ⁴	Violet, changing to brown		218-222		
5 2,4-Dimethylcoumarane ⁵			228-232 (103, 11 mm.)		
Products with <i>m</i> -Cresol					
6 5-Methyl-2-isopropenylphenol ^{8,9,10}	Green, changing to brown		220-224		
7 2,5-Dimethylcoumarane ⁵			250-255 (99-100, 11.5 mm.)		
Products with <i>o</i> -Cresol					
8 6-Methyl-2-isopropenylphenol ⁸	Green		212-216		
9 Pentabromo-6-methyl-2-isopropenylphenol			190-191		
10 2,6-Dimethylcoumarane			253-258		
	Formula	Sp. gr.	n_D	Carbon, % Calcd. Found	Hydrogen, % Calcd. Found
1	CH ₂ =C(CH ₃)C ₆ H ₄ OH		1.5414 (24°)		
2	C ₉ H ₈ OBr ₆				
3	C ₉ H ₁₀ O	1.028 (25°)	1.5302 (25°)	80.59 80.20	7.46 7.68
4	CH ₂ =C(CH ₃)C ₆ H ₃ (CH ₃)OH		1.5380 (24°)		
5	C ₁₀ H ₁₂ O	1.000 (25°)	1.5281 (25°)	81.08 81.40	8.10 8.20
6	CH ₂ =C(CH ₃)C ₆ H ₃ (CH ₃)OH		1.5399 (23°)		
7	C ₁₀ H ₁₂ O	1.007 (23°)	1.5364 (23°)	81.08 81.45	8.10 8.27
8	CH ₂ =C(CH ₃)C ₆ H ₃ (CH ₃)OH	1.012 (25°)	1.5390 (25°)		
9	C ₁₀ H ₉ OBr ₅			22.01 22.32	1.65 1.32
10	C ₁₀ H ₁₂ O	0.993 (25°)	1.5289 (25°)	81.08 81.35	8.10 8.32

TABLE II
CINNAMYL ALCOHOL-PHENOL CONDENSATIONS

Compound	With ferric chloride in alcoholic solution		M. p., °C.	B. p., °C.
	Products with Phenol			
1 3-Phenyl-2-(2-hydroxy)-phenylpropene-1	Brown		193-196	
2 2-Benzylcoumarane			308-311	
Products with <i>p</i> -Cresol				
3 3-Phenyl-2-(2-hydroxy-5-methyl)-phenylpropene-1	Green		208-212	
4 2-Benzyl-4-methylcoumarane			198-199	
5 2,3,5,6-Tetrabromo- <i>p</i> -cresol ¹³			320-325	
6 1,4-Dimethyl-2-phenylcoumarane ^{11,a}			249	
7 Pentabromo-1,4-dimethyl-2-phenylcoumarane			310-314	
Products with <i>m</i> -Cresol				
8 3-Phenyl-2-(2-hydroxy-4-methyl)-phenylpropene-1	Green, slowly changing to brown		207-211	
9 2-Benzyl-5-methylcoumarane			322-327	
Products with <i>o</i> -Cresol				
10 3-Phenyl-2-(2-hydroxy-3-methyl)-phenylpropene-1	Brown		212-216	
11 2-Benzyl-6-methylcoumarane			318-322	

TABLE II (Concluded)

	Formula	Sp. gr.	n_D	Carbon, %		Hydrogen, %	
				Calcd.	Found	Calcd.	Found
1	$\text{CH}_2=\text{C}(\text{HOC}_6\text{H}_4)\text{CH}_2\text{C}_6\text{H}_5$	0.953 (25°)	1.5027 (25°)	85.71	85.37	6.66	6.43
2	$\text{C}_{15}\text{H}_{14}\text{O}$	1.061 (25°)	1.5760 (25°)	85.71	85.46	6.66	6.46
3	$\text{CH}_2=\text{C}(\text{HOC}_6\text{H}_3\text{CH}_3)\text{CH}_2\text{C}_6\text{H}_5$	1.000 (27°)	1.5314 (27°)	85.71	85.40	7.14	7.36
4	$\text{C}_{16}\text{H}_{16}\text{O}$	1.047 (26°)	1.5778 (26°)	85.71	86.03	7.14	7.53
5	$\text{C}_7\text{H}_4\text{OBr}_4$			19.81	20.32	0.94	0.98
6	$\text{C}_{16}\text{H}_{16}\text{O}$	1.080 (29°)	1.5671 (29°)				
7	$\text{C}_{16}\text{H}_{14}\text{OBr}_5$			31.02	31.39	1.77	1.52
8	$\text{CH}_2=\text{C}(\text{HOC}_6\text{H}_3\text{CH}_3)\text{CH}_2\text{C}_6\text{H}_5$	1.033 (24°)	1.5299 (24°)	85.71	85.75	7.14	7.15
9	$\text{C}_{16}\text{H}_{16}\text{O}$	1.080 (24°)	1.5836 (24°)	85.71	85.38	7.14	7.08
10	$\text{CH}_2=\text{C}(\text{HOC}_6\text{H}_3\text{CH}_3)\text{CH}_2\text{C}_6\text{H}_5$	0.993 (21°)	1.5352 (21°)	85.71	85.56	7.14	7.54
11	$\text{C}_{16}\text{H}_{16}\text{O}$	1.047 (21°)	1.5860 (21°)	85.71	85.40	7.14	7.15

^a This compound was prepared by P. F. Geller and M. Rothstein in conjunction with research work for the Master of Science degree at New York University.

Summary

1. Further studies in the addition reaction of phenols to unsaturated alcohols (allyl alcohol in the aliphatic and cinnamyl alcohol in the aromatic series) have shown that by altering experimental conditions, coumaranes can be obtained.

2. Under the new conditions (elevated temperature and solvent), the chief products were shown to be methylated coumaranes (with allyl alcohol), benzyl and methylbenzyl substituted coumaranes (with cinnamyl alcohol). This affords a new and convenient method for the synthesis of alkyl and aryl substituted benzodihydrofurans.

3. Further work is now in progress extending these studies to polyhydroxy phenols and other unsaturated alcohols (crotyl-, oleyl alcohols) under various reaction conditions.

NEW YORK, N. Y.

RECEIVED JUNE 2, 1933
PUBLISHED NOVEMBER 7, 1933

[CONTRIBUTION FROM THE SCHOOL OF CHEMISTRY AND PHYSICS OF THE PENNSYLVANIA STATE COLLEGE]

Preparation and Reactions of 4,4-Dimethylpentene-1 (Neopentylethylene)

BY FRANK C. WHITMORE AND AUGUST H. HOMEYER¹

The peculiar effects of the presence of a neopentyl system on the nature of a variety of compounds have been studied extensively in this Laboratory.² 4,4-Dimethylpentene-1 was synthesized from *tert*-butylmagnesium chloride and allyl bromide. Addition of hydrogen bromide gave only the primary bromide, 1-bromo-4,4-dimethylpentane. This appears to be the first case in which complete reversal of Markownikoff's Rule³ has been observed in an aliphatic olefinic hydrocarbon. This anomalous behavior is

(1) Mallinckrodt Research Fellow.

(2) Whitmore and co-workers, *THIS JOURNAL*, 1932-1933.

(3) Markownikoff, *Ann.*, **153**, 256 (1870).