infrared spectrum was identical with that of the latter compound (prominent peaks at λ_{max}^{Nujol} 6.27, 6.70, 7.11, 11.2, 12.9, 13.1, 13.5, 14.2 μ).

Oxidation of Chromic Acid Oxidation Product to 4-Phenylacridinic Acid.—A mixture of 1.00 g (3.8 mmoles) of the above chromic acid oxidation product, 0.63 g (5.7 mmoles) of freshly resublimed selenium dioxide, 5 ml of purified dioxane,[13] and 0.3 ml of water was refluxed for 2 hr, after which the hot reaction mixture was filtered to remove the precipitated selenium. The filtrate was diluted with *ca.* 100 ml of water and the resultant suspension was allowed to stand for 30 min. The supernatant liquid was then decanted and the precipitate was collected, washed with water, and dried to give 0.42 g of pale yellow powder, mp 125–135° dec. This product was added to a solution of 1.5 ml of 30% hydrogen peroxide in 15 ml of acetone, and the mixture was refluxed for 1 hr and was then evaporated to a small volume (*ca.* 3 ml) on a steam bath. The residue was diluted with 50 ml of water, and the resultant waxy precipitate was collected, washed with water, and dried. Treatment of this product with acetic anhydride at 120–150° as previously described for the conversion of 4-phenylacridinic acid to 4-phenylacridinic anhydride[14] provided almost colorless crystals, mp 263–265°, after recrystallization from benzene; no melting-point depression was observed when this compound was mixed with an authentic sample of 4-phenylacridinic anhydride (mp 264–266°).

---

[13] L. F. Fieser, "Experiments in Organic Chemistry," 3rd ed, D. C. Heath and Co., Boston, Mass., 1955, p 285, method a.

[14] E. A. Fehnel, J. A. Deyrup, and M. B. Davidson, *J. Org. Chem.*, **23**, 1996 (1958).

Synthesis and Cyclization Reactions of 3-(2-Hydroxybenzylidene)-2(3H)-coumaranones

RODERICH WALTER,

Medical Research Center, Brookhaven National Laboratory, Upton, New York

HANS ZIMMER,

Chemistry Department, University of Cincinnati, Cincinnati, Ohio

AND THOMAS C. PURCELL

Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

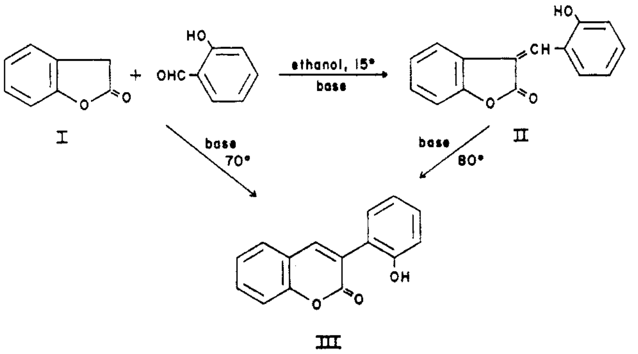
Received June 24, 1966

That aromatic aldehydes condense in the presence of an organic base with the α-methylene group of 2,3-dihydrofuran-2-ones is well established.[1] However, in spite of previous attempts[1b,2] the base-catalyzed preparation of 3-(2-hydroxybenzylidene)-2,3-dihydrofuran-2-ones, in which the phenolic hydroxyl remains free, has yet to be documented.

In the present study the effect of temperature on the aldol condensation of the lactone 2(3H)-coumaranone (I) with 2-hydroxybenzaldehydes was investigated. The results revealed that 3-(2-hydroxybenzylidene)-2(3H)-coumaranones (II) are indeed isolated in high yields (Table I) as long as the condensation is carried out below room temperature. The reaction proceeded most favorably in ethanol at 15° with dropwise addition of triethylamine. From the corresponding coumarin isomers the type II compounds, characterized by their superior solubility in ethanol, ultraviolet absorption at longer wavelengths, and higher lactone carbonyl stretching frequency (1750–1765 cm^{-1}),[1d] are readily distinguishable.

Preliminary experiments revealed that an increase in temperature (25–40°) during the condensation of I with 2-hydroxybenzaldehyde diminished the yield of II while giving rise to an additional product, 3-(2-hydroxyphenyl)coumarin[3] (III, Scheme I). At a still higher temperature (70°) III represented the sole product. Under these rigorous reaction conditions the primary condensation product II evidently underwent intramolecular cyclization *in situ* to the coumarin isomer. Similar results were recorded during the condensation of the lactone with substituted 2-hydroxybenzaldehydes (Table II). These findings recall the isolation of coumarins from the cyclodehydration of 2-hydroxybenzaldehydes with 5-methyl-2,3-dihydrofuran-2-ones[4] and, similarly, with β-aroylpropionic acids and acylglycines.[5,6]

SCHEME I



An unequivocal structure proof in favor of the coumaranone skeleton for the condensation product was advanced by treatment of 3-(2-hydroxy-3,5-dibromobenzylidene)-2(3H)-coumaranone with diazomethane and by subsequent oxidation of the resulting methyl ether with potassium permanganate. The ensuing isolation of 2-hydroxybenzoic acid and 2-methoxy-3,5-dibromobenzoic acid[7] from this reaction mixture can be explained only if a coumaranone, rather than a coumarin, was the original product.

Treatment of II at 80° with an organic base resulted in the expected formation of III in high yields. That these coumaranones also underwent thermocyclization to coumarins at temperatures near their melting point was indicated by decolorization and resolidification of the melt of several type II compounds (see footnotes in Table I).[8] The phenolic coumarins were likewise formed upon irradiation of an ethanolic solution of the corresponding coumaranones with a tungsten lamp. These light-catalyzed cyclizations were accompanied by a hypsochromic shift of the absorption maxima in the ultraviolet region, and the final curve for each compunod was superimposable with the ul-

---

[1] (a) J. Thiele, R. Tischbein, and E. Lossow, *Ann.*, **319**, 180 (1910); (b) W. F. von Oettingen, *J. Am. Chem. Soc.*, **52**, 2024 (1930); (c) E. Erlenmeyer and E. Braun, *Ann.*, **333**, 254 (1904); (d) R. Walter and H. Zimmer, *J. Heterocyclic Chem.*, **1**, 205 (1964).

[2] E. Baltazzi and E. A. Davis, *Chem. Ind.* (London), 1653 (1962).

[3] See the reference in Table II.

[4] D. H. Marrian and P. B. Russel, *J. Chem. Soc.*, 753 (1946).

[5] Y. S. Rao, *Chem. Rev.*, **64**, 353 (1964).

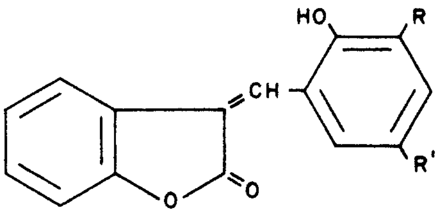
[6] E. Baltazzi, *Quart. Rev.* (London), **9**, 150 (1955).

[7] N. W. Hiwe and B. V. Patil, *Proc. Indian Acad. Sci.*, **5A**, 321 (1937).

[8] The infrared spectra from melts of coumaranones revealed the presence of the corresponding coumarins.

TABLE I

3-(2-HYDROXYBENZYLIDENE)-2(3H)-COUMARANONES

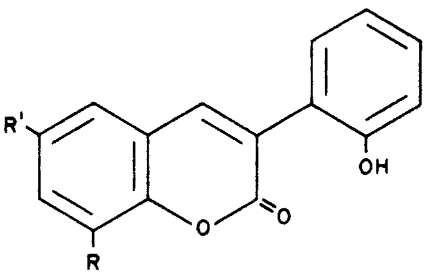


R	R'	Mp, °C	Yield, %	Formula	Carbon, % Calcd	Carbon, % Found	Hydrogen, % Calcd	Hydrogen, % Found	Halogen, % Calcd	Halogen, % Found
H	H	167-168[a]	76	$C_{15}H_{10}O_3$	75.6	75.8	4.23	4.38	—	—
H	Cl	227-229[b]	62	$C_{15}H_9ClO_3$	66.1	66.2	3.33	3.56	13.0	13.0
H	Br	190[c]	82	$C_{15}H_9BrO_3$	56.8	56.6	2.86	2.92	25.2	25.3
H	NO_2	232-234[d]	62	$C_{15}H_9NO_5$	63.6	63.3	3.20	3.40	—	—
Cl	Cl	207	91	$C_{15}H_8Cl_2O_3$	58.6	58.8	2.63	2.74	23.1	23.1
Br	Br	202[e]	93	$C_{15}H_8Br_2O_3$	45.6	45.4	2.04	2.12	40.4	40.3

[a] Turned red at 150-155°. [b] Turned pale at 180-190°. [c] The gold yellow melt solidified immediately and turned pale yellow during the next 15°. The material melted again at 235-236°, this mp corresponds to that of 3-(2-hydroxyphenyl)-6-bromocoumarin. [d] The melt turned colorless. [e] The melt solidified upon further heating and melted at 240° which corresponds to the mp of the 3-(2-hydroxyphenyl)-6,8-dibromocoumarin.

TABLE II

3-(2-HYDROXYPHENYL)-COUMARINS



R	R'	Mp, %	Yield, %	Formula	Carbon, % Calcd	Carbon, % Found	Hydrogen, % Calcd	Hydrogen, % Found	Halogen, % Calcd	Halogen, % Found
H	H	212-213[a]	100	$C_{15}H_{10}O_3$	75.6	76.0	4.23	4.39	—	—
H	Cl	230-231	89	$C_{15}H_9ClO_3$	66.1	66.1	3.33	3.31	13.0	13.2
H	Br	235-236	96	$C_{15}H_9BrO_3$	56.8	57.0	2.86	2.92	25.2	25.2
H	NO_2	236-237	97	$C_{15}H_9NO_5$	63.6	64.1	3.20	3.46	—	—
Cl	Cl	252	84	$C_{15}H_8Cl_2O_3$	58.7	58.7	2.63	2.63	23.1	23.2
Br	Br	240-241	81	$C_{15}H_8Br_2O_3$	45.6	45.6	2.04	1.95	40.4	40.6

[a] Reported mp 208-209°, J. Grimshaw and R. D. Haworth, J. Chem. Soc., 4225 (1956).

traviolet spectrum of its corresponding coumarin. In the case of II the solvent was evaporated after completion of the cyclization and III was identified by melting point. Three isosbestic points were observed in each experiment, indicating that, as in the cases of 3-(2-aminobenzylidene)- and 3-(2-hydroxybenzlidene)-γ-butyrolactones,[9] and 2-phenyl-4-(2-hydroxy-5-methylbenzylidene)-5-oxazolone,[10] the cyclization occurred without the formation of intermediates in any appreciable concentration. The molar absorptivity at each of these three points is recorded in Table III, along with data for the absorption maxima of starting material and product.

TABLE III

ULTRAVIOLET SPECTRA

R	R'	3-(2-Hydroxybenzylidene)-2(3H)-Coumaranones: λ_{max}, mμ	ϵ_{max}	λ_{max}, mμ	ϵ_{max}	λ_{max}, mμ	ϵ_{max}	3-(2-Hydroxyphenyl)-Coumarins: λ_{max}, mμ	ϵ_{max}	λ_{max}, mμ	ϵ_{max}	λ_{max}, mμ	ϵ_{max}	Isosbestic Points[a]: λ mμ	ϵ	λ mμ	ϵ	λ mμ	ϵ
H	H	372	13600	316	6900	243	12000	326	9600	290	7600	272	7400	342	8700	258	5200	216	20000
H	Cl	380	6200	336	9000	245	10300	332	9700	284	9700	272	12000	349	8500	255	7300	234	12000
H	Br	378	11700	312	7800	246	13900	334	11000	286	10300	273	12800	350	9300	356	8900	240	14500
H	NO_2	360	12400	312	13900	234	13800	325	10500	268	24000	225	14000	296	12400	245	12000	230	13500
Cl	Cl	350	9300	310	7500	247	10000	338	9000	292	10500	275	12600	343	9000	255	6000	238	13500
Br	Br	368	9500	316	6800	248	10300	338	8200	292	9600	276	11000	345	8900	252	8300	242	11700

[a] Observed during the light-catalyzed cyclization of type II to type III compounds.

Concurrent investigations are in progress to determine whether a *trans–cis* isomerization precedes the formation of the δ-lactone under treatment of 3-(2-hydroxybenzylidene)-2,3-dihydrofuran-2-ones with base, heat, or light.

The successful synthesis of 3-(2-hydroxybenzylidene)-2(3H)-coumaranones invites attention to the possibility of extending the aldol condensation under proper reaction conditions to more complex polyfunctional 2,3-dihydrofuran-2-ones.

Experimental Section[11]

Procedure for Condensation of 2(3H)-Coumaranone (I) at 15° with 2-Hydroxybenzaldehydes. 3-(2-Hydroxybenzylidene)-2(3H)-coumaranones (II).—A solution (or suspension) of 0.01 mole of I and 0.01 mole of 2-hydroxybenzaldehyde in 3 ml of ethanol was vigorously stirred at 15° while 1 drop of triethylamine was added; in a few instances, it was necessary to add 4 drops over a period of 10 min. The reaction mixture turned yellow and then red while stirring was continued. After 10 to 60 min the product began to crystallize. The reaction was allowed to go to completion within the next 5 hr. After this period ethanol was added to the reaction mixture at room temperature until the solid dissolved. Subsequently, the temperature of the solution was brought to 0°, inducing crystallization of II in yellow needles. The yields were increased by the addition of petroleum ether (bp 30–60°). After recrystallization as described above the melting point remained unchanged.

Condensation Procedure for 2(3H)-Coumaranone at 70° with 2-Hydroxybenzaldehydes. 3-(2-Hydroxyphenyl)coumarins (III).—In a 10-ml flask, equipped with reflux condenser, 0.01 mole of I and 0.01 mole of phenolic aldehyde were dissolved in 3 ml of triethylamine (or pyridine). The mixture was heated in a water bath to 70° for 30 min. The solvent was then removed under reduced pressure, and the resulting solid material was crystallized from a large excess of ethanol.

3-(2-Methoxy-3,5-dibromobenzylidene)-2(3H)-coumaranone.—A solution of 3-(2-hydroxy-3,5-dibromobenzylidene)-2(3H) coumaranone (0.8 g) in 20 ml of methanol was treated with an excess of etheral diazomethane. After 3 hr the solvent was evaporated and the residue was recrystallized from ethanol to yield 0.75 g of 3-(2-methoxy-3,5-dibromobenzylidene)-2(3H)-coumaranone in pale yellow platelets with mp 160–161°. The infrared spectrum exhibited a lactone carbonyl absorption at 1770 cm^{-1}.

Anal. Calcd for $C_{16}H_{10}Br_2O_3$: C, 46.9; H, 2.46; Br, 38.9. Found: C, 46.8; H, 2.43; Br, 38.9.

Oxidation of 3-(2-Methoxy-3,5-dibromobenzylidene)-2(3H)-coumaranone with Potassium Permanganate.—A mixture of 0.7 g of 3-(2-methoxy-3,5-dibromobenzylidene)-2(3H)-coumaranone and 2.0 g of potassium permanganate in 15 ml of water

---

[9] H. Zimmer, F. Haupter, J. Rothe, W. E. Schrof, and R. Walter *Z. Naturforsch.*, **18b**, 165 (1963).

[10] R. Walter, T. C. Purcell, and H. Zimmer, *J. Heterocyclic. Chem.*, **3**, 235 (1966).

[11] Melting points are corrected. Infrared spectra were recorded by a double-beam grating Perkin-Elmer Model 337 spectrophotometer. The samples were measured at a concentration of 0.3% in KBr disks. Ultraviolet spectra were determined on a Cary Model 11 recording spectrophotometer in 95% ethanol.

was refluxed for 2 hr. The manganese dioxide precipitate was removed by filtration from the boiling solution. Acidification of the hot filtrate with 10% sulfuric acid resulted in the crystallization of 2-methoxy-3,5-dibromobenzoic acid, mp 193–194° (lit.[7] 193–194°). These crystals were filtered off as soon as they formed. Upon concentration of the solution a second product, 2-hydroxybenzoic acid, with mp 157–159° (confirmed by an undepressed mixture melting point with authentic material) precipitated.

3-(2-Acetoxyphenyl)coumarin.—One-half gram of III and 0.3 g of anhydrous sodium acetate were refluxed with 10 ml of acetic anhydride for 2 hr. Upon addition of 30 ml of ice–water the acetate crystallized. The material was filtered off and yielded colorless needles upon recrystallization from ethanol, yield 0.25 g, mp 139–140° (lit.[3] mp 137–138°).

Anal. Calcd for $C_{17}H_{12}O_4$: C, 72.9; H, 4.32. Found: C, 73.0; H, 4.47.

Light-Induced Synthesis of 3-(2-Hydroxyphenyl)coumarins.—A stirred 1×10^{-4} *M* solution at 47 ± 0.05° was irradiated for 2–4 hr with a 75-w G.E. tungsten lamp (FG 1096 AX) placed into a water-cooled quartz immersion well (Hanovia Lamp Division, 19434, C.F. Quartz, Engelhardt Industries). At timed intervals a sample was taken and its absorption spectrum was scanned in the 220- to 400-mμ range. The final curve was superimposable with the ultraviolet spectrum of a 1×10^{-4} *M* solution of authentic III.

Base-Catalyzed Cyclization of 3-(2-Hydroxybenzylidene)-2(3H)-coumaranones.—Two-tenths of a gram of II was heated to 80° in 2 ml of triethylamine (or pyridine). Within a few minutes the color of the solution turned from deep red to yellow. After 1 hr the solvent was evaporated and the residue was recrystallized from ethanol. The δ-lactones III were isolated in almost quantitative yields, and their identity was established by undepressed mixture melting points and by comparison of their infrared spectra with those of authentic material.

Acknowledgments.—This work was supported by the U. S. Atomic Energy Commission and by U. S. Public Health Grant No. GM-08797 of the National Institutes of Health, Bethesda, Maryland. The authors wish to thank Dr. J. Z. Ginos for valuable discussion.

Sterically Hindered Group IVa Organometallics. VI.[1] Preparation and Some Properties of Neophyltins and Related Compounds

Hans Zimmer, Otto A. Homberg,[2] and
Madhusudan Jayawant

*Department of Chemistry, University of Cincinnati,
Cincinnati, Ohio*

Received May 12, 1966

In the course of our investigations into sterically hindered group IV-A organometallics, we prepared several previously unreported organotin compounds containing the 2,2-dimethyl-2-phenylethyl (neophyl), the 2-phenylpropyl, the 3-phenylpropyl, and the 2,2,4-trimethylpentyl groups. In addition several more as yet unreported neopentyltins were prepared.[3] The typical reactions associated with this bulky group were again observed. The formation of the tetrasubstituted compounds proceeded rather sluggishly only with groups having a "neo" structure, though it occurred faster with these substituted "neo" structures than with the parent neopentyl group. On the other hand, no significant decrease in the tendency of the formation of tetrakis(2-phenylpropyl)tin and tetrakis(3-phenylpropyl)tin was observed. These findings seem to permit the conclusion to be drawn that the formation of symmetrically tetrasubstituted organotins is most difficult if an aliphatic neopentyl type group is involved. That not only size and thus steric effects play a role was demonstrated by the fact that tetraneophyltin was formed in a higher yield than was the case with any of the other "neo" structures. Only one bulky group either at the β or γ position of the alkyl chain does not effectively interfere with the formation of the corresponding tetrasubstituted organotin compound. Also, only those tetrasubstituted organotins which have a "neo" structure react sluggishly with bromine and do not undergo the Kozechkov reaction. Among the organotins containing a "neo" group the tetraneophyltin was more reactive than its aliphatic analogs, again pointing to the fact that steric hindrance is not solely responsible for the chemical behavior of this type of compound. Noteworthy also is the failure to obtain tris(2,2,4-trimethylpentyl)tin bromide by treating tetrakis(2,2,4-trimethylpentyl)tin with bromine. Instead of undergoing the expected Sn–C bond cleavage reaction considerable amounts of HBr were generated. When preparing this manuscript an article by Reichle appeared in which several neophyltins were reported.[4] Specifically compounds **7**, **12**, and **18** (see Table I) were described also by this author. There are, however, two noteworthy differences in the results: one, while we found 12 to be formed in a 27% yield, Reichle reported a yield of 8.8%; two, we definitely characterized compound 14 as bis(trineophyltin) oxide by virtue of a C–H analysis and lack of an OH absorption peak in the 3600–3000-cm area of the infrared spectrum.

The position of the neopentyl group in the cleavage series of Bullard[5] was found to be below the *n*-pentyl group. Di-*n*-pentyldineopentyltin was cleaved by bromine to yield dineopentyltin bromide. In Scheme I are listed the reactions involving organotin substituted by the neopentyl group.

Scheme I

$$\mathrm{Pent_2SnCl_2} \xrightarrow{\mathrm{NeopMgCl}} \underset{1}{\mathrm{Pent_2Neop_2Sn}} \xrightarrow{\mathrm{Br_2,\ \Delta}}$$

$$\underset{2}{\mathrm{Neop_2SnBr_2}} \xrightarrow{\mathrm{CH_3CO_2Na}} \underset{3}{\mathrm{Neop_2Sn(OAc)_2}}$$

$$\mathrm{Bu(Neop)_2SnBr} \xrightarrow[\text{2. HOAc}]{\text{1. NaOH}} \underset{5}{\mathrm{Bu(Neop)_2SnOAc}}$$

$$\mathrm{Neop_3SnCl} \xrightarrow[\text{2. HOAc}]{\text{1. NaOH}} \underset{4}{\mathrm{Neop_3SnOAc}}$$

Bu = *n*-butyl
Pent = *n*-pentyl
Neop = neopentyl

In Scheme II the reactions involving the neophyl and the 3-phenylpropyl groups are summarized. Table I contains a summary of all new compounds prepared together with their analyses and some pertinent physical constants.

---

[1] Part V of this series: H. Zimmer and O. A. Homberg, *J. Org. Chem.*, **30**, 947 (1966).

[2] Part of Ph.D. Thesis, University of Cincinnati, 1965.

[3] H. Zimmer, I. Hechenbleikner, O. A. Homberg, and M. Danzik, *J. Org. Chem.*, **29**, 2632 (1964).

[4] W. T. Reichle, *Inorg. Chem.*, **5**, 87 (1966).

[5] R. H. Bullard, *J. Am. Chem. Soc.*, **51**, 3065 (1929).