butylammonium iodide, 50% dioxane solution, the solution around the drop is no longer acid and a second type of reduction occurs.

The nature of this reduction is not clear but it may possibly be a reduction of the pseudo acid. This same type of reduction appears with some of the anhydrides. In buffered media where the acid is present as an anion, the ion must exist in the open form since the half-wave potential changes with *p*H. Such a behavior is in agreement with absorption spectra data obtained in dilute alkali.[2]

No definite structures can be assigned to the anhydrides due to the fact that they are hydrolyzed or interact with the more alkaline buffer II. The mixed acetic anhydride is largely hydrolyzed in both buffers, and gives a reduction wave characteristic of the 2-benzoylbenzoate ion. The anhydride and 3,3′-diphenyldiphthalyl sulfide are apparently stable in buffer I. The approximately equal reduction potentials observed for these two compounds in buffer I would suggest similar structures provided no interaction has occurred with the buffer.

Experimental

The current–voltage curves were determined with a Model XI, Heyrovsky Polarograph having a current scale calibrated in microamperes. Curves for anthraquinone in buffer I and II were obtained with a Fisher Elecdropode. No changes in anode potential with increasing potential was observed with either of these buffers.

The electrolysis cell had a simple cylindrical shape with a mercury pool anode and was provided with side arms for anode connections and for admission of nitrogen for the removal of dissolved oxygen. Anode potentials were measured against a saturated calomel electrode (S. C. E.) by using a sintered glass salt bridge of the type described by Laitinen.[7]

The dropping mercury electrode had the following characteristics. At a pressure of 46.5 cm. of mercury, the drop time in the solvent used was 3.34 seconds (open circuit). The value of m was 2.05 mg. sec.$^{-1}$ with a calculated value of $m^{2/3}t^{1/6}$ of 1.973 mg. $^{2/3}$ sec.$^{-1/2}$.

Materials.—The solutions used had the following compositions and anode potentials: 0.1 *M* tetrabutylammonium iodide,[8] 50% dioxane, anode potential, −0.400 volt; 0.1 *M* hydrochloric acid, 50% dioxane, anode potential, −0.249 volt.

Buffer I.—A mixture which was 0.172 *M* in tetramethylammonium hydroxide, 0.1 *M* in tetramethylammonium iodide, 0.102 *M* in phosphoric acid and 50% dioxane by volume, anode potential, −0.390 volt.

Buffer II.—A mixture which was 0.196 *M* in tetramethylammonium hydroxide, 0.10 *M* in tetramethylammonium iodide, 0.092 *M* in phosphoric acid and 50% dioxane by volume, anode potential, −0.382 volt.

2-Benzoylbenzoic acid, benzophenone, benzoic acid, ethyl benzoate and anthraquinone were obtained from stock. The aromatic esters,[5a,9] 3-phenylphthalide,[10] 4′-hydroxydiphenylphthalide,[11] anhydrides,[12] 3,3′-diphenyldiphthalyl sulfide,[13] methyl,[4] and ethyl esters[3] were prepared by appropriate methods given in the literature.

Summary

The polarographic method is a suitable means of distinguishing between the cyclic and normal esters of 2-benzoylbenzoic acid.

The anhydrides of 2-benzoylbenzoic acid cannot be assigned structures with certainty since they hydrolyze in more alkaline solutions.

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[7] H. A. Laitinen, *Ind. Eng. Chem., Anal. Ed.*, **13**, 393 (1941).

[8] Laitinen and Wawzonek, This Journal, **64**, 1765 (1942).

[9] The authors wish to thank Dr. F. F. Blicke for small amounts of the isomeric thiophenyl and B-naphthyl esters which were used for mixed melting points with the compounds prepared for this study.

[10] Ullmann, *Ann.*, **291**, 23 (1896).

[11] Blicke and Swisher, This Journal, **56**, 923 (1934).

[12] Freiherr and Von Pechmann, *Ber.*, **14**, 1865 (1881).

[13] O'Brochta and Lowy, This Journal, **61**, 2766 (1939).

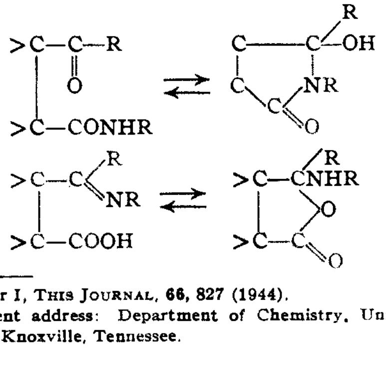
Knoxville, Tenn. Received January 31, 1944

[Contribution from the Noyes Chemical Laboratory, University of Illinois]

The Behavior of γ-Keto- and Aldehydo-Acid Derivatives at the Dropping Mercury Electrode. II. Amides of 2-Benzoylbenzoic Acid[1]

By S. Wawzonek,[2] H. A. Laitinen and S. J. Kwiatkowski

Amides of γ-keto- and aldehydo-acids can exist in two isomeric forms and can exhibit ring-chain tautomerism of the types



Chemical evidence can indicate what type of ring-chain tautomerism exists or is possible but does not as a rule denote which form is the predominant one.

In this paper the use of the polarograph as a means of ascertaining the type and the approximate amount of ring-chain tautomerism present with amides of 2-benzoylbenzoic acid will be presented.

Results

The behavior of various amides of 2-benzoylbenzoic acid and their derivatives was studied in both unbuffered and buffered media. A summary of the observed half-wave potentials and individual diffusion current constants in the various solutions is given in Table I.

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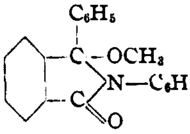
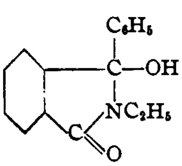
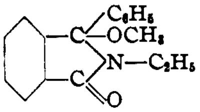
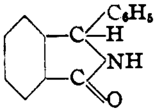
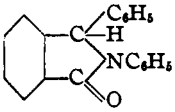
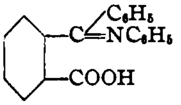
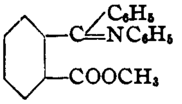
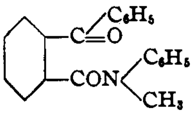
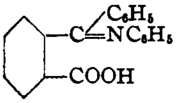
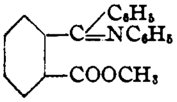
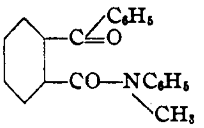
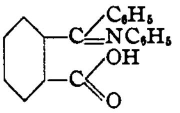
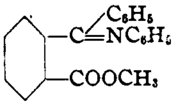
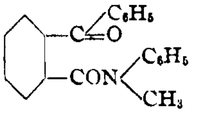
(1) Paper I, This Journal, **66**, 827 (1944).

(2) Present address: Department of Chemistry, University of Tennessee, Knoxville, Tennessee.

TABLE I

HALF-WAVE POTENTIALS AND DIFFUSION CURRENT CONSTANTS FOR THE AMIDES OF 2-BENZOYLBENZOIC ACID, THEIR DERIVATIVES AND RELATED COMPOUNDS IN VARIOUS SOLUTIONS

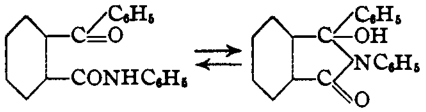
Compound	$\pi_{1/2}$ vs. S. C. E. volts	i_d, microamperes	c, millimoles/liter	i_d/c microamperes/millimole/liter
0.1 *M* Tetrabutylammonium Iodide, 50% Dioxane				
n-Anilide	1.48	3.12	1.00	3.12
(m. p. 195°)	max.	0.91		0.91
	2.20	3.59		3.59
	1.88	4.62	1.33	3.48
	2.20	5.56		4.19
Amide	1.52	1.36	1.00	1.36
	1.94	2.53		2.53
	2.26	4.42		4.42
	2.06	4.42	1.99	3.56
	2.22	5.74		4.54
	1.95	3.59	0.90	4.00
	2.38	5.19		5.76
	2.25	4.16	1.00	4.16
	2.16	4.42	1.00	4.42
	0.96	1.74	1.00	1.74
	1.70	2.21		2.21
	1.42	3.77	1.00	3.77
	2.11	5.85		5.85
	1.46	3.64	1.00	3.64
	1.97	6.37		6.37
Benzamide	1.82	10.14	1.10	9.21
Buffer I				
	1.15	2.24	0.82	2.72
	1.32	3.14	0.92	3.43
	1.30	4.92	1.16	4.24
Buffer II				
	1.61	4.36	1.01	4.33
	1.45	3.83	0.85	4.52
	2.15	5.02		5.94
	1.48	3.61	1.12	3.22
	2.05	4.38		3.91

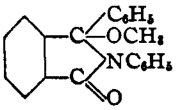
In general all of the compounds gave well-defined reduction waves. Maxima could be suppressed in most cases by means of gelatin. The buffers used are the same as those reported in the first paper.[1] No curves were obtained for the amide or anilide (195°) in buffer I.

Discussion of Results

An examination of the half-wave potentials obtained in 0.1 *M* tetrabutylammonium iodide, 50% dioxane solution indicates that the amides and their derivatives are reduced in most cases to the corresponding 1-keto-3-phenylisoindole. In each case the final wave obtained corresponds to the values obtained for the related 1-keto-3-phenylisoindole. Both forms apparently yield the same reduction product through mechanisms similar in nature to those proposed for the production of 3-phenylphthalide from the normal and cyclic esters.[1] The normal N-methylanilide and anil-type compounds are reduced in a slightly different manner and will be discussed later.

The anilide (195°) assigned an open structure by Meyer[3] gave three waves. The first wave at 1.48 volts must be due to the reduction of the open form I since such a wave is not shown by the methyl ether (III). The second wave which could not be measured because of a maximum is due to the reduction of the cyclic form (II) and would without doubt be similar in value to the first wave obtained for the methyl ether (III). Disappearance of the wave at 1.48 volts in buffer 1


I II


III

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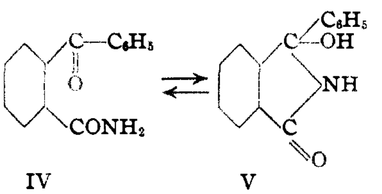
(3) Meyer, *Monatsh.*, 28, 1211 (1907).

indicates that alkali easily converts the open form (I) into the cyclic form (II). Comparison of the diffusion current constants of the first two waves would indicate that the anilide (195°) is almost completely present as the open form (I). The small amount of the cyclic form (II) present may be produced by the hydroxide ions formed at the mercury drop during the reduction.[4]

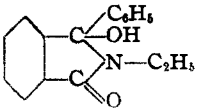
The amide is very similar to the *n*-anilide (195°) in its behavior giving three waves, the first at 1.52 volts disappearing in buffer I. Such a behavior together with a comparison of the diffusion current constants for the first two waves would



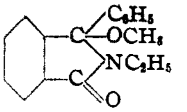
IV V

indicate an equilibrium structure for the amide in which approximately one-third is present as the open form (IV) and the remainder as the cyclic derivative (V).

The N-ethylamide (VI) gives only two waves which are very similar to those obtained for its methyl ether (VII). Such a behavior points to the existence of the N-ethylamide entirely in the cyclic form.

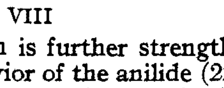


VI

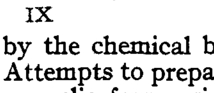


VII

The anilide (221°), which has been assigned the cyclic form (II) in neutral solution by Meyer,[3] exhibits a behavior at the dropping mercury electrode which is not in accordance with this structure. In unbuffered medium this compound's behavior resembles that of 2-benzoylbenzoic acid[1] in that an early reduction is obtained at 0.96 volt. This wave represents without doubt the reduction of the anil grouping in acid medium, the acid being provided by the compound itself. Such a behavior would point to structure VIII for the compound in neutral or acid medium. This formulation is further strengthened by the chemical behavior of the anilide (221°). Attempts to prepare the methyl ether (III) of the cyclic form using methanol and hydrochloric acid gave only the normal methyl ester of 2-benzoylbenzoic acid.



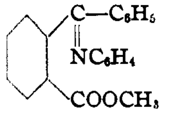
VIII



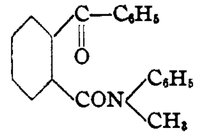
IX

The behavior of the anilide (221°) in buffer I is somewhat irregular. The low diffusion current constant and positive half-wave potential (−1.15 volts) obtained are not in agreement with an anil structure for this compound in this buffer. The values would be expected to be similar to those obtained for the methyl ester (X). If the compound had a cyclic structure (IX), the value would likewise be expected to be more negative since cyclic forms are more difficult to reduce. In buffer II the value of −1.60 volts obtained is in agreement with the anil structure (VIII). The much more negative half-wave potential obtained for this compound than for the methyl ester (X) illustrates the effect of a carboxylate ion on the reduction of the anil group. A similar effect can be seen from a comparison of the half-wave potentials of 2-benzoylbenzoic acid and the normal methyl ester in buffer I.[1]

The methyl ester of the anil (X) and the N-methylanilide (XI) behaved rather similarly in buffered and unbuffered media. In buffered media they resembled benzophenone[1] since their half-wave potentials varied with *p*H, and therefore they must have structures X and XI. In unbuffered media the final waves obtained would indicate the formation of an isoindole and 3-phenylphthalide, respectively. The high diffusion currents obtained however preclude the formation of such compounds, instead pointing to the reductions of the ester and anilide groupings respectively, since the values obtained are of approximately the same magnitude as has been observed for ethyl benzoate and benzamide.



X



XI

Experimental[5]

The conditions and electrode used were exactly the same as described in the first paper of this series.[1]

Materials.—The amide,[6] anilides, anil, methyl ester of the anil, 1-keto-2,3-diphenylisoindole,[3] 1-keto-3-phenylisoindole[7] and N-ethylamide[8] were prepared by appropriate methods given in the literature.

1-Keto-2,3-diphenyl-3-methoxyisoindole (III).—A solution of the anilide (195°) (I) (1.0 g.) in thionyl chloride (10 ml.) was allowed to stand at room temperature for one hour. The excess thionyl chloride was removed under reduced pressure, the resulting solution treated with methanol (75 ml.) and allowed to stand for twelve hours. Addition of water followed by concentration in an air stream gave a white solid (1.0 g.) melting at 125–128°. After two recrystallizations from methanol the compound melted at 128–129°.

Anal. Calcd. for $C_{21}H_{17}O_2N$: C, 80.00; H, 5.40. Found: C, 79.97; H, 5.66.

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(4) The estimation of the relative concentrations of the two tautomeric forms relative wave heights is based on the assumption that the rate of the tautomeric shift at the electrode surface is negligibly slow. Two opposing effects should be recognized. A shift to the more easily reduced open form because of its depletion would cause an abnormally high first wave to be obtained. However, the opposite shift is catalyzed by the hydroxyl ions produced at the electrode surface. The estimates of relative amounts of cyclic and open forms should be considered only semi-quantitative.

(5) Melting points are not corrected.

(6) Graebe and Ullmann, *Ann.*, **291**, 8 (1896).

(7) Rose, This Journal, **33**, 388 (1911).

(8) Sachs and Ludwig, *Ber.*, **37**, 388 (1904).

The compound could likewise be prepared in the following manner. A solution of the anilide (195°) (I) (1.0 g.) in methanol (100 ml.) treated with concentrated hydrochloric acid (2 ml.), was allowed to stand at room temperature for seven hours and then refluxed for eleven hours. The resulting solution was neutralized with a sodium carbonate solution, treated with water until precipitation occurred and then concentrated with an air stream. The white solid (1.0 g.) obtained melted at 128–129° and was identical with the compound from the thionyl chloride method.

The anil (221°) (VIII) when treated in a similar fashion to the above gave the normal methyl ester of 2-benzoylbenzoic acid.

Hydrolysis of 1-Keto-2,3-diphenyl-3-methoxyisoindole (III).—A solution of 1-keto-2,3-diphenyl-3-methoxyisoindole (III) (1.0 g.) in acetic acid (20 ml.) and concentrated hydrochloric acid (2 ml.) was allowed to stand for seventeen hours at room temperature. During this time white crystals (0.60 g.) melting at 195–197° separated. An additional amount (0.25 g.) was obtained by addition of water to the filtrate. A mixture with the anilide (195°) (I) gave no lowering when melted together.

1-Keto-2-ethyl-3-methoxy-3-phenylisoindole (VII).—A solution of the N-ethylamide (VI) (1.0 g.) in thionyl chloride (10 ml.) was allowed to stand at room temperature for twenty minutes. The excess thionyl chloride was removed under reduced pressure, methanol (50 ml.) added and the resulting solution allowed to stand at room temperature for eleven hours. Addition of water gave an oil which was taken up in ether and washed with a sodium carbonate solution. Removal of the ether gave an oil which gave white crystals (0.72 g.) upon the addition of 30–60° petroleum ether. After two crystallizations from the same solvent the compound melted at 73–75°.

Anal. Calcd. for $C_{17}H_{17}O_2N$: C, 76.40; H, 6.36. Found: C, 76.33; H, 6.68.

The compound (VII) could likewise be prepared in the following way. A solution of the N-ethylamide (VI) (1.0 g.) in methanol (40 ml.) and concentrated hydrochloric acid (1 ml.) was allowed to stand at room temperature for fourteen hours and then refluxed for ten hours. Neutralization with sodium carbonate followed by concentration in an air stream gave an oil which formed white crystals (0.45 g.) melting at 75–78° which were identical with the above (VII).

Hydrolysis of 1-Keto-2-ethyl-3-methoxy-3-phenylisoindole (VII).—A solution of 1-keto-2 ethyl-3-methoxy-3-phenylisoindole (VII) (0.5 g.) in a mixture of glacial acetic acid (10 ml.) and concentrated hydrochloric acid (1 ml.) was allowed to stand for twelve hours and poured into water. The N-ethyl amide (VI) (0.4 g.) thus obtained melted at 170–173° and gave no lowering when mixed with an authentic sample.

Normal N-Methyl Anilide (XI).—To a cold solution of the acid chloride of 2-benzoylbenzoic acid, prepared from the acid (7.5 g.) and thionyl chloride, in benzene (20 ml.), methylaniline (10 ml.) in dry benzene (10 ml.) was added and the resulting solution allowed to stand for twenty-four hours at room temperature and then poured into water. Extraction with ether followed by washing with dilute acid and sodium bicarbonate gave an oil upon removal of the solvent. The oil upon being taken up in a mixture of benzene and (80–90°) petroleum ether gave, after treatment with norite and aluminum oxide, upon cooling, white crystals (1.5 g.) (XI) which melted at 125–140°. Two crystallizations from the same mixture gave white crystals melting at 144–146°.

Anal. Calcd. for $C_{21}H_{17}O_2N$: C, 80.00; H, 5.39. Found: C, 80.23; H, 5.49.

Summary

The polarographic method offers a suitable means of ascertaining the type and the approximate amount of ring-chain tautomerism present with amides of 2-benzoylbenzoic acid.

KNOXVILLE, TENN. RECEIVED JANUARY 31, 1944

[CONTRIBUTION FROM THE RESEARCH DIVISION OF THE GENERAL PRINTING INK CORPORATION]

Orientation in the Biphenyl System.[1] Derivatives of 2-Aminobiphenyl[2]

BY A. H. POPKIN, G. M. PERRETTA AND R. SELIG

As a continuation of the studies of orientation in the biphenyl system, it was decided to prepare 2-dimethylaminobiphenyl and to observe its behavior in various reactions. This compound should prove more versatile than the 4-isomer[3] because of the possible existence of an activated hydrogen in the 5 position in competition with the known activity of the 4′ hydroxygen.[1,4]

Evans and Williams[5] reported the preparation of 2-dimethylaminobiphenyl in 94% yield from the reaction of dimethyl sulfate on 2-aminobiphenyl. In duplicating this reaction, a 92% yield of methylated product was obtained. On treatment with acetic anhydride followed by distillation, 2-dimethylaminobiphenyl and 2-(N-methyl)-acetamidobiphenyl were obtained in 66:34 ratio. This indicates that the yield previously reported is for a mixture of dimethyl and monomethyl compounds rather than pure dimethyl compound.

The action of methyl alcohol and sulfuric acid on 2-aminobiphenyl at elevated temperature and pressure gave 82–85% yields of a methylated mixture. This when acetylated was found to consist of 2-dimethylaminobiphenyl and 2-(N-methyl)-acetamidobiphenyl in the ratio of 87:13. The identity of the latter was established by analysis and synthesis in 84% yield by the reaction of sodium and methyl iodide on a solution of 2-acetamidobiphenyl in dry xylene.

2-(N-Methyl)-acetamidobiphenyl showed a greater stability toward hydrolysis than 2-acetamidobiphenyl and its derivatives[6] which is in agreement with the observation of Schoorl[7] on the stability of N-methylacetanilide.

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(1) Previous paper, Popkin and McVea, THIS JOURNAL, **66**, 796 (1944).

(2) Presented before the Division of Organic Chemistry, Cleveland meeting of the American Chemical Society, April, 1944.

(3) Banus and Tomas, *Anal. Fis. Quim.*, **19**, 293 (1921); Vorländer, *Ber.*, **58**, 1913 (1925); Bell and Kenyon, *J. Chem. Soc.*, 2705 (1926); Kenyon and Robinson, *ibid.*, 3050 (1926).

(4) Popkin, THIS JOURNAL, **65**, 2043 (1943).

(5) Evans and Williams, *J. Chem. Soc.*, 1199 (1939).

(6) Popkin and Perretta, THIS JOURNAL, **65**, 2046 (1943).

(7) Schoorl, *Pharm. Weekblad*, **78**, 433 (1941).