Beckmann Rearrangement of Some Benzophenone Oximes Having an *ortho*-N-Substituted Carboxamide or Sulfonamide Group Leading to Cyclization[1]

HAMAO WATANABE, CHUNG-LING MAO, AND CHARLES R. HAUSER

Department of Chemistry, Duke University, Durham, North Carolina 27706

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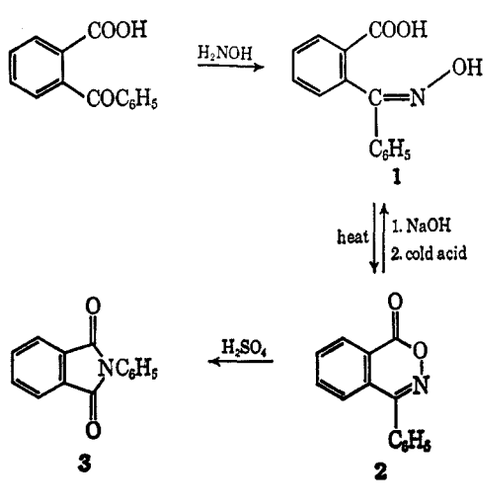
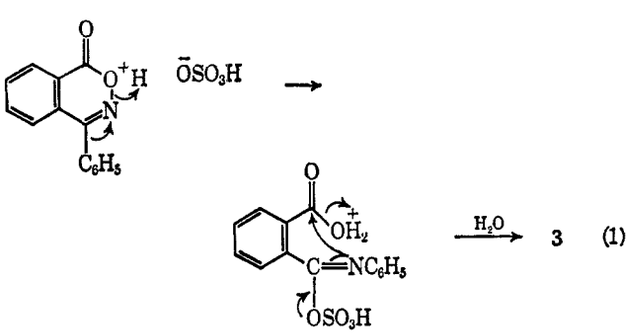
Although oximation of *o*-benzoylbenzoic acid is accompanied by cyclization to form the lactone, ring opening of this lactone with sodium hydroxide and lithiobenzylamine to form the corresponding oxime acid and oxime amide was achieved. These *ortho*-substituted benzophenone oximes underwent Beckmann rearrangement, accompanied by cyclization, with phosphorus pentachloride to form phthalanil; also, the intermediate diamide was isolated from the oxime amide. In contrast, benzophenone oximes having an *ortho*-N-substituted sulfonamide group were prepared by oximation of corresponding imine sulfonamides and found to undergo rearrangement accompanied by a different type of cyclization, with phosphorus pentachloride to form saccharin anils. Possible mechanisms and reasons for the different modes of cyclization are considered, and the synthetic utility of some of the reactions is indicated.

It has previously been shown that oximation of *o*-benzoylbenzoic acid to form oxime acid **1** is accompanied by cyclization to give lactone **2**,[2,3] and that treatment of **2** with concentrated sulfuric acid affords phthalanil (**3**)[4] (Scheme I).

SCHEME I



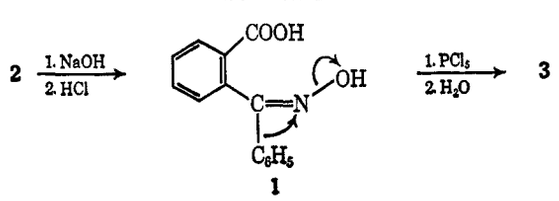
The conversion of lactone **2** into phthalanil (**3**) was apparently assumed to involve ring opening to form oxime acid **1** which underwent a Beckmann rearrangement accompanied by cyclization.[4] However, rearrangement of lactone **2** without intermediate formation of **1** now seems more likely (eq 1).



In the present investigation oxime acid **1** and, more significantly, certain related oxime amides and oxime sulfonamides were found to undergo interesting rearrangement–cyclizations with phosphorus pentachloride.

Although oxime acid **1** was not prepared satisfactorily by oximation of *o*-benzoylbenzoic acid (see Scheme I),[2] **1** was obtained by ring opening of lactone **2** with aqueous sodium hydroxide, and found to undergo rearrangement–cyclization with phosphorus pentachloride in tetrahydrofuran (THF) to form phthalanil (**3**) (Scheme II).

SCHEME II



Similarly, oxime amide **4** was prepared by ring opening of lactone **2** with lithiobenzylamine in THF and found to undergo rearrangement and/or rearrangement–cyclization with phosphorus pentachloride in ether or THF to form diamide **5** and phthalanil (**3**), respectively (Table I). Diamide **5** was independently synthesized from N-benzylbenzamide (**6**) and phenyl isocyanate by means of *n*-butyllithium (Scheme III).[5]

TABLE I

YIELDS OF DIAMIDE 5 AND PHTHALANIL (3) FROM OXIME AMIDE 4 WITH PHOSPHORUS PENTACHLORIDE UNDER VARIOUS CONDITIONS

Solvent	Reaction temp, °C	Nature of medium	Yields % 5	Yields % 3
Ether	0[a]	Heterogeneous	90	
Ether	35	Heterogeneous	6	85
THF	0[a]	Homogeneous		74
THF–ether	0[a]	Homogeneous	10	60

[a] The latter part of the reaction may have occurred at 25–30° (see Experimental Section).

(1) Supported by Army Research Office (Durham) and by the National Science Foundation.

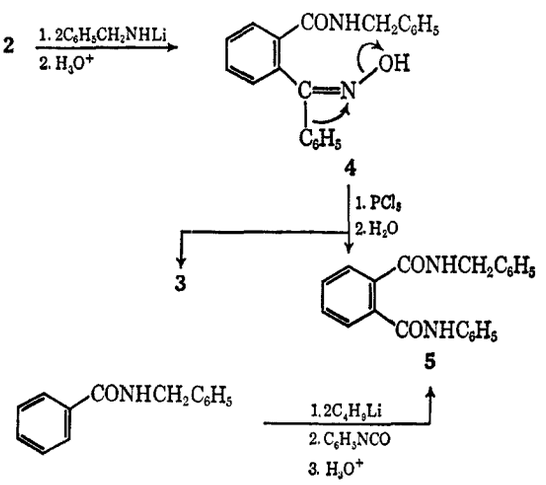
(2) F. H. Thorp, *Ber.*, **26**, 1795 (1893). Isolation of intermediate oxime acid **1** has more recently been reported by no yield was given: M. V. Pativardhan, N. L. Phalnikar, and B. V. Bhide, *J. Univ. Bombay*, **18** (Pt. 5, Sect. A), 22 (1950).

(3) We have observed that oximation of *o*-benzoylbenzanilide is similar accompanied by cyclization to form lactone **2**.

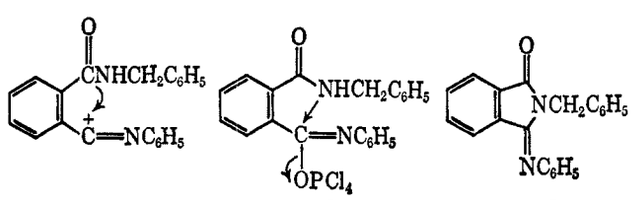
(4) J. Meisenheimer and J. H. Meis, *Ber.*, **57**, 289 (1924). For similar results with ring substituted lactone **2**, see B. Oddo and D. Curti, *Gass. Chim. Ital.*, **54**, 577 (1924).

(5) For related condensations at the *ortho* position of N-methylbenzamide see W. H. Puterbaugh and C. R. Hauser, *J. Org. Chem.*, **29**, 853 (1964).

SCHEME III



Although diamide **5** was the expected rearrangement product, phthalanil (**3**) was not necessarily the anticipated rearrangement–cyclization product. Since the indicated rearrangement of oxime amide **4** (see Scheme III) should form carbonium ion **7** or phosphorus chloride complex **8**, direct cyclization to give anil **9** seemed possible. That **9** was not produced as an intermediate and then converted into phthalanil (**3**) was shown by a blank experiment with **9** and phosphorus pentachloride with which **9** was found to be stable; **9** was prepared by a known method.



The formation of phthalanil (**3**) is suggested to involve cyclization of complex **10** to form **11** which affords **3** on hydrolysis (eq 2); complex **10** is a protonated species of complex **8**. Of course protonation of oxime amide **4** may occur leading directly to complex **10** on rearrangement. Also, diamide **5** could arise by hydrolysis of complex **10**.

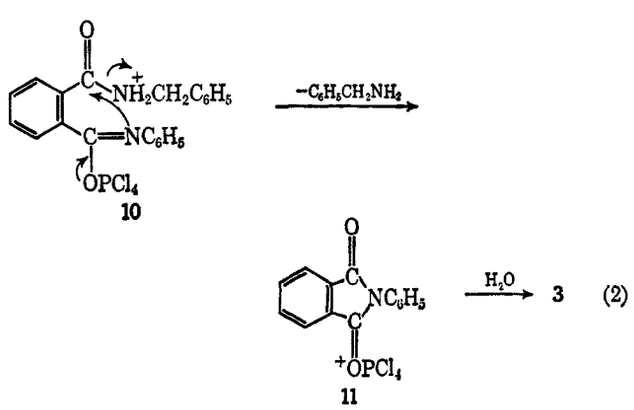


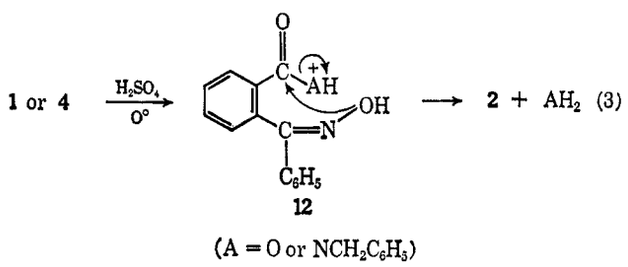
Table I shows that the relative yields of diamide **5** and phthalanil (**3**) were dependent on the temperature at which the reaction was effected and on the solvent used. Appratently the greater solubility of the reactants in THF favored cyclization to form **3**.

As might be expected, diamide **5** underwent cyclization to form phthalanil (**3**) with phosphorus pentachloride. However, conversion of **5** into **3** occurred more slowly than that of oxime amide **4** to **3** (see Experimental Section). This indicates that intermediate formation of an enol-type complex such as **10** is required for the cyclization. Also, diamide **5** was cyclized to form **3** with refluxing hydrochloric acid.

In contrast to phosphorus pentachloride, concentrated sulfuric acid failed to effect rearrangement of oxime acid **1** or oxime amide **4** at 0–25°; instead, cyclization occurred to regenerate lactone **2**, the protonated species **12** presumably being an intermediate (eq 3).

This regeneration of lactone **2** by sulfuric acid may be regarded as indirect evidence that the conversion of **2** into phthalanil (**3**) by this acid observed earlier[4] (presumbaly under more drastic conditions) did not involve the intermediate formation of oxime acid **1** (see above).

The indicated configurations of oxime acid **1** and oxime amide **4** in which phenyl and hydroxyl are *trans* were supported, not only by migration of phenyl group in the rearrangements, but also by the ring openings with nucleophiles and ring closure with cold sulfuric acid (see Schemes II and III and eq 3).



(A = O or $NCH_2C_6H_5$)

In contrast to oxime acid **1** and oxime amide **4**, oxime sulfonamides **14a** and **14b** were prepared by an oximation reaction and found to undergo Beckmann rearrangement accompanied by a different type of cyclization than that observed with **1** and **4**. Thus, **14a** and **14b** were obtained from imine sulfonamides **13a** and **13b**[6] and hydroxylamine and found to undergo rearrangement and/or rearrangement–cyclization with phosphorus pentachloride in ether or ether–THF to form *o*-sulfamylbenzanilides **17a** and **17b** and/or saccharin anils **16a** and **16b**, respectively (Table II). The latter compounds, which presumably arose through cyclizations of phosphorus chloride complexes **15a** and **15b** or the corresponding chloride or carbonium ions, underwent acid-catalyzed hydrolysis to give *o*-sulfobenzoic imides **18a** and **18b** respectively (Scheme IV). The indicated *trans* configuration of the oximes **14a** and **14b** was supported by migration of the phenyl group in the rearrangement.

Table II shows that the saccharin anils **16a** and **16b** were obtained exclusively under three of the four conditions studied but that the uncyclized *o*-sulfamylbenzamide **17b** was isolated in good yield when the reaction was effected in ether–THF at 0° for only 3.5 hr. Although *o*-sulfamylbenzanilide **17a** was not found under these conditions, it presumably could be isolated under milder conditions. Evidently phosphorus chlo-

(6) For preparation and ring-chain tautomerism of these compounds, see H. Watanabe, C.-L. Mao, I. T. Barnish, and C. R. Hauser, *J. Org. Chem.*, **34**, 919 (1969).

TABLE II

YIELDS OF *o*-SULFAMYLBENZANILIDES **17a** AND **17b** AND SACCHARIN ANILS **16a** AND **16b** FROM OXIME SULFONAMIDES **14a** AND **14b** WITH PHOSPHORUS PENTACHLORIDE

					Yields			
Oxime	Solvent	Temp, °C	Time, hr	Nature of medium[a]	Product	%	Product	%
14a	Ether	25–30	16	Heterogenous	**17a**	0	**16a**	88
14a	Ether–THF	0	3.5	Homogenous	**17a**	0	**16a**	89
14b	Ether	35	24	Heterogenous	**17b**	0	**16b**	93
14b	Ether–THF	0	3.5	Homogenous	**17b**	54	**16b**	42

[a] At the end of the reaction period.

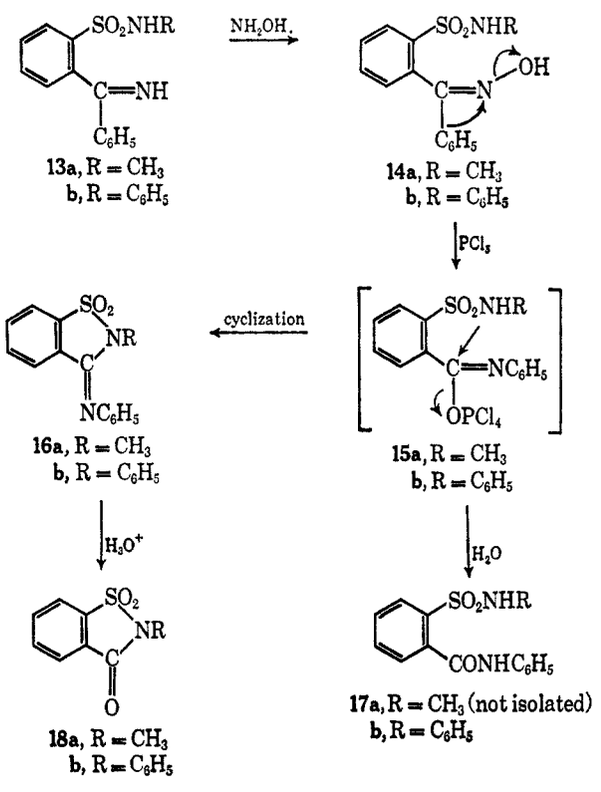
TABLE III

YIELDS OF SACCHARIN ANILS **16a** AND **16b** FROM *o*-SULFAMYLBENZANILIDES **17a** AND **17b** WITH PHOSPHORUS PENTACHLORIDE AND OXYCHLORIDE

						Yields	
Anilide	Reagent	Solvent	Temp, °C	Time, hr	Nature of medium	Product	%
17a	PCl_5	Ether	35	24	Heterogenous	**16a**	22
17a	PCl_5	Ether–THF	0	3.5	Heterogenous	**16a**	0
17a	$POCl_3$	$POCl_3$	107[a]	0.5	Homogenous	**16a**	80
17b	PCl_5	Ether	35	24	Heterogenous	**16b**	54
17b	PCl_5	Ether–THF	0	3.5	Homogenous	**16b**	0
17b	$POCl_3$	$POCl_3$	107[a]	0.5	Homogenous	**16b**	84

[a] Refluxing temperature of phosphorus oxychloride.

SCHEME IV



ride complex **15a** underwent cyclization more readily than complex **15b**, but this is not surprising since the N-methyl group should be a better nucleophile than the N-phenyl group.

Both of the *o*-sulfamylbenzanilides **17a** and **17b** were synthesized more conveniently from sulfonamides **19a** and **19b** and phenyl isocyante by means of *n*-butyllithium;[7] they were then cyclized with phosphorus pentachloride or, preferably, with phosphorus oxychloride to form the saccharin anils **16a** and **16b**, respectively (Scheme V, Table III).

SCHEME V

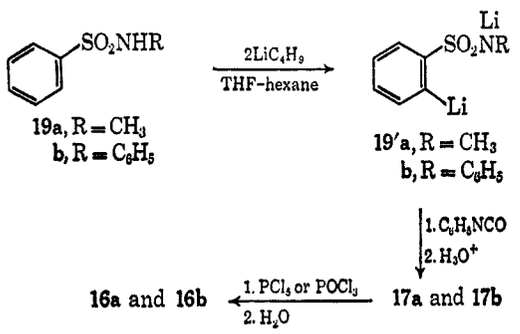
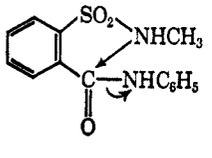


Table III shows that, when phosphorus pentachloride was used, the yields of the saccharin anils **16a** and **16b** from the *o*-sulfamylbenzanilides **17a** and **17b** were considerably lower than those obtained from oximes **14a** and **14b** even under milder conditions. This indicates that, before the cyclization could occur, conversion of **17a** and **17b** into enol-type intermediates such as **15a** and **15b** is required. Actually, good yields of the saccharin anils **16a** and **16b** were obtained from **17a** and **17b** only with phosphorus oxychloride, but this reagent was employed at a much higher temperature than phosphorus pentachloride (see Table III).

Whereas carboxamide sulfonamides **17a** and **17b** underwent cyclization with phosphorus pentachloride or oxychloride to form saccharin anils **16a** and **16b** (see Scheme V), carboxamide sulfonamide **17a** was found to undergo thermal cyclization to give *o*-sulfobenzoic imide **18a** and aniline (eq 4). Indeed this method of preparation of **18a** is preferable to that involving hydrolysis of the saccharin anils (see Scheme IV).



→ **18a** + $C_6H_5NH_2$ (4)

(7) For related condensations by this method, see H. Watanabe and C. R. Hauser, *J. Org. Chem.*, **33**, 900 (1968).

In contrast to phosphorous pentachloride, concentrated sulfuric acid failed to effect the Beckmann rearrangement of oxime sulfonamides **14a** and **14b** at 0–100°; at 100°, **14a** was converted into the corresponding ketone sulfonamide.

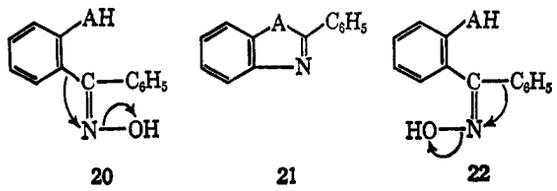
Discussion

The fact that Beckmann rearrangements of oxime amide **4** and axime sulfonamides **14a** and **14b** were accompanied by different types of cyclization is interesting. Apparently protonation at the amide nitrogen of **4** before rearrangement or of carbonium ion **7** or complex **8** after rearrangement prevented the type of cyclization indicated in **7** and **8**, since such protonation at the sulfonamide nitrogen of **14a** and **14b** or of complexes **15a** and **15b** should occur to a much less extent. Moreover, even if such protonation of **14a** and **14b** or **15a** and **15b** did occur, the type of cyclization indicated in complex **10** involving the carbonyl group should not be expected with the sulfonamide, since the sulfonyl group is known to be much less susceptible to such a nucleophilic attack.

Although the *trans* configuration of the oxime amide **4** seems well established, especially by the nucleophilic ring opening of lactone **2** (see Scheme III), that of the oxime sulfonamides **14a** and **14b** might be questioned. Thus, had the latter compounds had the *syn* configuration, they might have undergone isomerization accompanied by Beckmann rearrangement of phenyl because of expected reluctance of the aryl group containing the strongly electron-attracting sulfonyl substituent to rearrange. Apparently, there is no well-established example of a Beckmann migration of an aryl group having a strongly electron-attracting substituent; this would require isolation of both of the isomers of the oxime in order to preclude the possibility of isomerization prior to rearrangement. An attempt to prepare the second isomer of oxime sulfonamide **14a** so that the configuration could be definitely established was unsuccessful.

Several of the types of reaction described above appear to be of synthetic value. They include the ring opening of lactone **2** with nucleophiles (see Schemes II and III), the rearrangement and *n*-butyllithium methods of preparation diamides such as **5** (see Scheme III), the oximation of imine sulfonamides and rearrangement of the resulting oxime sulfonamides (see Scheme IV), and, especially, the *n*-butyllithium method of synthesis of *o*-sulfamylbenzanilides and their cyclization to saccharin anils (see Scheme V). *o*-Sulfamylbenzanilide **17b** has previously been prepared by a rather tedious method.[8] Our method is, not only much simpler, but also more general. The cyclization of **17b** with phosphorous oxychloride to form saccharin anil **16b** has been reported earlier.[8]

It should be mentioned that only one other type of Beckmann rearrangement–cyclization appears to have been reported previously;[9] this involved compounds of type **20** where A is oxygen or nitrogen to form a cyclic product of type **21** (A = O or NH). The isomeric oxime **22** underwent rearrangement without cyclization to form the corresponding benzanilides.



20 **21** **22**

Experimental Section[10]

Preparation of Oxime Acid 1.—Lactone **2**[2] (2.0 g) was dissolved (stirred) in 50 ml of 6 *N* sodium hydroxide at 60–70°. The clear solution was cooled and poured onto an ice–hydrochloric acid mixture (stirred). The precipitate was collected, washed with water, and redissolved in aqueous sodium bicarbonate solution. The solution was acidified with ice-cooled hydrochloric acid, and the resulting precipitate was collected to give 1.75 g (81%) of oxime acid **1**: mp 120–125° dec (lit.[2] mp 118°); ir 2800–3480 (broad, COOH) and 1700 cm^{-1} (C=O). The melting point sample resolidified to form lactone **2**, mp 162–164° (lit.[2] mp 163°).

Rearrangement–Cyclization of Oxime Acid 1 with Phosphorus Pentachloride.—To a stirred solution of 1.2 g (0.005 mol) of oxime acid **1** in 50 ml of THF[11] in an ice bath was added 1.5 g (0.0075 mol) of phosphorus pentachloride. After 2 hr, the ice bath was removed and the mixture was stirred at room temperature for 8 hr. The yellowish reaction mixture was poured onto ice–water. The layers were separated. The organic layer and two ethereal extracts of the aqueous layer were combined, dried (K_2CO_3), and evaporated. The residue was recrystallized from acetone–ethanol to give 0.9 g (80%) of phthalanil (**3**), mp and mmp 206–208° (lit.[12] mp 206°).

Preparation of Oxime Amide 4.—To a stirred solution of 4.46 g (0.02 mol) of lactone **2** in 100 ml of THF[11] was added 0.04 mol of lithiobenzylamine, prepared from 0.04 mol each of benzylamine and *n*-butyllithium[13] in THF–hexane. After 2 hr, the reaction mixture was poured onto 10 ml of concentrated hydrochloric acid and 300 g of crushed ice. The layers were separated. The organic layer and ethereal extracts of the aqueous layer were combined and dried (K_2CO_3). The solvent was removed, and the residue was recrystallized from ethanol–benzene to give 4.1 g (62%) of oxime amide **4**: mp 175–176° dec; ir 3400 (NH and OH) and 1650 cm^{-1} (C=O).

Anal. Calcd for $C_{21}H_{18}N_2O_2$: C, 76.34; H, 5.49; N, 8.48. Found: C, 76.62; H, 5.53; N, 8.40.

Rearrangement of Oxime Amide 4 with Phosphorus Pentachloride.—In Table I are summarized the results obtained from this reaction under various conditions. The details are described below.

A. In Ether.—To a stirred suspension of 2.0 g of **4** in 200 ml of anhydrous ether cooled in an ice bath was added 2.5 g of phosphorus pentachloride. After 3 hr, the ice bath was removed, and stirring was continued at room temperature for 8 hr. The reaction mixture was poured onto ice–water, and the layers were separated. The organic layer (containing suspension) was combined with ethereal extracts of aqueous layer. The resulting solution was dried (K_2CO_3). The solvent was removed under reduced pressure, and the residue was recrystallized from acetonitrile–dimethylformamide (DMF) to give 1.8 g (90%) of diamide **5**: mp 182–184°; ir 3470, 3450 (NH), 1690, and 1670 cm^{-1} (C=O).

Anal. Calcd for $C_{21}H_{18}N_2O_2$: C, 76.34; H, 5.49; N, 8.48. Found: C, 76.10; H, 5.53; N, 8.42.

In another experiment, the mixture was refluxed for 6 hr and

(8) I. Remsen and J. H. Hunter, *Amer. Chem. J.*, **18**, 809 (1896).
(9) See A. H. Blatt, *J. Org. Chem.*, **20**, 591 (1955).

(10) Melting points are uncorrected. Elemental analyses were performed by Janssen Pharmaceutica, Beerse, Belgium, and M–H–W Laboratories, Garden City, Mich. Ultraviolet (uv) spectra were produced on a Beckman DB-G spectrophotometer using ethanol solvent. Infrared (ir) spectra (KBr method) were produced on a Perkin-Elmer Infracord Models 137 and 237. Nuclear magnetic resonance (nmr) spectra were obtained with a Varian A-60 spectrometer using tetramethylsilane (δ 0 ppm) as an internal standard.
(11) Freshly distilled from lithium aluminum hydride.
(12) Porai-Koshitz, *Trans. Leningrad Chem.-Tech. Inst.*, **1**, 135 (1934).
(13) Foote Mineral Co., Exton, Pa.

then poured onto ice–water. The resulting suspension was filtered. The solid was combined with the residue obtained from the organic layer and fractionally crystallized from acetonitrile–DMF to give **5** and **3** (see Table I).

B. In THF.—To a stirred solution of 1.0 g of **4** in 100 ml of THF[11] cooled in an ice bath was added 1.0 g of phosphorus pentachloride to produce a yellow solution. After 2 hr, the ice bath was removed, and stirring was continued at room temperature for 8 hr. The reaction mixture was poured onto ice and worked up essentially as described in method A to give, after recrystallization from acetone–ethanol, 0.7 g (74%) of **3**, mp 206–208° (lit.[12] mp 206°).

Anal. Calcd for $C_{14}H_9NO_2$: C, 75.32; H, 4.07; N, 6.28. Found: C, 75.02; H, 4.04; N, 6.12.

The reaction was repeated in equal volume of THF[11] and ether to give **5** and **3** (see Table I).

Independent Synthesis of Diamide 5 from N-Benzylbenzamide and Phenyl Isocyanate by Butyllithium.—To a stirred solution of 0.01 mol of N-benzylbenzamide (**6**) in 50 ml of THF[11] at 0° was added 0.02 mol of *n*-butyllithium in hexane[13] under nitrogen atmosphere followed, after 30 min, by 0.01 mol of phenyl isocyanate in 10 ml of THF.[11] After 30 min, the reaction mixture was poured onto ice–water and worked up to give 0.67 g (20%) of diamide **5**, mp and mmp 182–184°. This yield could probably be improved.

Blank Experiment with Anil 9 and Phosphorus Pentachloride.—Anil **9** was prepared as described previously[14] and treated with excess phosphorus pentachloride under the conditions employed for the rearrangement of oxime amide **4** and, also, in the presence of a little water to form hydrogen chloride which would presumably be produced in the rearrangement of **4**. In all cases 90% or more of the starting anil **9** was recovered.

Cyclization of Diamide 5 with Reagents. A. With Phosphorus Pentachloride.—To a stirred solution of 0.5 g of diamide **5** in 50 ml of THF[11] at 0° was added 0.6 g of phosphorus pentachloride. After 2 hr, the reaction mixture was stirred at room temperature for 48 hr, then poured onto ice–water, and worked up to give 0.25 g (74%) of phthalanil (**3**), mp and mmp 205–207°.

When the reaction mixture was allowed to stir for only 8 hr at room temperature, only starting diamide **5** was recovered.

B. With Concentrated Hydrochloric Acid.—Diamide **5** (0.5 g) was refluxed with 20 ml of concentrated hydrochloric acid for 2 hr. After cooling, the reaction mixture was worked up to give 0.27 g (80%) of phthalanil (**3**), mp 206–208°, and some benzylamine (identified by ir spectrum).

Cyclization of Oxime Acid 1 and Oxime Amide 4 with Sulfuric Acid.—Oxime acid **1** (1.0 g) was dissolved in 10 g of concentrated sulfuric acid at 0°. After 30 min, the solution was poured onto ice. The resulting precipitate was collected, washed with 5% of sodium bicarbonate solution, and then water, and recrystallized from 95% ethanol to give 0.8 g (86%) of lactone **2**, mp and mmp 163–165° (lit.[2] mp 163°).

Similarly, oxime amide **4** (1.0 g) was dissolved in 10 g of concentrated sulfuric acid at 0°, but the solution was then allowed to warm to room temperature. After 2 hr, the yellow solution was poured onto ice, and the resulting white precipitate was collected and recrystallized to give 0.6 g (82%) of lactone **2**, mp and mmp 162–164°.

Preparation of Oxime Sulfonamides 14a and 14b.—A solution containing 5.50 g (0.02 mol) of imine sulfonamide **13a**,[6] 2.23 g (0.032 mol) of hydroxylamine hydrochloride, and 8.16 g (0.06 mol) of sodium acetate hydrate ($3H_2O$) in 200 ml of 70% (by weight) aqueous ethanol was refluxed for 24 hr and then cooled. The ethanol was evaporated in a current of air under a hood to leave an aqueous mixture containing an oil, which solidified on scratching. The mixture was stirred with 100 ml of water and filtered. The solid was washed with water and dried in air to give, after two recrystallizations from methanol, 4.28 g (75%) of *o*-(N-methylsulfamyl)benzophenone oxime (**14a**): mp 156.5–158.5°; ir 3400 (OH), 3230 (NH), 1310, and 1358 cm^{-1} (SO_2); nmr (acetone-d_6) δ 10.53 (s, 0.9, OH), 8.20–7.00 (m, 10.0, aromatic), 5.45 (broad, 1.1, NH), and 2.50 ppm (d, 3.0, J = 4.0 cps, NCH_3).

Anal. Calcd for $C_{14}H_{14}N_2SO_3$: C, 57.91; H, 4.86; N, 9.65. Found: C, 57.53; H, 4.80; N, 9.40.

Similarly, a solution of 3.03 g (0.009 mol) of imine sulfonamide **13b**, 1.26 g (0.018 mol) of hydroxylamine hydrochloride, and 3.69 g (0.027 mol) of sodium acetate hydrate in 150 ml of 70% aqueous ethanol was refluxed for 24 hr. Evaporation of the solvent left a solid, which was collected, washed with 95% ethanol, and dried to give 2.95 g (93%) of *o*-(N-phenylsulfamyl)-benzophenone oxime (**14b**): glittering fine leaflets; mp 220–221° dec; ir 3420 (OH), 3180 (NH), 1320 and/or 1310 (SO_2), and 1155 cm^{-1} (SO_2).

Anal. Calcd for $C_{19}H_{16}N_2SO_3$: C, 64.75; H, 4.58; N, 7.95. Found: C, 64.82; H, 4.53; N, 7.67.

Attempts to condense the corresponding ketone sulfonamides with hydroxylamine under similar conditions or in the presence of sodium hydroxide were unsuccessful, and the starting ketones were recovered.

Rearrangement of Oxime Sulfonamides 14a and 14b with Phosphorus Pentachloride.—In Table II are summarized the results obtained under various conditions. The details are described below.

A. Rearrangement of 14a to Form 16a.—To a stirred mixture of 1.0 g of oxime sulfonamide **14a** in 100 ml of dry ether cooled in an ice bath was added 1.0 g of phosphorus pentachloride. After stirring at room temperature for 16 hr, the reaction mixture (faint yellow solution with white solid) was poured onto 50 g of crushed ice. The acidic mixture was made basic with potassium carbonate, and the layers were separated. The ethereal layer was combined with ethereal extracts of the aqueous layer. The ethereal solution was washed with saturated sodium chloride solution and dried ($MgSO_4$) and the solvent was removed. The residue was recrystallized from methanol to give 0.82 g (88%) of N-methyl saccharin anil (**16a**): prismatic crystals; mp 139–140.5°; uv λ_{max} 335 mμ (log ϵ 3.7) and 238 (4.5); ir 1660 (strong, C=N), 1320 and/or 1290 (SO_2), and 1185 and/or 1175 cm^{-1} (SO_2); nmr ($CDCl_3$) δ 8.10–6.70 (m, 9.4, aromatic) and 3.30 ppm (s, 2.8, NCH_3).

Anal. Calcd for $C_{14}H_{12}N_2SO_2$: C, 61.74; H, 4.44; N, 10.29. Found: C, 61.80; H, 4.67; N, 10.10.

Similarly, a solution of 0.3 g of oxime sulfonamide **14a** in 15 ml of THF[11] and 10 ml of dry ether was treated at 0° with 0.3 g of phosphorus pentachloride. After stirring at 0° for 3.5 hr, the pale yellow solution was poured onto 10 g of crushed ice and worked up to give **16a** (see Table II).

B. Rearrangement of 14b to Form 16b and 17b.—To 0.50 g of oxime sulfonamide **14b** in 100 ml of dry ether was added 0.50 g of phosphorus pentachloride, and the mixture was refluxed for 24 hr. The solid dissolved but soon a faint yellow precipitate formed. After cooling, the reaction mixture was poured onto crushed ice, and the resulting mixture was shaken with 30 ml of benzene. After making basic with potassium carbonate, the layers were separated. The organic layer was combined with a 50:50 benzene–ether extract of the aqueous layer; the solution was washed with saturated sodium chloride solution and dried ($MgSO_4$). The solvent was removed, and the residue was recrystallized from 95% ethanol to give 0.44 g (93%) of N-phenyl saccharin anil (**16b**): yellow prismatic crystals; mp 190.5–192° (lit. mp 189.5°,[8] 187–189°[15]); uv λ_{max} 338 mμ (log ϵ 3.7) and 238 (shoulder) (4.6); ir 1660 (strong, C=N), 1320 and/or 1295 (SO_2), and 1177 cm^{-1} (SO_2); nmr ($CDCl_3$) δ 8.20–6.60 ppm (m, aromatic).

Anal. Calcd for $C_{19}H_{14}N_2SO_2$: C, 68.24; H, 4.22; N, 8.38. Found: C, 68.21; H, 4.59; N, 8.27.

Similarly, a solution of 0.40 g of oxime sulfonamide **14b** in 30 ml of THF[11] and 10 ml of dry ether at 0° was treated with 0.40 g of phosphorus pentachloride. After stirring at 0° for 3.5 hr, the faint yellow solution was poured onto 15 g of crushed ice and made basic with sodium carbonate and most of the organic solvent was evaporated in air (hood). The resulting solid was collected, washed with water, and dried in air. The solid (0.46 g) was fractionally crystallized from 95% ethanol to give, first, 0.16 g (42%) of N-phenyl saccharin anil (**16b**), fine yellow crystals, mp 185–189° and 189–191° after recrystallization from ethanol, and, second, 0.21 g (54%) of *o*-sulfobenzdianilide (**17b**), fine needles, mp 186–191° and 191–193.5° after recrystallization from methanol.

Hydrolysis of Saccharin Anils 16a and 16b to Form *o*-Sulfobenzoic Imides 10a and 10b.—A mixture of 0.30 g of saccharin anil **16a** and 16 ml of 20% hydrochloric acid was refluxed for

(14) I. K. Kormendy, *Acta Chim. Acad. Sci. Hung.*, **17**, 255 (1958).

(15) J. A. Jesurun, *Ber.*, **26**, 2292 (1893).

30 min and then cooled in an ice bath. The precipitate was collected, washed with water, and dried to give 0.15 g (69%) of N-methyl-*o*-sulfobenzoic imide (**18a**), fine needles, mp 126–128° and 130.5–131.5° after recrystallization from 95% ethanol. Admixture with an authentic sample[7] of **18a** (mp 131.5–132°) showed no depression (mmp 130.5–132°) and the ir spectra of the two samples were identical.

The acidic filtrate (and washings) was concentrated and treated with sodium hydroxide and benzoyl chloride to give 0.14 g (62%) of benzanilide, mp and mmp 162–164°.

Similarly, 0.40 g of saccharin anil **16b** was refluxed with 10 ml of concentrated hydrochloric acid for 1 hr. After cooling, the mixture was filtered. The solid was washed with water and dried to give 0.28 g (90%) of N-phenyl-*o*-sulfobenzoic imide (**18b**), mp 188–190° and 191–192° after recrystallization from 95% ethanol. Admixture with an authentic sample[7] of **18b** (mp 192–192.5°) showed no depression (mmp 191–192°) and the ir spectra of the two samples were identical.

Aniline was isolated from the filtrate as benzanilide, mp 162–164°, in 49% yield.

Synthesis of *p*-Sulfamylbenzanilides by *n*-Butyllithium Method.—To a stirred suspension of dilithiosulfonamide **19'a** in THF–hexane at 0° under nitrogen,[7] prepared from 0.025 mol of N-methylbenzenesulfonamide (**19a**) and 37 ml (0.055 mol) of 1.6 *M* *n*-butyllithium in hexane,[13] was added a solution of 3.57 g (0.03 mol) of phenyl isocyanate in 30 ml of THF.[11] After 30 min, the reaction mixture was decomposed with water followed by 5% hydrochloric acid. After evaporation of THF in air, the mixture was filtered. The solid was washed with ether and dried to give 4.86 g (67%) of *o*-(N-methylsulfamyl)benzanilide (**17a**), mp 202.5–204.5°, and 4.76 g (66%) of **17a**: fine prismatic crystals; mp 204–206° after recrystallization from acetone–methanol; ir 3323 (NH in SO_2NH), 3250 (NH in CONH), 1660 and 1642 (CO), and 1320 and 1160 cm^{-1} (SO_2).

Anal. Calcd for $C_{14}H_{14}N_2SO_3$: C, 57.91; H, 4.86; N, 9.65. Found: C, 58.17; H, 4.94; N, 9.87.

Similarly, dilithiosulfonamide **19'b**, prepared from N-phenylbenzenesulfonamide (**19b**) and *n*-butyllithium,[7] was treated with phenyl isocyanate to give 4.70 g (53%) of *o*-sulfobenzdianilide (**17b**): prismatic crystals, mp 190–194° and 193.5–195.5° after recrystallization from acetone–methanol (lit. mp 196°,[16a] 192°[16b]); ir 3320 (NH in SO_2NH), 3200 (NH in CONH), 1650 (CO), and 1320 and 1160 cm^{-1} (SO_2); nmr (acetone-d_6) δ 7.95–6.80 ppm (m, aromatic).

Anal. Calcd for $C_{19}H_{16}N_2SO_3$: C, 64.75; H, 4.58; N, 7.95. Found: C, 64.66; H, 4.60; N, 7.90.

Admixture with a sample obtained in the rearrangement described above (under B) showed no depression (mmp 193–195°) and the ir spectra of the two samples were identical.

Cyclizations of *o*-Sulfobenzdiamides 17a and 17b to Form Saccharin Anils 16a and 16b.—In Table III are summarized the results obtained under various conditions. The details are described below.

A. Phosphorus Pentachloride Method.—To a suspension of 1.0 g of *o*-sulfobenzdiamide **17a** in 100 ml of dry ether was added 1.0 g of phosphorus pentachloride, and the mixture was stirred and refluxed for 24 hr. After cooling, the precipitate was collected and washed with ether to give 0.46 g (46%) of the recovered starting compound **17a**, mp 203.5–205°. The filtrate (and ethereal washings) was poured onto 20 g of crushed ice. The acidic mixture was made basic with sodium carbonate, and the solvent was removed in air (hood). The solid was collected to give a little more of recovered **17a**. The filtrate (and ethereal washings) was evaporated to give 0.21 g (22%) of N-methyl saccharin anil (**16a**), mp 138.5–139.5° after recrystallization from methanol. Admixture with a sample of **16a** obtained in the rearrangement described above showed no depression (mmp 138.5–139.5°) and the ir spectra of the two samples were identical.

Similarly, 1.0 g of *o*-sulfobenzdiamide **17b** in 100 ml of dry ether was treated with 1.0 g of phosphorus pentachloride. After stirring and refluxing for 24 hr, the mixture was poured onto crushed ice and made basic and most of the solvent was evaporated. The resulting solid was collected, washed with water, and dried in air. The solid was fractionally crystallized from methanol to give, first, 0.51 g (54%) of N-phenyl saccharin anil (**16b**), yellow fine leaftets, mp 187–189.5° and 188–189.5° after recrystallization from acetone–methanol, and second, 0.31 g (31%) of the recovered starting compound of **17b**, mp 187–188°. Admixture of the N-phenyl saccharin anil with a sample of **16b** obtained in the rearrangement described above showed no depression (mmp 189.5–190.5°) and the ir spectra of the two samples were identical.

Attempts to cyclize 0.40 g of *o*-sulfobenzdiamides **17a** and **17b** with 0.40 g of phosphorus pentachloride in 30 ml of THF[11] and 10 ml of dry ether at 0° for 3.5 hr, as described in the rearrangements of **14a** and **14b**, were unsuccessful, and the starting amides were recovered.

B. Phosphorus Oxychloride Method.—A mixture of 0.60 g of *o*-sulfobenzdiamide **17a** and 2.00 g of phosphorus oxychloride was refluxed for 30 min, and most of the excess oxychloride was distilled off under reduced pressure. The hot liquid residue was spread (by swirling) over as much surface of the flask as possible. After a few minutes, 50 g of ice–water was added and the resulting mixture was stirred. The yellow solid was collected, washed with water, and dried in air to give 0.45 g (80%) of N-methyl saccharin anil (**16a**), mp 133–137°, and 0.42 g (75%) of prismatic crystals, mp 138–140° after recrystallization from methanol (charcoal). Admixture with a sample of **16a** obtained in the rearrangement described above showed no depression (mmp 138–140°) and the ir spectra of the two samples were identical.

Similarly, 0.60 g of *o*-sulfobenzdiamide **17b** was treated with 2.00 g of phosphorus oxychloride[8] and worked up to give 0.57 g (100%) of N-phenyl saccharin anil (**16b**), mp 178–186°, and 0.48 g (84%), mp 188–189°, as yellow prismatic crystals after recrystallization from acetone–methanol (charcoal). Admixture with a sample of **16b** obtained in the rearrangement described above showed no depression (mmp 188–190°) and the ir spectra of the two samples were identical.

Thermal Cyclization of *o*-Sulfobenzdiamide 17a to Form 18a.—A 1.0-g sample of *o*-sulfobenzdiamide **17a** was heated on a Wood's metal bath at 240–250° for 5 hr in a slow stream of nitrogen and then cooled. The solid mass was washed with water and dried in air to give 0.59 g (82%) of N-methyl-*o*-sulfobenzoic imide (**18a**), mp 126–130°, and 0.46 g (68%), mp 130.5–132°, as fine prismatic plates after recrystallization from 95% ethanol. Admixture with an authentic sample[7] of **18a** showed no depression (mmp 131–132°) and the ir spectra of the two samples were identical. Aniline (0.04 g) was collected from the wall of the outlet tube of the reaction flask and identified by ir.

Attempt to Rearrange Oxime Sulfonamide 14a by Sulfuric Acid.—A solution of 0.20 g of **14a** in 2 ml of concentrated sulfuric acid was heated at 100° for 1 hr to give, on work-up, 0.17 g (90%) of *o*-(N-methylsulfamyl)benzophenone, mp 114–117° and 119–120.5° after recrystallization from ethanol. Admixture with an authentic sample[8] of this ketone sulfonamide (mp 119–120.5°) showed no depression, and the ir spectra of the two samples were identical.

When the reaction was effected at 0°, the starting oxime sulfonamide **14a** was recovered. Similar treatment of oxime sulfonamide **14b** at 0 or 100° afforded water-soluble material.

Attempt to Prepare Second Isomer of Oxime Sulfonamide 14a.—A 0.20-g sample of **14a** was dissolved in 30 ml of dry, refluxing ether. After cooling to 5°, the solution was saturated with dry hydrogen chloride but no precipitate formed; 90% of **14a** was recovered on work-up.

Registry No.—**1**, 19298-28-3; **2**, 19298-29-4; **3**, 520-03-6; **4**, 19298-31-8; **5**, 16497-40-8; **14a**, 19298-33-0; **14b**, 19298-34-1; **16a**, 19298-35-2; **16b**, 19298-36-3; **17a**, 19298-37-4; **17b**, 19298-38-5; **18a**, 15448-99-4.

(16) (a) I. Remsen and C. E. Coates, Jr., *Amer. Chem. J.*, **17**, 316 (1895); (b) I. R. Remsen and E. P. Kohler, *ibid.*, **17**, 340 (1895).