alkyl group. In addition to the greater tendency to α-fission, it is noticeable that hydrogen rearranges or is lost more easily. This can be seen from the relative intensities of the $M - 26$ (—CN), $M - 27$ (—HCN), and $M - 28$ (—H_2CN) peaks.

Cyanide mass spectra have an $M + 1$ peak which is pressure sensitive (and therefore is caused by an "ion-molecule" reaction), and McLafferty has shown how this can be used to identify molecular ions in mixtures.[3] The isocyanides also show a pressure dependent $M + 1$ peak which must be caused by hydrogen transfer in an ion–molecule reaction.

A further object of this work was to measure the appearance potentials of the molecular ions. Only five compounds gave a sufficiently intense molecular peak to make the necessary measurements. The results were 11.8, 11.2, and 11.1 e.v. for methyl, ethyl and propyl isocyanides, and 12.3 and 11.9 e.v. for methyl and ethyl cyanides. The last two values are in good agreement with the results of Morrison and Nicholson,[4] 12.39 and 11.85 e.v., respectively. Other ionization potentials determined by electron impact which are recorded for methyl cyanide are 12.52,[5] 12.48,[6] and 12.42 e.v.[7]

In the methyl and ethyl pairs of isomers the ionization potential of the isocyanide is smaller. It requires approximately 0.6 e.v. less energy to remove one electron from the isocyanide molecule. While this electron undoubtedly comes from the isocyanide group, it is not possible to determine whether it is from the bonding electrons or the lone pair.

Experimental

Spectra were determined in an Atlas mass spectrometer, a 60°, 20-cm. radius instrument using magnetic scanning. The inlet temperature was maintained at 90° and the ion source at 250°; the electron energy was 70 e.v. Appearance potentials were measured by the energy compensation method.[8] Argon was used as reference and its ionization potential was taken as 15.7 e.v. The argon was admitted to the ion source at the same time as the sample. The reproducibility of argon and sample readings was 0.05 e.v., so that the over-all accuracy is ±0.1 e.v. The resolution ($m/\Delta m$) available was 800 at 1%. This was adequate to distinguish argon from C_3H_4 or C_2H_2N, but not to distinguish those fragments from one another. The preparation of the isocyanides has been described[1]; all compounds were repurified by gas chromatography.

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(4) J. D. Morrison and A. J. C. Nicholson, *J. Chem. Phys.*, **20**, 1021 (1952).

(5) C. A. McDowell and J. W. Warren, *Trans. Faraday Soc.*, **48**, 1084 (1952).

(6) B. C. Cox, thesis, University of Liverpool, 1953, quoted by R. W. Kiser; "Tables of Ionization Potentials," U. S. Atomic Energy Commission, 1960.

(7) C. J. Varsell, F. A. Morell, F. E. Resnick, and W. A. Powell, *Anal. Chem.*, **32**, 182 (1960).

(8) R. W. Kiser and E. J. Gallegos, *J. Phys. Chem.*, **66**, 947 (1962).

The Phenolysis of N-Bromomethylphthalimide. A Correction

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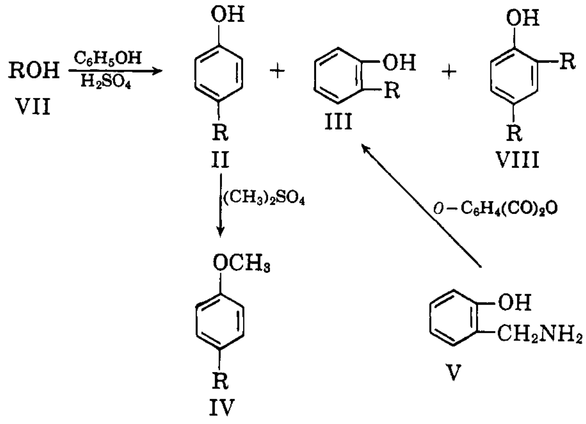
Received April 17, 1963

Because of the high solvolytic reactivity of its bromine atom and the ready isolation of derived products, N-bromomethylphthalimide (I) twice has been recommended as an identification reagent for alcohols.[1,2] Both groups of workers extended its use to the characterization of phenol; and, by analogy to the products obtained from alcohols, they assigned the phenyl ether structure VI to their derivatives. However, their melting points (171–172°[1] and 205°[2]) did not agree.

This discrepancy, coupled with the original observation of Tscherniac[3] that ring substitution of phenol by N-methylolphthalimide VII (in strong sulfuric acid) furnishes a derivative, m.p. 205°, suggested that phenolysis of the bromide I occurs with alkylation at carbon rather than at oxygen. Position isomerism could then be invoked to account for the melting point discrepancy. This note reports the verification of this expectation.

Preliminary work demonstrated that the crude products obtained by the prescribed[1,2] procedures did indeed possess free hydroxyl groups. The Tscherniac[3] condensation of phenol with N-methylolphthalimide was then repeated and the products were identified (Scheme I). The material, m.p. 205–206°, assumed by Tscherniac to be the *para* isomer II, indeed possesses the expected structure. Methylation of it gave the ether IV identical with an authentic sample.[4]

SCHEME I
(R = o-$C_6H_4(CO)_2NCH_2$–)



The corresponding *ortho* isomer III, m.p. 177°, was synthesized independently by treatment of *o*-hydroxybenzylamine (V)[5] with phthalic anhydride. Its presence in the Tscherniac reaction mixture was then demonstrated by means of qualitative thin-layer silica gel chromatography. Further application of a quantitative column chromatographic technique (see Experimental) to the mixture of monosubstitution products showed that the *para* isomer II had been formed in 38% yield and *ortho* isomer III in 9% yield. An insoluble material, m.p. 297–298°, characterized as a disubstituted product was also obtained in 33% yield. Although its structure was not rigorously proved, confinement of monosubstitution in this reaction to the *ortho* and *para* positions enables the reasonably confident assignment to it of the 2,4-disubstituted structure VIII.

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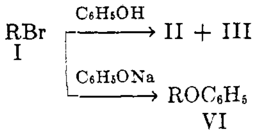
(1) H. H. Hopkins, *J. Am. Chem. Soc.*, **45**, 541 (1923).

(2) O. Mancera and O. Lemberger, *J. Org. Chem.*, **15**, 1253 (1950).

(3) J. Tscherniac, German Patent 134,979; *Chem. Zentr.*, **II**, 1084 (1902).

(4) K. Shirakawa and H. Kawasaki, *J. Pharm. Soc. Japan*, **71**, 1213 (1951); *Chem. Abstr.*, **46**, 5544 (1952). We are indebted to Dr. Shirakawa for the gift of a generous supply of compound IV.

(5) Prepared by reduction of salicylamide with lithium aluminum hydride.



$$\underset{\text{I}}{\text{RBr}} \xrightarrow{C_6H_5OH} \text{II} + \text{III} \qquad \underset{\text{I}}{\text{RBr}} \xrightarrow{C_6H_5ONa} \underset{\text{VI}}{ROC_6H_5}$$

$R = o\text{-}C_6H_4(CO)_2NCH_2$—

The same techniques were then applied to the mixture obtained from the phenolysis of the bromide I. Whether the reaction was conducted in excess phenol at 100° or in refluxing benzene, the only characterizable products were the two isomers II and III. No disubstituted material VIII and none of the phenyl ether VI could be detected in the mixture by means of thin-layer chromatography. (For purposes of comparison, a sample of the ether VI, m.p. 140–141°, was prepared by alkylation of sodium phenoxide with the bromide I.) Furthermore, the yield of the *para* isomer II barely predominated over that of the *ortho* form III, thus maximizing the probability that either pure form might be obtained[1,2] by crystallization from the mixture. The possibility that the relatively high proportion of *ortho* isomer III in the mixture might stem from a rearrangement of preformed ether VI was further ruled out by the direct observation that VI did not rearrange appreciably under the conditions of the phenolysis. Indeed, in benzene solution, the ether VI was not even cleaved by hydrogen bromide.

The autocatalytic nature of this reaction was demonstrated by conducting the phenolysis (in benzene) in the presence of the neutral "acid trap," β-pinene. Although thin-layer chromatography showed that both II and III were formed in small amounts, much unchanged bromide I was recovered. Interestingly, the chromatogram also indicated the formation of a trace of the phenyl ether VI, which was absent in the autocatalyzed reaction.

Discussion

In light of the foregoing results, structural revision of two other phenolysis products is in order. Aryl ether structures (*i.e.*, VI) previously[2] assigned to products of the reaction of N-bromomethylphthalimide with thymol and with 2-naphthol must be changed to appropriate phenolic structures or isomeric mixtures thereof.

The findings of the present work place N-bromomethylphthalimide I in the same category with trityl and benzyl type halides. Hart and his co-workers[6] showed that the latter undergo ready autocatalyzed phenolysis to give nuclearly alkylated phenols. Although kinetic results argued against the probability of a rearrangement mechanism involving preformed phenyl ethers, it was found that phenyl trityl ether[6a] and aryl α-phenethyl ethers[6b] could be cleaved and rearranged under the reaction conditions. The stability of the phenyl ether VI observed in the present work shows clearly that phenolysis of I, in benzene at least, must occur by electrophilic aromatic substitution processes and not by rearrangement of VI. The relatively high ratio of *ortho* to *para* substitution may be accounted for by assuming that in the former process (but not in the latter) the phenolic hydroxyl can assist ionization of the bromide I by a cyclic concerted SNi mechanism identical to the one invoked by Hart[6b] to account for the observation that *ortho* substitution of phenol by α-phenethyl chloride occurs with configurational retention whereas *para* substitution takes place with inversion.

Experimental[7]

Condensation of Phenol with N-Methylolphthalimide.—To a mixture of 175 ml. of concentrated sulfuric acid and 65 ml. of water cooled to −4° was added, with stirring, 88.5 g. (0.5 mole) of N-methylolphthalimide (VII) and 47 g. (0.5 mole) of phenol. The temperature was maintained at 0° or slightly below during the addition and for 4 hr. thereafter. The mixture was then poured over ice and allowed to stand overnight.

The precipitated product was collected at the filter, washed with water, and resuspended in warm (60°) water. Filtration and drying gave 103.5 g. of a mixture. This was treated successively with four 300-ml. portions of boiling ethanol followed by filtration of each hot suspension. The insoluble product remaining (33.5 g., 33% yield based on N-methylolphthalimide) consisted of crude 2,4-diphthalimidomethylphenol (VIII), m.p. 290–291°. Recrystallization of a sample twice from dimethylformamide gave pure VIII, m.p. 297–298°; $\lambda_{\max}^{\text{Nujol}}$ 3.00, 5.63, 5.85 μ.

Anal. Calcd. for $C_{24}H_{16}N_2O_5$: C, 69.89; H, 3.91. Found: C, 69.59; H, 3.93.

The combined alcoholic extracts were concentrated to dryness to give 67.5 g. of a solid which, by quantitative column chromatography (subsequently described), was found to consist of 48 g. (38% yield) of N-(4-hydroxybenzyl)phthalimide (II) and 11.5 g. (9% yield) of N-(2-hydroxybenzyl)phthalimide (III). Fractional crystallization of a sample of this mixture from ethanol gave pure II, m.p. 205–206°; $\lambda_{\max}^{\text{CHCl}_3}$ 2.78, 5.62, 5.82 μ; 277 (2190), 282, (2310), 294 mμ (ε 1830); $\lambda_{\max}^{\text{CH}_3\text{OH}}$ 222 (39,100), 278 (2440), 283 mμ (ε 2480). Its purity was checked by the observation that it give a single spot in a thin-layer silica gel chromatographic analysis.

When N-methylolphthalimide was refluxed for 6 hr. in benzene with an equivalent quantity of phenol, no water was formed, and 77% of the methylol compound could be recovered.

N-(4-Methoxybenzyl)phthalimide (IV).—To a stirred suspension of 0.21 g. (0.0085 mole) of sodium hydride in dimethylformamide was added dropwise a solution of 2.15 g. (0.0085 mole) of N-(4-hydrox-benzyl)phthalimide (II) in dimethylformamide. After completion of the addition, stirring was continued for 1 hr. and then a solution of 1.2 g. (0.0094 mole) of dimethyl sulfate in dimethylformamide was added dropwise.

After stirring at room temperature overnight, the reaction mixture was concentrated to dryness under reduced pressure and the residue was partitioned between ether and water. The ether layer was washed with 10% sodium hydroxide solution and water and dried over anhydrous magnesium sulfate. Filtration and removal of the solvent by distillation gave 2.19 g. (97%) of crude IV, m.p. 123–126°. Recrystallization from 95% ethanol gave pure IV, m.p. 130–130.5°; $\lambda_{\max}^{\text{CHCl}_3}$ 5.63, 5.83 μ, no OH absorption, identical (infrared spectrum and mixture melting point) with an authentic sample.[4]

Anal. Calcd. for $C_{16}H_{13}NO_3$: C, 71.90; H, 4.91. Found: C, 71.88; H, 4.69.

N-(2-Hydroxybenzyl)phthalimide (III).—To a stirred suspension of lithium aluminum hydride (10 g., 0.263 mole) in 200 ml. of tetrahydrofuran was added dropwise, in an atmosphere of dry nitrogen, a solution of 13.71 g. (0.10 mole) of salicylamide in a minimum amount of tetrahydrofuran. After addition was complete the mixture was stirred and refluxed overnight. To the stirred, cooled (15–20°) reaction mixture, 20 ml. of water was carefully added (dropwise) followed by 20 ml. of 50% sodium hydroxide solution, also added dropwise. The insoluble material was removed by filtration and the filtrate was concen-

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[6] (a) H. Hart and F. A. Cassis, *J. Am. Chem. Soc.*, **76**, 1634 (1954); (b) H. Hart, W. L. Spliethoff, and H. S. Eleuterio, *ibid.*, **76**, 4547 (1954).

[7] Melting points were determined in capillary tubes heated in a metal block and are uncorrected. The ultraviolet absorptions were determined in a Beckman DU spectrophotometer and the infrared spectra by a Perkin-Elmer Model 21 spectrophotometer. The authors are indebted to Mrs. T. Anderson for technical assistance with thin-layer chromatography, Mr. O. Kolsto for the microanalyses, Mr. W. H. Washburn for the infrared spectra, and Mr. V. Papendick for assistance with the ultraviolet spectra.

trated to dryness. The residual oil solidified on standing. This material had no well defined melting point and left an ash on combustion. It weighed 10.7 g. (74% yield, calculated as the sodium salt of *o*-hydroxybenzylamine) and its infrared spectrum was devoid of any carbonyl absorption. It was taken up in a minimum quantity of water and treated carefully with dilute hydrochloric acid until no more precipitate formed. Filtration and drying gave 6.71 g. of *o*-hydroxybenzylamine (V), m.p. 121–123°. This material could be recrystallized from water, but the melting point varied greatly (114 to 120°) with the apparent degree of hydration of the resulting crystals. Completely anhydrous material was not obtained.

A mixture of 2.8 g. (*ca.*, 0.02 mole) of *o*-hydroxybenzylamine (V), m.p. 118–119°, and 2.96 g. (0.02 mole) of phthalic anhydride was heated in an oil bath at 170–180° for 0.5 hr. After cooling, the resulting solid was taken up in boiling methanol, filtered, and cooled. Crystalline product thus obtained was added to several further crops obtained by concentration of successive filtrates to give 3.3 g. (65%) of crude N-(2-hydroxybenzyl)-phthalimide (III), m.p. 171–173°. Several recrystallizations from ethanol gave pure III, m.p. 177°; $\lambda_{\max}^{\text{Nujol}}$ 2.98, 5.67, 5.90 μ; $\lambda_{\max}^{\text{CHCl}_3}$ 275 (3200), 280 (3250), 297 mμ (ϵ 2150).

Anal. Calcd. for $C_{15}H_{11}NO_3$: C, 71.14; H, 4.38. Found: C, 71.09; H, 4.59.

N-Phenoxymethylphthalimide (VI).—To a stirred suspension of 2 g. (0.084 mole) of sodium hydride in 50 ml. of 1,2-dimethoxyethane was added dropwise a solution of 7.9 g. (0.08 mole) of phenol in 50 ml. of 1,2-dimethoxyethane. After stirring 1 hr. at room temperature, a solution of 19.2 g. (0.08 mole) of N-bromomethylphthalimide in 1,2-dimethoxyethane was added dropwise, and stirring was continued overnight at room temperature. The reaction mixture was filtered from sodium bromide and concentrated to dryness under reduced pressure. The solid residue was triturated with acetone, filtered, and dried to give 8.17 g. (42%) of crude VI, m.p. 133–135°. Recrystallization from acetone (charcoal) gave pure N-phenoxymethylphthalimide (VI), m.p. 140–141°; $\lambda_{\max}^{\text{CHCl}_3}$ 5.60, 5.80 μ, no OH absorption.

Anal. Calcd. for $C_{15}H_{11}NO_3$: C, 71.14; H, 4.38. Found: C, 71.19; H, 4.33.

Attempted Rearrangement of the Ether VI to II or III.—When a benzene solution of the ether VI was refluxed for 5 hr. in the presence of a continuous stream of either dry hydrogen chloride or hydrogen bromide, it was recoverable quantitatively. When phenol was used as a solvent and hydrogen bromide was continuously bubbled through the mixture for 5 hr. at steam-bath temperature, no starting ether VI could be recovered. A 9% yield of N-(4-hydroxybenzyl)phthalimide (II), m.p. 205–206°, was isolated, but the bulk of the product consisted of a refractory polymeric mixture.

Phenolysis of N-Bromomethylphthalimide. A. In Benzene.—A solution of 3 g. (0.0125 mole) of N-bromomethylphthalimide and 2 g. (0.021 mole) of phenol in 10 ml. of dry benzene was refluxed for 3 hr. The solvent was then removed by distillation under reduced pressure and the residue was suspended in hot (60–80°) water, collected at the filter, and washed thoroughly with more hot water. Drying gave 1.60 g. (51%) of product which, after thorough grinding to ensure homogeneity was found, by thin-layer silica gel chromatography, to consist of a mixture of *o*- and *p*-substituted phenols II and III. Neither the disubstituted phenol VIII nor the phenyl ether VI was present. Quantitative column chromatography (described later) showed that this mixture consisted of 54% *para* isomer II and 49% *ortho* isomer III. Thus, within the limits of experimental error of detection, II and III are the only products identifiable in this reaction mixture.

When the foregoing procedure was repeated in the presence of 4.1 ml. (*ca.* 0.021 mole) of β-pinene, as expected, no hydrogen bromide evolution was detectable. Working up the reaction in the usual way gave a semisolid mixture which contained (thin-layer chromatography) a large amount of the bromide I together with smaller amounts of II, III, the phenyl ethyl VI, and a fourth unknown substance (possibly bornyl bromide). Trituration of the product with ether followed by filtration gave a crude solid whose infrared spectrum was qualitatively identical to that of the starting bromide I.

B. In Phenol.—A mixture of 3 g. of N-bromomethylphthalimide and 2 g. of phenol was heated on the steam bath for 3 hr. and worked up as in the foregoing procedure. There was obtained 2.68 g. (85%) of a mixture which thin-layer chromatography showed to be mainly II and III, together with a small amount of an unknown substance which remained at the origin. Again, neither the phenyl ether VI nor the disubstituted phenol VIII was detectable. Quantitative column chromatography showed the presence in the mixture of 53% *para* isomer II and 40% of *ortho* isomer III.

A sample of the mixture was fractionally crystallized from a benzene–pentane mixture to give pure N-(*p*-hydroxybenzyl)-phthalimide (II), m.p. 205–206°, identical (infrared spectrum and mixture melting point) with an authentic sample.

Anal. Calcd. for $C_{15}H_{11}NO_3$: C, 71.14; H, 4.38. Found: C, 71.35; H, 4.11.

Several fractions of the chromatographic eluate, which, judging from the plotted chromatogram ($E_{1\,\text{cm}}^{1\%}$ *vs.* fraction number), contained the *ortho* isomer III, were combined and distilled to dryness under reduced pressure. The residue proved to be identical (infrared spectrum and qualitative thin-layer chromatography) with an authentic sample of N-(2-hydroxybenzyl)phthalimide (III).

Thin-Layer Silica Gel Chromatography.—Solutions of the compounds or their mixtures were prepared in a 1:1 methanol–chloroform mixture, and 5-λ volumes were spotted at the origins of the plates. After drying the spots, a solvent mixture, composed of 9 volumes of benzene to 1 of ethyl acetate was employed to develop the chromatograms. After drying once more, the resolved spots were visualized by means of iodine vapor. Under these conditions, the following R_f values were observed: N-(4-hydroxybenzyl)phthalimide (II), 0.2; N-(2-hydroxybenzyl)-phthalimide (III), 0.5; and N-phenoxymethylphthalimide (VI), 0.65. The disubstituted phenol could be identified by the observation that, unlike the other three substances, it could not be cleanly resolved under these conditions. It usually smeared out over a considerable portion of the chromatogram or, at best, gave spots much too elongated for the determination of any meaningful R_f value.

Column Chromatography.—A solution of the mixture of isomers (0.10 g.) in a minimum amount of a methanol–chloroform or ethyl acetate–chloroform mixture was placed on a column (2 × 28 cm.) of silica gel (100–200 mesh) previously packed in chloroform. Development was effected with pure chloroform (150–200 ml.) and elution was accomplished with chloroform containing gradually increasing amounts (2.5 → 10%) of ethyl acetate. Eluate was collected in 20-ml. fractions and the quantity of phenolic material in each fraction was determined spectrophotometrically using the optical density at 280 mμ. The $E_{1\,\text{cm}}^{1\%}$ values employed in the calculations were 127 for the *ortho* isomer III and 86.5 for the *para* isomer II. A plot of absorbance *vs.* volume of eluate in a successful chromatogram gave two peaks separated by a trough extending very nearly to the base line. The first peak represented the quantity of *ortho* isomer III and the second that of the less mobile *para* isomer II. A complete chromatogram usually required less than 400 ml. of eluate. Some chromatographic experiments failed to give appreciable separation. This was usually ascribable to the difficulty of applying the mixture to the top of the column in a sufficiently small volume of solvent.

On the Occurrence of Hydronootkatinol in the Heartwood of *Cupressus Lindleyi* Klotsch

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Received April 15, 1963

Continuing our investigations[1] of the tropolones present in heartwood of *Cupressus* species, we examined *Cupressus lindleyi* Klotsch, a species native to Mexico.

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(1) E. Zavarin, *J. Org. Chem.*, **27**, 3368 (1962).