



Emile Eugène Burcker

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Resumen

Emile-Eugène Burcker (1846-1908) fue un farmacéutico militar francés que llevó a cabo un exitoso programa de investigación sobre la aplicación del método Friedel-Crafts a la síntesis de ácidos, cetonas, aldehídos y glicoles en la serie aromática, que finalmente culminó en su tesis doctoral. En particular, fue capaz de sintetizar un número significativo de nuevos ácidos acetónicos y cetónicos caracterizados por la presencia en su molécula tanto del grupo carbonilo CO como del grupo COOH; teniendo así la capacidad de reaccionar como acetonas, formando sales, ésteres, así como ácidos ordinarios, y todo también, bajo la influencia del hidrógeno nascente, de formar oxácidos o ácido-alcoholes. Algunos de los nuevos compuestos incluían el ácido benzoilpropiónico, ácido benzhidrilpropiónico, fenil propil acetona, ácido tolulilpropiónico, ácido fenilcanfórico, etc. Burcker también estableció el mejor procedimiento para dosificar KOH, así como una versión mejorada del método Kjeldahl para determinar la cantidad de nitrógeno presente en compuestos orgánicos.

Palabras clave

Ácido benzoilpropiónico; alcanfor; hidróxido de potasio; método de Kjeldahl; reacción de Friedel-Crafts.

Abstract

Emile-Eugène Burcker (1846-1908) was a French military pharmacist who carried out a successful research program on the application of the Friedel-Crafts method to the synthesis of acids, ketones, aldehydes, and glycols in the aromatic series, which finally culminated in his doctoral thesis. In particular, he was able to synthesize a significant number of new acetonic and ketonic acids characterized by the presence in their molecule of both the carbonyl group CO and the group COOH; thus, having the ability to react as ketones, forming salts, esters, and as ordinary acids, and everything also, under the influence of nascent hydrogen, of forming oxyacids or acid-alcohols. Some new compounds included benzoylpropionic acid, benzhydrylpropionic acid, phenyl propyl acetone, toluylpropionic acid, phenylcamphoric acid, etc. Burcker also established the best procedure for dosing KOH, as well as an improved version of the Kjeldahl method to determine the amount of nitrogen present in organic compounds.

Keywords

Benzoylpropionic acid; camphor; Friedel-Crafts reaction; Kjeldahl method; potassium hydroxide.

Life and career (Sitzman, 1909; Labrude, 2020; Anonymous, 2023)

Emile-Eugène Burcker was born in Pfaffenhoffe on May 6, 1846, the son of Jean-Michel Burcker, an indirect tax controller of second class, and Caroline Strohl. He took his basic education at the school in Bouxwiller (Bas-Rhin, France) and after graduation he entered the École de Impériale du Service de Santé Militaire in Strasbourg and the École d'Application of Val-de-Grace (military hospital) from where he graduated in 1869 as pharmacien aide-major de 2^e classe. His special aptitudes for physical science led him to the highest degrees in military pharmacy. Thus, he was pharmacien de 1^{ère} classe in Strasbourg in 1868, pharmacien principal de 2^e classe in 1874, and pharmacien principal de 1^e classe in 1880. In 1898, he was promoted to pharmacien inspecteur du Service de Santé. Between 1877 and 1882 he was appointed professor agrégé de chimie at Val-de-Grace, and in 1882 he obtained his diploma of licencié ès-sciences physiques from the Sorbonne and his degree of docteur ès-sciences physiques from the Faculté de Sciences de Paris, after successfully defending a thesis of about the synthesis of acids, ketones, aldehydes, and glycols of the aromatic series, carried under the direction of Charles Friedel (1832-1899) (Burcker, 1882a). The jurors were Paul Quentin Desains (1817-1885), Louis Joseph Troost (1825-1911), and Charles-Adolph Würtz (1817-1884). The same year, he moved to Alger to serve as chef des travaux of chemical practice at the École de Sciences d'Alger. In 1887, he returned to France to serve as professor of applied chemistry at the École d'Application de Médecine et de Pharmacie at Val-de-Grace, a position he kept until 1897. During this period, he was member and President of the Société de Pharmacie et de Chimie in Paris. In 1886, he was appointed Chevalier of the Légion d'Honneur and in 1896 promoted to Officier. He was elected Officier de l'Instruction Publique (awarded to distinguished academics and teachers and for valuable service to universities, education, and science). In 1892, he was awarded the Vernois Prize by the Académie de Médecine.

In 1876 Brucker married Claire Marie Eulriet; two children were born of this union, Jean Marie Georges and Eugénie Marguerite.

Emile-Eugène Burcker passed away in Suresnes (Hauts-de-Seine), on July 14, 1908.

Scientific contribution

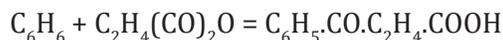
Burcker wrote more than 20 papers and books (i.e., Brucker, 1891; Dechambre 1879-1889) about his research activities in organic, inorganic, and analytical chemistry, chemical synthesis, etc. As candidate to the Council d'Hygiène Publique et de Salubrité du Département de la Seine and to the Académie de Médecine, he published a booklet describing his research and achievements (Brucker, 1895a). In addition to the few subjects defined below, Brucker described the preparation of the double carbonate of uranium and ammonia and the separation of the oxides of iron and uranium (Brucker, 1878), he analyzed an eau-de vie formed in the marcs of dry grapes (Brucker, 1892); studied the stability of the aqueous solutions of mercuric chloride (Brucker, 1894b); carried on the dosage of the volatile acids from wine (Brucker, 1895b); together with L. A. Georges and L. C. Gaillard he studied the problem of the emulsification of heavy coal oils using soap solutions, and developed a method to obtain stable emulsions where heavy oils of any composition could be used by modifying, the relative proportions of the emulsifying body and of the body to be emulsified (Burcker, Georges, & Gaillard, 1894); etc.

Organic synthesis using the Friedel-Crafts reaction

Burcker wrote that the methods of chemical synthesis developed in the last fifty years had allowed the preparation of many new organic acids belonging to the aromatic and fatty series, having simple and complex functions, (Burcker, 1882a). Unfortunately, none of these procedures were sufficiently broad to generate systematically acids having complex functions. In 1877, Charles Friedel (1832-1899) and James Mason Crafts (1839-1917) presented a new method of synthesis, based on the use of anhydrous aluminum chloride as a catalyst, which they first applied to the production of hydrocarbons and then successively extended to that of acetones, nitriles, and acids in the fatty series and especially, in the aromatic series. The Friedel-Craft method was so versatile that it rapidly became a general method of organic synthesis. Among many others, it allowed the synthesis of an acetic acid, hydroxyisobutyric acid, $(\text{CH}_3)_2\text{C}(\text{OH})\text{COOH}$], of *o*-benzoylbenzoic acid, and benzoyl sulfurous acid (Burcker, 1882a).

Burcker carried an extensive research program on the application of the Friedel-Crafts method to the synthesis of acids, ketones, aldehydes, and glycols in the aromatic series, which eventually culminated in his doctoral thesis (Burcker, 1882a).

His first work was devoted to the synthesis of benzoylpropionic acid (Burcker, 1881, 1882a). In his initial experiments, he heated to boiling a mixture of 500 g of pure crystallizable benzene with 500 g of succinic acid and then added piecewise 78 g of anhydrous aluminum chloride. The resulting reaction was very lively and accompanied by the release of a large amount of HCl. Once this release stopped, he added distilled water and noted that the liquor separated into two phases. The upper red layer, which contained the product and the non-reacted benzene, was concentrated by evaporation and the residue treated with water and HCl to liberate the benzoylpropionic acid. The resulting white flaky crystals were separated by filtration and purified by repeated recrystallization from boiling water and ether. This procedure was found to have a very low yield, it produced only 5 to 6 g of pure product, according to the reaction.



while leaving a brown-red residue, soluble in alkalis, and forming with calcium carbonate an amorphous calcium salt.

Burcker carried numerous experiments trying to find the appropriate ratio of the reagents, which would provide a yield close to the theoretical one. This turned out to be 10 parts of benzene (large excess), 1 part of succinic anhydride, and 1.5 of aluminum chloride. This mixture was put in a sufficiently large flask and found to react at room temperature, accompanied, as previously, by the release of abundant HCl. When the evolution of gas was over, the mixture, slightly brown, was sprayed in small portions into a large quantity of water and the whole stirred, taking care to add from time to time a little HCl to facilitate the passage of the product to be formed into benzene, and to convert $\text{Al}_2\text{Cl}_5(\text{HO})$, which arose in the reaction, into Al_2Cl_6 , to make it more soluble. The upper layer was constituted mainly of benzoylpropionic acid dissolved in the excess benzene. The aluminum regenerated aluminum chloride was found in the lower aqueous layer. The upper layer was distilled to eliminate the benzene and then treated with HCl to release the benzoylpropionic acid in the form of small white crystalline flakes. The desired compound was washed with cold water to completely remove the HCl, and then purified by recrystallization from boiling water and ether (Burcker, 1881, 1882a).

Burcker wrote that benzoylpropionic acid dissolved very easily in the cold, in ether, alcohol, benzene and in chloroform and melted at 116 °C. Analysis of the product obtained by crystallization from ether and dried over sulfuric acid in vacuum indicated that it contained, by weight, 66.82% carbon, 5.90% hydrogen, and 27.28% oxygen, corresponding to the formula $C_{10}H_{10}O_3$. Molten with KOH, it split down into benzoic acid and propionic acid. It was strongly attacked by nitric acid of relative density 1.315, with release of abundant nitrous vapors. The mixture of sulfuric acid and potassium dichromate decomposed benzoylpropionic acid into benzoic and propionic acids. In short, all oxidative reactions led to the same result: formation of benzoic acid and propionic acid. Nascent hydrogen produced with the aid of sodium amalgam or zinc and HCl, reduced benzoylpropionic acid into an alcohol acid or oxyacid, which Brucker named *benzhydrylpropionic acid*, $C_6H_5-CHOH-C_2H_4-COOH$ (see below). Benzoylpropionic acid had no action on the plane of polarized light, it was a monobasic acid; its basicity emerged from the study of some of its salts (Burcker, 1881, 1882a).

Burcker prepared several salts of benzoylpropionic acid, among them, the benzoylpropionates of sodium, potassium, barium, calcium, cobalt, copper, silver, and silver, and described their properties. For example, sodium benzoylpropionate, $C_{10}H_9NaO_3$, was prepared by directly saturating a suspension of the acid in water with NaOH or neutralizing a hot solution of the acid with sodium carbonate. The salt appeared as white masses, agglomerated and without crystalline appearance. It was very soluble in cold water, and more in boiling water. It was insoluble in alcohol, ether, and chloroform. Burcker also mentioned that this acid formed composed of esters with alcohols (Burcker, 1881, 1882a).

Burcker added that there was another acid, with the same centesimal composition as benzoylpropionic acid, corresponding to the formula $C_{10}H_{10}O_3$; it was *phenyloxycrotonic acid* of constitution $C_6H_5-CH=CH-CH(OH)(COOH)$, prepared by long boiling a mixture of cinnamic aldehyde, hydrogen cyanide, and HCl. It was an acid alcohol, having properties and forming derivatives totally different from those of benzoylpropionic acid (Burcker, 1881, 1882a).

As mentioned above, benzhydrylpropionic acid was obtained by the action of nascent hydrogen on benzoylpropionic acid, in which the group CO was transformed into CHOH. This transformation, characteristic of acetic acids, occurred just as well with sodium amalgam as with zinc and HCl in alcoholic solution. When using sodium amalgam, care had to be taken to avoid carrying the hydrogenation too far and obtaining a considerable quantity of another acid, *benzylpropionic acid*. The purified acid appeared as small anhydrous prismatic crystals belonging to the orthorhombic system. They were very soluble in alcohol, ether, and chloroform, insoluble in cold water, and more soluble in boiling water. Chemical analysis indicated that they contained, by weight, 66.80% carbon, 6.68% hydrogen, and 26.52% oxygen. The crystals melted around 30°-31 °C and boiled between 230° and 235 °C. Maintained for a certain time at this temperature, they lost water and turned into a crystalline anhydride like lactide. This anhydride was almost completely insoluble in water, sparingly soluble in alcohol and chloroform, and a little more soluble in ether. Benzhydrylpropionic acid, treated by oxidants such as potassium chromate and sulfuric acid, diluted nitric acid, and potassium permanganate, turned again into benzoylpropionic acid. Burcker prepared a variety of salts of this acid, among them the sodium, potassium, calcium, and barium ones (Burcker, 1881, 1882ae).

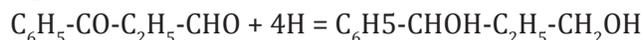
Burcker also studied the action of dichlorochromic acid on certain mixed acetones, looking for a method of preparing benzoylpropionic acid by oxidation of phenyl propyl acetone or propyl benzoyl $C_6H_5-CO-C_3H_7$, by analogy with the formation of benzoylbenzoic acid achieved by Theodor Zincke (1843-1928) by oxidizing phenyl tolyl acetone, $C_6H_5-CO-C_6H_4-CH_3$ (Zincke, 1872; Burcker, 1882ac). In this study, Burcker was guided by the principle established by Alexandre-León Étard (1852-1919) that aromatic hydrocarbons containing one or more methyl groups, formed an addition product with chlorochromic, where two molecules of the latter attached to a single methyl carbon. The resulting dichlorochromic combinations were decomposed by water, and, in by virtue of their constitution, the result of the reaction was an aldehyde (Étard, 1881).

Burcker wrote that phenyl propyl acetone, $C_6H_5-CO-C_3H_7$, was usually prepared by calcining a mixture of calcium benzoate and calcium butyrate, with a relatively low yield. Once again, he substantially increased the yield by preparing this compound using the Friedel-Crafts method: the reaction between butyryl chloride and a large excess of benzene, in the presence of aluminum chloride, at room temperature. When the evolution of HCl was complete, the whole was sprayed in small portions into cold water. The acetone formed remained in the upper liquid phase, together with the excess of benzene; 30 g of butyryl chloride acting on an excess of benzene in the presence of 40-45 g of aluminum chloride, yielded 20 to 25 g of pure mixed acetone (Burcker, 1882d).

Burcker carried the reaction between phenyl propyl acetone and dichlorochromic acid and found that the experimental results justified his assumption, he not only obtained an aldehyde-acetone, but treating it with nascent hydrogen generated by the sodium amalgam he obtained, for the first time, an aromatic glycol, which was simultaneously both primary and secondary (Burcker, 1882ac). The mixed acetone was synthesized using the Friedel-Crafts reaction on a mixture of 10 parts of benzene, 1 part of butyryl chloride, and 1 to 2 parts of aluminum chloride, which was added in small portions. The reaction was very lively at room temperature, with liberation of large amounts of HCl, and without the help of heat. Once again, after the release of HCl had stopped, the whole was sprayed with small portions of water. The liquid separated into two layers; the top layer was composed of the excess of benzene, holding in solution the mixed acetone. The upper layer was distilled to evaporate the mayor part of the benzene, and the residue, subjected to successive fractional distillations, with phenyl propyl acetone distilling at 220°-222 °C. The overall yield was 75 to 80 g of pure acetone for 100 g of butyryl chloride. Burcker prepared butyryl chloride by reacting phosphorus trichloride with butyric acid (Burcker, 1882ac).

Burcker remarked that he prepared the reagent dichlorochromic acid following the recommendations given by Étard and his proportions of the reactants. The yield was very good, especially if care was taken to properly calcine the mixture of sodium chloride and potassium bichromate before treating it with fuming sulfuric acid. The direct reaction between dichlorochromic acid and the acetone was very dangerous, and usually accompanied by explosion. Proper precautions indicated the use of a solvent such as anhydrous chloroform and adding the dichlorochromic acid in small portions to the chloroform solution of the acetone. The total amounts were 1 molecule of phenyl propyl acetone and 2 molecules of dichlorochromic acid. The purified aldehyde-acetone was a colorless liquid, which turned yellow and even turned brown very quickly in contact with air; it had a pleasant odor, a burning flavor, and its vapors strongly irritated the eyes. It was insoluble in water and very soluble in ether, alcohol, and chloroform. Its relative

density at 0 °C was 1.005; it boiled at around 245 °C under a pressure of 775 mmHg and decomposed at a slightly higher temperature. The aldehyde-acetone, under the influence of nascent hydrogen and according to its constitution, turned into a glycol containing the groups CHOH and CH₂O:



The purified glycol appeared as a very thick syrupy liquid, slightly yellow, easily soluble in alcohol, ether, chloroform, and acetyl chloride (Burcker, 1882ac).

As mentioned before, benzoylpropionic acid C₆H₅-CO-C₂H₄-COOH, under the action of nascent hydrogen fixed two hydrogen atoms on its carbonyl group and transformed into benzhydrylpropionic acid, C₆H₅-CHOH-C₂H₄-COOH. The purified acid appeared as white crystalline needles, belonging to the orthorhombic system, melting between 30° and 31 °C, and boiling at 235 °C. It was soluble in alcohol, ether, chloroform, and boiling water, and insoluble in cold water. It combined with the bases to form salts, which were hard to crystallize. Brucker described the preparation and properties of the benzhydrylpropionates of potassium, sodium, calcium, barium, and silver. Benzhydrylpropionic acid was the higher homolog of phenylglycollic acid C₈H₈O₃ = C₆H₅-CH(OH)(COOH) and phenyllactic acid: C₈H₁₀O₃ = C₆H₅-CH₂-CH(OH)(COOH) (Burcker, 1882e).

Based on his work, Burcker made some remarks regarding acetic or ketonic acids. These composed were characterized by the presence, in their molecule, of the carbonyl group CO, in addition to the COOH group; consequently, they possessed the ability of reacting like to acetones and, all, in fact, could form salts, ethers, like ordinary acids, and all also, under the influence of nascent hydrogen, of forming oxyacids or acid-alcohols, due to the transformation of the CO group into CHOH. They were therefore acids with a complex function. He then went on to describe many of these compounds, their synthesis, and properties; among them those belonging to the fatty series (i.e., pyruvic acid and acetylacetic acid) and to the aromatic series (i.e., phenylglyoxalic acid and benzoylbenzoic acid) (Burcker, 1882a).

In a following work, Burcker reported the synthesis of toluylpropionic acid by reacting succinic anhydride with a large excess of toluene, in the presence of anhydrous aluminum chloride, at room temperature. The resulting upper liquid phase contained the toluylpropionic acid dissolved in the excess of toluene. The latter was eliminated by distillation. The residue was purified by successive crystallizations in boiling water. The purified toluylpropionic acid appeared as blades or fine needles, insoluble in cold water and very soluble in ether, alcohol, chloroform, benzene, toluene, and boiling water. It melted at 120 °C and decomposed before reaching its boiling temperature. This acid formed easily crystallizable salts, among them, those of potassium, sodium, barium, silver, cobalt, nickel, and copper (Burcker, 1888).

Brucker also found that the Friedel-Crafts procedure could also be applied to the reaction between benzene and camphoric anhydride, in the presence of anhydrous aluminum chloride (Brucker, 1890, 1894c, 1895cd, and Burcker & Stabil, 1894). His results indicated the formation of a series of new compounds, depending on the operating conditions, among them, phenyl camphoric acid, a body endowed with acidic and acetic properties, containing, by weight, 73.3% carbon, 7.8% hydrogen, and 18.9% oxygen, corresponding to the formula C₁₆H₂₀O; its anhydride, C₁₆H₁₈O₂, a diphenyl combination, C₂₂H₂₄O₂, and a white resinous compound, appearing as white pearly crystals, melting at

135°-137 °C, boiling at 320 °C under the pressure 760 mmHg, insoluble in water, sparingly soluble in ligroin, and very soluble in acetic acid, ether, benzene, chloroform, and carbon disulfide; it was dextrorotary, and contained, by weight, 77.7% carbon, 8.58% hydrogen, and 14.25% oxygen, corresponding to the formula $C_{15}H_{20}O_2$. Burcker prepared its methyl and ethyl derivatives, the anhydride, and various salts (Burcker, 1895d).

All these work about the application of the Friedel-Crafts reaction earned Burcker part of the 1895 Jecker Prize of the Académie des Sciences.

Analytical chemistry

Dosage of KOH

According to Burcker, the standard method for the dosage of KOH was based on precipitating the hydroxide as cream of tartar by addition of potassium bitartrate. The precipitate was separated by filtration, washed with a cold saturated solution of potassium bitartrate, and then dissolved in hot water, followed by alkalimetry with a normal solution of NaOH (Burcker, 1882b). In 1882, Eugène Marchand (1816-1895) published a method for dosage of KOH, which he believed was new, but was just a modification of the standard process (Marchand, 1882). In his method, Marchand used a standard solution of potassium bitartrate of which one cubic centimeter precipitated 0.1 g of KOH. The sample tested was precipitated with an excess of the standard solution, followed by alkalimetric titration of the excess of reagent. Marchand used a water-alcohol solution of cochineal for detecting the end point of the alkalimetry (Marchand, 1882).

These facts led Burcker to make a comparison of both methods from the double point of view of accuracy and speed of execution. For this purpose, he carried a series of analyses using a potassium solution containing 0.5 g of pure and dry potassium chloride for 0.1 g of liquid. The average of six determinations with the direct method gave 0.5009 g and 0.520 g for the Marchand method. These results indicated that the direct method was clearly more accurate than the indirect one. In addition, the indirect method took longer to execute because it required two titrations of the bitartrate solution, one before the analysis, the second, afterward. Burcker also tested Marchand's claim that the presence of sodium, magnesium, and calcium salts did not interfere with the analysis. Burcker results indicated that this claim was true only for sodium and magnesium salts; the calcium salts were precipitated by the sodium bitartrate (Burcker, 1882b).

The Kjeldahl method

In 1841, Heinrich Will (1812-1890) and Warrentrapp proposed a new method for determining the presence of nitrogen in an organic compound, based in decomposing the organic substance by means of heat, in the presence of an excess of alkali (Will & Warrentrapp, 1841). This reaction liberated all the nitrogen in the state of ammonia, which would be dosed easily. The substance being tested was mixed with sodium hydroxide and calcium hydroxide and put in a combustion tube. The open end of the tube was connected to another tube formed by balls, full of HCl. The released ammonia reacted with the acid, forming ammonium chloride. The pertinent dissolution was mixed with another of platinum chloride and the precipitate of the double chloride of platinum ammonium filtrated, washed, dried, and weighed; 223.25 g of the double chloride corresponded to 14 grams of nitrogen (Will and Warrentrapp, 1841).

The Will and Warrentrapp method were adopted as the standard method of analysis of nitrogen for many years, with minor modifications. In 1893, Johan Kjeldahl (1849-1900) developed an alternative method for determining nitrogen based on a three-step process: (1) a digestion with hot and concentrated sulfuric acid, which transformed the nitrogen of the organic matter into ammoniacal nitrogen in the presence of an oxidizing body, such as anhydrous copper sulfate, metallic mercury (which transformed into sulfate), and potassium permanganate; (2) the ammonium ions were then converted into ammonia gas, heated and distilled, and (3) the ammonia gas was absorbed in a standard solution of HCl or sulfuric acid, which was back titrated with NaOH to indirectly measure the nitrogen (Kjeldahl, 1893).

According to Burcker, the oxidants used in the first stage could be replaced by sulfuric acid mixed with phosphoric acid, and better, by using fuming sulfuric acid from Nordhausen. The Kjeldahl method promptly replaced the Will-Warrentrapp because it was simpler, much faster, and allowed several dosages to be carried out simultaneously (Burcker, 1894a).

Burcker made a detailed study of the Kjeldahl method and recommended that it be carried schematically as follows: 0.5 to 2 g of the material to be analyzed were placed in a flask of capacity 200 to 250 cm³ and then sprayed with about 20 cm³ of fuming sulfuric acid or concentrated and pure sulfuric acid mixed with 1 g of metallic mercury; the balloon was then closed and the whole heated to boiling with a Bunsen burner until the liquid became clear perfect. After cooling, distilled water was added to have about 100 cm³; the mercury salt which formed was stirred to dissolve. Before distillation, the entire was mixed with enough concentrated NaOH to obtain a basic medium, and with sodium sulfide to precipitate the mercury. The resulting ammonia was then distilled off and collected in a known volume of a standard solution of sulfuric acid. If the sample contained nitrates, they could be eliminated by heating the sample to dryness with ferrous chloride and HCl. The nitric acid was thus eliminated in the form of nitrogen dioxide; heating was continued until no more acid vapors were given off (Burcker, 1894a).

Burcker added that the Kjeldahl method had gone through several modifications to extend its use for the determination of the total nitrogen of nitrogenous substances. For example, the modification proposed by Max Jodlbauer was intended for the dosage of nitrate nitrogen and, consequently, for that of the total nitrogen contained in fertilizers (Jodlbauer, 1886). It was based on the successive use of phenylsulfuric acid and zinc; the sulfuric acid reacted with phenol to yield mononitrophenol, which the zinc then transformed into an amide derivative. If necessary, the phenylsulfuric could be prepared by dissolving 50 g of phenol in concentrated and pure sulfuric acid, used in sufficient quantity to obtain 100 cm³ of solution (Burcker, 1894a).

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