

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, YALE UNIVERSITY]

SYNTHESIS OF PHENYLETHYL ALCOHOL¹

BY CLIFFORD SHATTUCK LEONARD

RECEIVED APRIL 7, 1925

PUBLISHED JUNE 5, 1925

Introductory

β -Phenylethyl alcohol (benzyl carbinol) is today a chemical substance of commercial importance. This colorless liquid possessing a faint but lasting rose odor is valuable to the perfume industry not only for its own odor but also because of the fact that when admixed with other essential oils it has the property of increasing, modifying and more permanently fixing their odors. Certain derivatives of the alcohol such as its formic, propionic benzoic and phenylacetic esters are also valuable perfume fixatives. Recently, phenylethyl alcohol has been found to have local anesthetic properties.²

Phenylethyl alcohol occurs in nature in the rose flower and constitutes about 60% of the oil extractable with ether from the flower. Rose oil of commerce, however, contains but a trace of the alcohol, for it is water-soluble and is thus separated in the process of steam distillation. It is

¹ This paper is constructed from a thesis presented to Yale University in June, 1917, for the degree of Master of Science. The work was done on the J. B. Williams Company Industrial Fellowship. The results have recently been released for publication. The writer wishes to thank the J. B. Williams Company. Thanks are also due to Professors T. B. Johnson and Arthur J. Hill for their guidance and advice.

² Hjort and Eagen, *J. Pharmacol.*, **14**, 211 (1919). Thierfelder and Schempp, *Arch. ges. Physiol.*, **167**, 280 (1917). See *Physiol. Abstr.*, **2**, 465 (1917-18).

then to be found in the distillation waters, known as rose water of commerce. Eighty per cent. of the oil extractable from this water with ether is phenylethyl alcohol. Pomade and maceration oils contain the alcohol while attar of roses contains but a trace.³

There are three other natural occurrences of phenylethyl alcohol noted in the literature.⁴ Many syntheses of this alcohol are described. Few of these are of more than theoretical interest. A survey of the methods of synthesis described in the literature is appended below. (Table I.)

In the work outlined here attention was confined to the process of Bouveault and Blanc which involves four steps: (1) chlorination of toluene to benzyl chloride; (2) the preparation of benzyl cyanide from this chloride; (3) the hydrolysis and esterification of the cyanide giving ethyl phenylacetate; (4) the reduction to phenylethyl alcohol.

The first step will be passed over without comment, for benzyl chloride is a readily available commercial chemical. The experimental part begins therefore, with the preparation of benzyl cyanide.

Preparation of Benzyl Cyanide

Recommended Synthesis.—Three parts by weight of the finely pulverized sodium cyanide mixture are dissolved in two parts of water, in an iron tank with reflux condenser and stirrer. Then three parts of benzyl chloride, dissolved in four parts of 95% alcohol, are introduced. The mixture is digested at the temperature of boiling alcohol during constant stirring. Portions of the upper, oil layer are removed from time to time and subjected to a test for organic chlorine. When the oil contains no unchanged benzyl chloride, the heating is discontinued. The cooled reaction mixture is tapped into the extraction apparatus, the water layer separated, and the benzyl cyanide extracted with benzene. The extract is washed with water several times, dried and the benzene removed by slowly running the filtered solution into a heated still. A vacuum pump is then connected and the oil distilled under reduced pressure. The wash waters from the benzene extraction are concentrated in order to recover the phenylacetamide. The latter is then filtered and dried.

Cannizzaro⁵ carried out this preparation of benzyl cyanide from benzyl chloride with potassium cyanide. In the work here recorded this latter chemical was replaced with the cheaper sodium cyanide mixture of com-

³ Von Soden and Rojahn, *Ber.*, **33**, 1720, 3063 (1900); **34**, 2803 (1901). Walbaum, *Ber.*, **33**, 1903 (1900). Walbaum and Stephan, *Ber.*, **33**, 2303 (1900).

⁴ Neroli oil distillation waters, (a) Hesse and Zeitschel, *J. prakt. Chem.*, [2] **66**, 509 (1902). Oil of Aleppo pine, (b) Grimal, *Compt. rend.*, **144**, 434 (1907). Bourbon geranium, (c) Schimmel and Co., *Semi-Ann. Rept.*, Oct., 1910, p. 69; through *Proc. Am. Pharm. Assoc.*, **59**, 378 (1911); *C. A.*, **5**, 569 (1911).

⁵ Cannizzaro, *Ann.*, **96**, 247 (1855); *Ann. chim. phys.*, **45**, 468 (1855); *Compt. rend.*, **41**, 517 (1855). See also Radziszewski, *Ber.*, **3**, 198 (1870); **18**, 1282 (1885).

TABLE I
LIST OF SYNTHESSES

Investigator	Reference	Immediate raw material	Yield %	Ultimate source	No. of steps
Radziszewski	<i>Ber.</i> , 9, 372 (1878)	Phenylacetalddehyde	?	Cinnamic acid or toluene	4
Soden and Rojahn	<i>Ber.</i> , 33, 1720 (1900)	Phenylacetalddehyde	?	Cinnamic acid or toluene	4
Skita and Ritter	<i>Ber.</i> , 43, 3393 (1910)	Phenylacetalddehyde	"Good"	Cinnamic acid or toluene	4
Neuberg and Welde	<i>Biochem. Z.</i> , 62, 477 (1914)	Enol-phenylacetalddehyde	?	Cinnamic acid or toluene	5
Semmler	<i>Ber.</i> , 42, 581 (1909)	Enol-phenylacetalddehyde mono-acetate	?	Cinnamic acid or toluene	4
Ehrlich	<i>Ber.</i> , 40, 1027 (1907)	Phenylalanine	?	(Proteins)	1
Tiffeneau and Fourneau	<i>Compt. rend.</i> , 146, 697 (1908).	Styrolene oxide	?	.....	1
Grignard	<i>Ibid.</i> , 138, 1048 (1904)	Bromophenetol	?	Phenol	6
Grignard	<i>Ibid.</i> , 141, 44 (1905)	Ethylene chlorohydrin and bromobenzene	?	Benzene	4
Wohl and Berthold	<i>Ber.</i> , 43, 2175 (1910)	Phenylethyamine	38	Toluene	4
Braun	<i>Ber.</i> , 44, 2867 (1911)	Phenylethyamine	?	Toluene	6
Bouveault and Blanc	<i>Compt. rend.</i> , 137, 60; <i>Bull. soc. chim.</i> , 31, 666, 748 (1904); Ger. pat., 164,294; Brit. pat., 14,158 of 1904; French pat., 338,895	Ethyl phenylacetate	60-80	Toluene	4
Bouveault and Blanc	<i>Compt. rend.</i> , 138, 150 (1904); Ger. pat., 164,883	Phenylacetamide	25-30	Toluene	4
Chablay	<i>Compt. rend.</i> , 156, 1020 (1913); <i>Ann. Chim.</i> , [9] 8, 145 (1917)	Ethyl phenyl acetate	?	Toluene	4
Ranedo ^a	<i>Anales soc. españ. fis. quim.</i> , 16, 35 (1918); <i>C. A.</i> , 13, 2514 (1919)	Benzyl chloride and chloromethyl ether	?	Toluene	2
Marie and Marquis ^a	<i>Bull. soc. chim.</i> , [4] 25, 512 (1919)	Phenylacetic acid	33	Toluene	4
Altwegg ^a	U. S. pat., 1,315,619; <i>C. A.</i> , 13, 2883 (1919)	Bromobenzene and ethylene oxide	?	Benzene	2
Lewinsohn ^a	<i>Riv. ital. ess. profum.</i> , 4, 102 (1922); <i>C. A.</i> , 17, 2031 (1922)	Ethyl phenylacetate	65	Toluene	4

^a Published since the completion of this work in 1917.

merce (containing sodium chloride and possessing a cyanide equivalent of 98% potassium cyanide). Since this work was completed Gomberg and Buchler⁶ have described a preparation of benzyl cyanide using sodium cyanide but they obtain only 50–60% yield at best and they do not recover any valuable by-product such as phenylacetamide.⁷

Experimental.—The influence upon the yield of several factors was thoroughly studied and variations were made in amount of cyanide, digestion time and digestions with and without stirring. The stirring was most effective in shortening the time of digestion. A reaction mixture of 11 kg. was chlorine-free by test at the end of 35 hours of stirred digestion. The yield of fractioned benzyl cyanide was 76%. Extraction of phenylacetamide gave a total recovery of 93%. For the preparation of phenylacetic ester the amide is as useful a product as the cyanide.

Preparation of Ethyl Phenylacetate

Recommended Synthesis.—Fifty parts by weight of benzyl cyanide are slowly run into a large, round-bottomed Pyrex flask containing 75 parts of concd. sulfuric acid to which have been added 3.5 parts of water. The flask is first cooled and the temperature kept below 70° during the slow addition of the cyanide. Then, 131 parts of 95% alcohol are added. The mixture is heated to the boiling point of alcohol until a test portion of the oil gives no test for nitrogen. On cooling, the reaction mixture is poured into an equal volume of cold water, then extracted with ether or benzene, the extract washed with water and dried. The solvent is next removed and finally the ester distilled under diminished pressure (103–107°, at 6 mm.). The sulfuric acid solution left from the extraction contains considerable ammonium sulfate. The phenylacetic acid recovered in the final step, and the phenylacetamide from the first operation, may be esterified in this same operation.

Experimental.—Sulfuric acid was substituted for the hydrogen chloride gas used by Wislicenus⁸ in such hydrolysis. Variations in proportion of ingredients were thoroughly investigated with regard to their effect on the yield. Digestion was continued until a test for nitrogen in a small portion of the ester became negative. Lots of 2.3 kg. each were digested in ten-liter flasks, yielding 78% of an oil boiling at 103–107° under 6 mm. pressure. The best conditions were those of the recommended synthesis above.

⁶ Gomberg and Buchler, *THIS JOURNAL*, **42**, 2069 (1920).

⁷ Gomberg and Buchler note: "The reaction seems to be extremely sensitive to the influence of various factors and the yields of the cyanide vary in different experiments, notwithstanding the fact that these experiments have been carried out under as nearly identical conditions as possible."

The writer suggests that since Gomberg's experiments were carried out without *stirring*, the only mixing resulted from the boiling and from the running in, portion-wise, of benzyl chloride. This can very well account for the variability and the low yield. Their results were also obtained without the use of alcohol, which solvent probably serves to carry benzyl chloride into actual solution in the cyanide-water layer, as well as to prevent hydrolysis.

⁸ Wislicenus, *Ann.*, **296**, 361 (1897).

Ethyl Phenylacetate to Phenylethyl Alcohol

Recommended Synthesis.—Nine-tenths of a part of sodium (six atomic proportions) is placed in an enamel-lined, round-bottomed, reduction tank with about three parts of toluene. The tank, which must be equipped with efficient stirring device and reflux condenser, is then heated to the melting point of sodium. When the sodium is molten, the stirrer is started and the sodium brought to a state of emulsification. One part of ethyl phenylacetate, dissolved in three parts of absolute alcohol, containing one part of toluene, is slowly added. The heating is discontinued and the reaction controlled by the addition of the ester. When all the ester is added, three parts more of absolute alcohol are slowly run in and the reaction mixture again heated, if necessary, until all the sodium has reacted. The reaction mixture is next subjected to a distillation under diminished pressure to remove the alcohol and toluene. Practically, all of the alcohol-toluene introduced may be recovered, together with the alcohol resulting from the decomposition of the ester. The mud remaining in the still is dissolved in water and the phenylethyl alcohol extracted with ether or benzene. The extract is dried over sodium sulfate, the solvent removed and the oil distilled under diminished pressure. The fraction boiling between 100° and 106° at about 12 mm. is collected. The alkaline liquid from the extraction is neutralized with hydrochloric acid and, on cooling, the phenylacetic acid is crystallized. This is filtered and dried. As shown above, this acid may be re-introduced into the process by re-esterifying it. The phenylethyl alcohol may finally be purified by means of the calcium chloride addition compound.

Experimental (See Table II).—The use of Bouveault and Blanc's method without modification gave a yield of 30–31% of phenylethyl alcohol. This process was however modified by preliminary emulsification of the sodium in toluene.⁹ The table records the various proportions and conditions employed. With a final quantity of 1.3 kg. in each

TABLE II

PHENYLETHYL ALCOHOL.	THE MODIFIED BOUVEAULT AND BLANC REDUCTION METHOD						
Expt.	1	2	3	4	5	6	7
Ester, g.....	50	300	50	50	50	50	1407
Absolute alcohol, g...	380	1800	280	280	250	300	8440
Toluene, cc.....	120	800	200	200	200	200	5450
Sodium, at. equiv....	6	6	4	5	5	6	6
G.....	42	252	28	35	35	42	1225
Container.....	Round-bottom flask	Flat-bottom flask	Round flask	Round flask	Round flask	Round flask	Round-bottom iron pot
Yield, %.....	47.2	25	33.3	33.3	23	40.6	41
Phenylacetic acid, g...	Some	155	...	...	...	...	145
Total recovery (acid included), %.....	...	85.2	...	...	...	...	82

⁹ Levene and Allen, *J. Biol. Chem.*, **27**, 443 (1916).

run, the ester was reduced in an enamel-lined pot fitted with reflux condenser, dropping funnel and an efficient stirring device. The yield was 41-47% of fractionated phenylethyl alcohol distilling at 116-118° under 25 mm. pressure. Phenylacetic acid was recovered from the liquors, giving a total recovery of 82-85%. The phenylethyl alcohol was purified by treatment with calcium chloride as described by Hesse and Zeitschel.¹⁰

Recently a paper in an Italian journal¹¹ has described a modification of this Bouveault and Blanc reduction of ethyl phenylacetate to phenylethyl alcohol. The new method employs calcium shavings as well as sodium in the reduction, and it is claimed that a yield of 65% of the alcohol is obtained and also phenylacetic acid recovered.

Summary

Benzyl cyanide may be obtained in a yield of 76% from benzyl chloride and sodium cyanide mixture. Stirring is an important factor in the yield. Phenylacetamide may be recovered from the extraction wash-waters.

Ethyl phenylacetate may be prepared in a yield of 72% from benzyl cyanide or from phenylacetamide by a single-step hydrolysis and esterification with sulfuric acid and alcohol.

The ester on reduction with sodium and absolute alcohol in the presence of toluene as a diluent gives phenylethyl alcohol in a yield of 47%. Unreduced phenylacetic acid may be recovered and re-employed for the preparation of the ester. The efficiency of this step is 85%.

NEW HAVEN, CONNECTICUT

¹⁰ Ref. 4 a. The calcium chloride addition compound is washed with petroleum ether, then decomposed with water and the alcohol regained by extraction with ether.

¹¹ Lewinsohn, *Riv. ital. ess. profum.*, **4**, 102 (1922); *Abstr. Chem. ind.*, **9**, 553 (1923); *C. A.*, **17**, 2031 (1923).