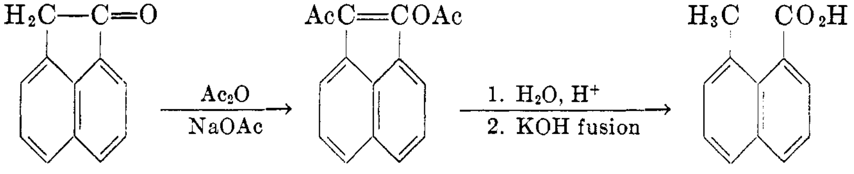
[Contribution from the Chemical Laboratory of the University of California]

PREPARATION OF 1,8-NAPHTHALIDE AND 8-METHYL-1-NAPHTHOIC ACID[1]

JAMES CASON and J. D. WORDIE[2]

Received November 14, 1949

For use in the syntheses described in the following paper, a quantity of 8-methyl-1-naphthoic acid was required. This acid has been reported by Errera and Ajon (1) as melting at 130–131°, but their method of synthesis by way of naphthalonic acid appeared quite unpromising, especially since their melting point was considerably below the value of 152–153° reported by Ghigi (2). The latter investigator prepared the acid by the sequence represented in formulas I–III. The structure assigned to II, the product obtained on heating acenaphthenone (I) with acetic anhydride and sodium acetate, is due to Ghigi and is not necessarily endorsed by the present authors, but there was obtained by us a product of the reported melting point. Hydrolysis of the enol acetate (II), followed by potassium hydroxide fusion, did yield the desired 8-methyl-1-naphthoic acid (III), m.p. 150.2–151°, but unfortunately the yield in the best of several runs was only 3%. Since this sample of acid was identical with that prepared by the method described below, the acid obtained by Ghigi is definitely identified, and the melting point reported by Errera and Ajon is in considerable error.



I II III

The potassium hydroxide fusion of acenaphthenone was also attempted, but the only product obtained was tar.

Ghigi reported that treatment of acenaphthenone with acetic anhydride and pyridine (2, 3) yielded a product described as II plus a molecule of pyridine, and it was reported that hydrolysis gave the same acetylacenaphthenone as obtained by hydrolysis of II. We obtained a product of the melting point reported by Ghigi, for the reaction in pyridine, but we were not able to hydrolyze it to the product obtained from II, and the structure assigned to the product obtained in pyridine seems to us in doubt.

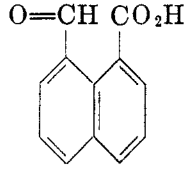
Another attempted synthesis of 8-methyl-1-naphthoic acid utilized 1,8-naphthaldehydic acid (IV) as starting material. The reduction of the aldehyde group was attempted by high pressure hydrogenation of the sodium salt, Clemmensen reduction, and modified Wolff-Kishner reduction (4), but no 8-methyl-1-naph-

---

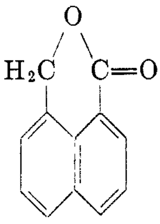
[1] The authors are indebted to the Cancer Research Fund of the University of California for a grant in support of part of this research.

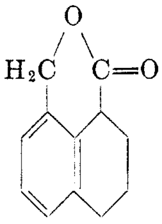
[2] Present address: The Texas Company, Beacon, N. Y.

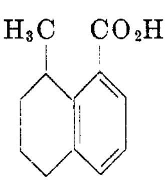
thoic acid was obtained. Since the completion of this work, Fuson and Munn (5) have reported isolation of about an 8% yield of 8-methyl-1-naphthoic acid from the Clemmensen reduction, and the melting point was in agreement with that reported by Ghigi (2) and also obtained by us. Fuson and Munn also reported an excellent yield of 1,8-naphthalide (V) by a cross-Cannizzaro reaction on 1,8-naphthaldehydic acid. Our best preparation of 8-methyl-1-naphthoic acid utilizes 1,8-naphthalide, but it was prepared by another method on account of the difficult accessibility of 1,8-naphthaldehydic acid. The latter compound is prepared by cleavage of acenaphthenequinone (6) with aqueous potassium hydroxide according to Graebe and Gfeller (7). These authors reported an "almost quantitative" yield, but Zink (8) reported an 82% yield and formation of some 1,8-naphthalic acid, while Fuson and Munn (5) reported a yield of 68–73% and did not report removal of naphthalic acid from their product. In our hands, no naphthaldehydic acid was obtained when the procedure of Graebe and Gfeller was followed rigorously, the chief product being 1,8-naphthalic acid. Under milder conditions, we were able to obtain naphthaldehydic acid, but separation of naphthalic acid was always necessary. In some runs the yields were of the order reported by Fuson and Munn; however, even under carefully controlled conditions, working in an atmosphere of nitrogen, the average yield was about 50%. This investigation was finally abandoned in favor of the one-step preparation of naphthalide described below.

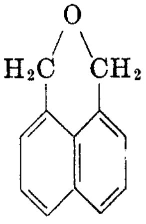

IV

The catalytic hydrogenation of phthalic anhydride to phthalide, using benzene solution and copper chromite catalyst, has been reported by Lazier and coworkers (9). The hydrogenation of 1,8-naphthalic anhydride with copper chromite catalyst in benzene solution has been found to yield a considerable variety of products, and the compounds represented by formulas V–VIII have been isolated from the mixture, although the structures represented by formulas VI and VIII have not been established unequivocally. The ether (VIII) was obtained only as an impure liquid and the structure was assigned on the basis of its


V


VI

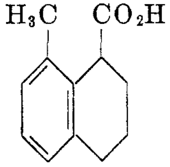

VII


VIII

stability to hot alkali and formation of a solid picrate whose analysis indicates only one atom of oxygen in the naphthalene derivative. The structure of the tetrahydronaphthalide (VI) seems established except for the position of the aromatic ring. The indicated position was assigned on the basis of the instability of the compound, which would indicate a methylene activated by the aromatic ring. This compound was not separated from the isomeric tetrahydronaphthalide, in the mixture obtained from hydrogenation of naphthalic anhydride, and the pure isomer was actually isolated from a reduction of naphthalide in alkali.

The position of the aromatic ring in 5,6,7,8-tetrahydro-8-methyl-1-naphthoic acid (VII) was established unequivocally by its ultraviolet absorption spectrum,[3] which is shown in Figures 1 and 2. In Figure 1, it is seen that the curve for VII is much more similar to that for benzoic acid than to that for phenylacetic acid. In Figure 2, it is apparent that the curve for VII is nearly identical with that for 5,6,7,8-tetrahydro-1-naphthoic acid, but bears no resemblance to the curve for 1,2,3,4-tetrahydro-1-naphthoic acid.

Fuson and Munn (5) hydrogenated naphthalic anhydride with copper chromite catalyst at 260°, but the only compound reported as isolated from this reaction was a tetrahydro-8-methyl-1-naphthoic acid, m.p. 150°, which was the same as the acid obtained on reduction of 1,8-naphthalide with Raney nickel-aluminum alloy. Although not mentioned by Fuson and Munn, this acid was also obtained by Willstätter and Jaquet (10) by reduction of naphthalic anhydride with a platinum catalyst. Since the structure of our acid (VII) of m.p. 118.9–119.6° has been established, it follows that the acid of m.p. 150° reported by the other investigators has the structure shown in formula IX.



IX

The composition of the mixture obtained on hydrogenation of naphthalic anhydride was found to be quite sensitive to temperature and amount of hydrogen absorbed. For maximum production of 1,8-naphthalide (V), it was found best to hydrogenate at 220° until about three mole-equivalents of hydrogen had been absorbed, then work up the mixture and rehydrogenate the material (mostly unreacted naphthalic anhydride) insoluble in benzene. In this manner, a 35% yield of naphthalide could be obtained. Separation of naphthalide (V) from the tetrahydronaphthalides proved exceedingly difficult until it was discovered that if the aqueous alkaline solution obtained by saponification of the mixed naphthalides is adjusted to *p*H about 10, the desired substance (V) crystallizes quanti-

---

[3] We are indebted to Mr. Joe Lavigne for these spectra, which were obtained on a Cary spectrophotometer. The tetrahydro-1-naphthoic acids were kindly supplied by Dr. W. G. Dauben.

tatively from the solution while the tetrahydronaphthalides remain in solution. Finally, acidification precipitates the tetrahydronaphthalides mixed with a little naphthalic acid.

The reduction of naphthalimide with zinc and alkali, according to the procedure of Gardner and Naylor (11) for preparation of phthalide, was attempted but no naphthalide was isolated. The hydrogenation of naphthalic anhydride with copper chromite catalyst in alcohol solution, or in alcohol containing one equivalent of sodium ethoxide yielded mixtures from which no known product could be isolated. The preparation of the half ester of naphthalic acid is not feasible, for when a solution of the salt obtained from naphthalic anhydride and one equivalent of sodium ethoxide is acidified, the original precipitate rapidly reverts to naphthalic anhydride. In this connection, it is of interest that when 1,8-naph-

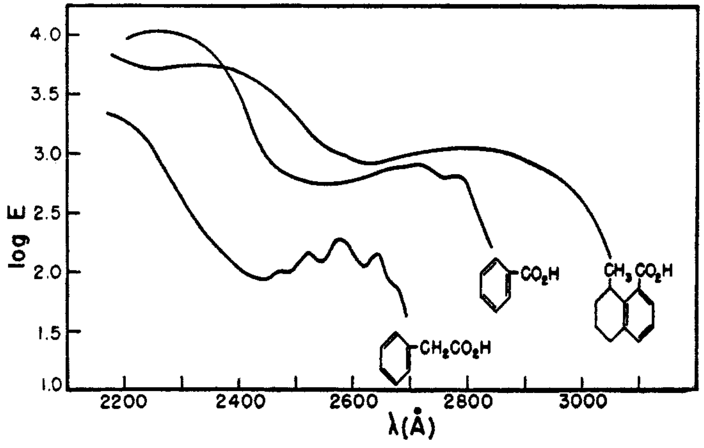


FIGURE 1

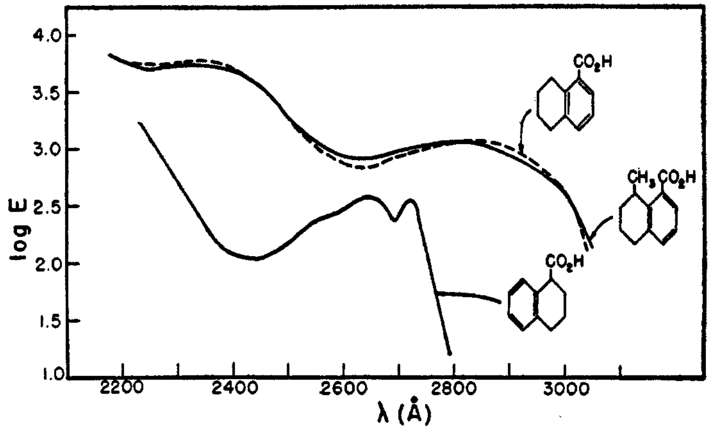
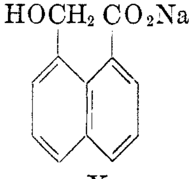


FIGURE 2

FIGURES 1-2. ABSORPTION SPECTRA OF AROMATIC AND HYDROAROMATIC ACIDS thalic acid is heated with ethanol at the boiling point, the acid is rapidly converted to naphthalic anhydride.

Since saponification of naphthalide gives the sodium salt of the hydroxy acid



X

(X), the hydrogenation to 8-methyl-1-naphthoic acid is readily accomplished with copper chromite catalyst. In a similar reduction (12) of a keto acid in aqueous alkali, hydrogenation proceeded at 200°, but the present hydrogenation was best carried out at 250° and a pressure of 300 atmospheres or more. It was also found that at least 1.3 equivalents of alkali are necessary for an optimum yield. With 1.05 equivalents of alkali, the yield of 8-methyl-1-naphthoic acid was only 11%.

EXPERIMENTAL

All melting points are corrected, and all boiling points are uncorrected. Analyses are by the Microanalytical Division of the Department of Chemistry of the University of California.

8-Acetyl-7-acenaphthenone. It was found most convenient not to isolate the acetyl derivative, II. The procedure of Ghigi (2) was modified as follows. A mixture of 7.7 g. of acenaphthenone (13), 1.0 g. of anhydrous sodium acetate, and 70 ml. of acetic anhydride was heated under reflux for ten hours (a shorter heating period leads to recovery of acenaphthenone). After cautious addition of 50 ml. of water to the hot solution there was added a mixture of 5 ml. of glacial acetic acid and 5 ml. of concentrated sulfuric acid; then refluxing was continued for one hour. Dilution of the reaction mixture with 750 ml. of water precipitated 7.5 g. of brown solid which was dissolved in 200 ml. of 1% aqueous sodium hydroxide. The insoluble material was extracted with an additional 100 ml. of water, only a trace of black tar remaining insoluble. Acidification of the deep red aqueous solution precipitated 5.4 g. (56%) of 8-acetyl-7-acenaphthenone as a yellow powder, m.p. 114.1–119.1°, re-m.p. 117.7°. Crystallization from hexane gave yellow needles, m.p. 116.7–120.6°. Ghigi (2) reported m.p. 117°.

Potassium hydroxide fusion of 8-acetyl-7-acenaphthenone. To 20 g. of potassium hydroxide in a nickel crucible heated in a bath at 265° there was added during ten minutes, with mixing, 2.0 g. of 8-acetyl-7-acenaphthenone. Heating and stirring at the same temperature was continued for an additional ten minutes, then the mixture was cooled and extracted with 250 ml. of boiling water. After filtration of 1.4 g. of insoluble material, the clear yellow alkaline solution was acidified to give a precipitate of 0.7 g. of crystals and gummy material. Sublimation at a bath temperature of 150–200° and 1 mm. pressure, followed by crystallization of the sublimate, gave 0.2 g. of yellow powder, m.p. 115–125°. After removal of 0.1 g. of carbonate-insoluble material and crystallization from acetone-hexane (1:5), there was obtained 0.06 g. of 8-methyl-1-naphthoic acid as colorless plates, m.p. 150.2–151.0°, no depression in m.p. on mixing with a sample of this acid prepared as described below.

1,8-Naphthaldehydic acid[4] (IV). Results in this preparation were variable, but the following represents average results obtained in the best procedure. A mixture of 5.0 g. of

---

[4] Preliminary work on this compound was carried out by Dr. Lloyd Beck in 1941 while he was a Senior at DePauw University, Greencastle, Indiana.

acenaphthenequinone (6) and 30 ml. of 30% aqueous potassium hydroxide was heated in a steam-bath, with stirring, in an atmosphere of nitrogen for 12 minutes (time elapsing from placing the cold mixture in the steam-bath until its removal). The color changed from yellow through green to red-purple. The reaction mixture was diluted with 300 ml. of water, a small precipitate was filtered, and the filtrate was acidified to yield a mixture of naphthalic acid and naphthaldehydic acid. The precipitate was heated under reflux in ethanol solution for 15 minutes to precipitate naphthalic acid as the insoluble anhydride (8). After treatment with charcoal and concentration of the filtrate to about 15 ml., 10 ml. of benzene was added. There crystallized 2.9 g. (53%) of brown naphthaldehydic acid, m.p. 155–162° (dec.). The decomposition point varies with rate of heating. The best sample, obtained after four crystallizations from benzene-ethanol, melted at 169–171° (dec.) when the bath was heated at the rate of 3° per minute. Previous investigators (5, 7, 8) have reported the m.p. 167°.

A heating time of 10 minutes at 150°, for the alkaline cleavage, has been previously reported (5). Since 30% aqueous potassium hydroxide was used, this temperature must have been that of the bath, so the internal temperature is unknown but it was obviously below 100° for much of the 10-minute period. For only 30 ml. of stirred aqueous alkali, we found that the internal temperature was only 87° after six minutes in a steam-bath.

1,8-Naphthalide (V). Commercial naphthalic anhydride could not be hydrogenated until after purification. Most of the material used in this investigation was the light-colored material commercially available in 1936. One recrystallization of this material from methyl benzoate (100 g. of anhydride per liter of solvent) gave colorless needles, m.p. 273–275°, suitable for hydrogenation. Samples of naphthalic anhydride currently available are of very poor quality and could be hydrogenated only after treatment with charcoal in alkaline solution followed by at least two crystallizations from methyl benzoate.

Hydrogenation of 1,8-naphthalic anhydride at 260° with copper chromite, according to the method reported for phthalic anhydride (9), gives over-hydrogenation, as will be described below in connection with the ether, VIII. Essentially no hydrogenation occurs below 190°, and best yields of naphthalide were obtained in the range 210–220°.

In the best procedure for preparation of 1,8-naphthalide, a steel pressure bomb was charged with 90 g. of purified naphthalic anhydride, 300 ml. of thiophene-free benzene, and 18 g. of copper chromite catalyst (14). For hydrogenation, the initial pressure at 20° was 2500 p.s.i., and the maximum pressure reached at 220° was 4250 p.s.i. When the pressure at 220° had dropped (10 hrs.) to a value corresponding to the consumption of 2.9 mole-equivalents of hydrogen, the hydrogenation was interrupted, and the cooled contents of the bomb were extracted with benzene. The benzene-insoluble material, containing the catalyst and unreacted naphthalic anhydride was re-hydrogenated similarly in 90 ml. of benzene. The separation of various fractions is most easily followed by a Flow Sheet, as indicated. The benzene extracts from the first and second hydrogenations may be most conveniently worked up together, but in the Flow Sheet the amounts isolated from the first and second hydrogenations are indicated in that order. The naphthalide crystallizing at the thymolphthalein end-point was white, m.p. 152–155°. This material was suitable for conversion to 8-methyl-1-naphthoic acid, but a purified sample was obtained by reprecipitation from alkaline solution at the thymolphthalein end-point and two crystallizations from ethanol. The constant m.p. of 156.6–157.2° was obtained [literature, m.p. 159–160° (1); 156–157° (5)]. The saponification equivalent could be determined by rapid titration in a solution containing more than 50% ethanol.

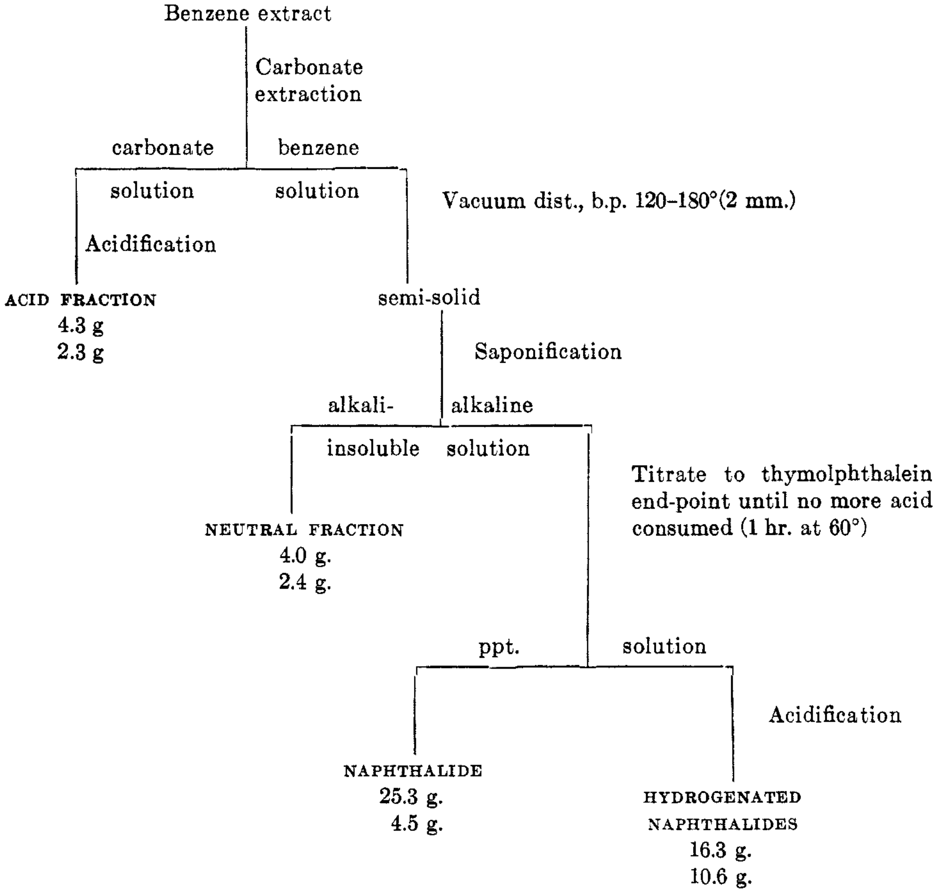
Anal. Calc'd for $C_{12}H_8O_2$: C, 78.25; H, 4.38; Eq. wt., 184.2.
Found: C, 78.01; H, 4.23; Eq. wt., 182.0.

Naphthalide and naphthalic anhydride appear to form a mixed crystal melting considerably above naphthalide, and samples of naphthalide not purified by precipitation at *p*H 10 always melted considerably above the purified material. Presence of naphthalic anhydride was first discovered by its isolation as follows. A 0.5-g. sample of impure naphthalide of m.p. 181–192° was dissolved in 80 ml. of hot ethanol containing 2.5 g. of picric acid. On cooling, there crystallized 0.05 g. of needles, which on crystallization from ethanol weighed

0.02 g. and melted at 271–273°, no depression on mixing with naphthalic anhydride. This anhydride was not formed by picric acid oxidation of naphthalide, for boiling of the filtrate caused no further crystallization of anhydride. Picric acid was removed with ammonium hydroxide, and naphthalide was recovered by solution in sodium hydroxide, acidification, and crystallization from ethanol. The recovered material melted at 155.8–158°. Addition of about 25% naphthalic anhydride to this material raised the m.p. to 200–250°.

FLOW SHEET

SEPARATION OF PRODUCTS FROM HYDROGENATION OF NAPHTHALIC ANHYDRIDE



Tetrahydronaphthalide (probably VI). The fraction designated hydrogenated naphthalides in the Flow Sheet was crystallized from ethanol-water (1:1) to give material of m.p. 76–150°. The analysis of this fraction gave: C, 76.50; H, 5.80 (calc'd for tetrahydronaphthalide: C, 76.57; H, 6.43). A pure sample of tetrahydronaphthalide was isolated from the hydrogenation of naphthalide in the presence of 1.1 equivalents of aqueous alkali with copper chromite catalyst at 250°. For details of a similar hydrogenation, refer to the preparation of 8-methyl-1-naphthoic acid. From 5.5 g. of naphthalide was obtained a lactone fraction consisting of 2.5 g. of yellow and white material. Mechanical separation of the white material, followed by crystallization from acetone-hexane (1:10) yielded 0.4 g. of colorless plates, m.p. 88.9–89.5°.

Anal. Calc'd for $C_{12}H_{12}O_2$: C, 76.57; H, 6.43.
Found: C, 76.35; H, 6.56.

After storage of the analytical sample for six months in the dark, it had changed to an orange semi-solid material.

8-Methyl-5,6,7,8-tetrahydro-1-naphthoic acid. When hydrogenation was carried out as described for preparation of 1,8-naphthalide, but with a larger ratio of catalyst, a smaller ratio of benzene, and highly purified naphthalic anhydride, a much larger acid fraction was obtained. The relative importance of these variables has not been established. In a typical run, a steel bomb was charged with 280 g. of naphthalic anhydride, 80 g. of copper chromite catalyst, and 320 ml. of benzene. The initial pressure at 25° was 2500 p.s.i. After 4½ hours at 200°, 2.5 mole-equivalents of hydrogen had been absorbed, and the mixture was worked up. The total material insoluble in benzene was 250 g. (catalyst and naphthalic anhydride). The benzene solution was worked up as outlined on the Flow Sheet to yield 42.0 g. of an acid fraction, 8.0 g. of a neutral fraction, 16.9 g. of naphthalide, and 21.6 g. of hydrogenated naphthalides. The acid fraction was distilled, b.p. 190–200° (4 mm.), and crystallized from acetone hexane (1:3) to yield a first crop of 5.8 g., m.p. 118.5–119.5°, and a second crop of 9.8 g., m.p. 97–103°. Recrystallization of the first crop yielded colorless needles, m.p. 118.9–119.6°.

Anal. Calc'd for $C_{12}H_{14}O_2$: C, 75.76; H, 7.41; Eq. wt. 190.
Found: C, 75.88; H, 7.32; Eq. wt. 187.

Picrate of peri-naphthopyran (VIII). On hydrogenation of 10 g. of naphthalic anhydride at 260° as described by Lazier (9), about half of the product (2.5 g.) was a yellow oil collected at 85–135° (5 mm.) on distillation in a Claisen flask. This oil was insoluble in boiling 1 *N* sodium hydroxide and yielded a picrate which, after three crystallizations from ethanol, melted at 173.5–175°.

Anal. Calc'd for $C_{18}H_{13}N_3O_8$: C, 54.14; H, 3.28.
Found: C, 53.69; H, 3.43.

No other products were isolated from this hydrogenation.

8-Methyl-1-naphthoic acid. A steel bomb was charged with 9.8 g. of naphthalide, 37.4 ml. of 1.85 *N* sodium hydroxide, 18.5 ml. of water, and 1.95 g. of copper chromite catalyst. Initial pressure at 20° was 2500 p.s.i. and maximum pressure at 250° was 4800 p.s.i. Hydrogenation was continued at 250° until the pressure became constant (about 3 hrs.); then the cooled bomb was washed out with water. Filtration and acidification of the clear yellow filtrate gave a precipitate which yielded 8.7 g. of carbonate-soluble product. Sublimation at a bath temperature of 130–190° (2 mm.) yielded 5.4 g. (55%) of nearly white 8-methyl-1-naphthoic acid, m.p. 147.2–151.0°. This material was suitable for use in synthesis. The best sample obtained by crystallization from acetone-hexane (1:5) melted at 152.2–153.2°.

A similar hydrogenation in which the maximum pressure at 250° was only 3900 p.s.i. gave a yield of only 40%. At the lower pressure, with only 1.2 equivalents of alkali the yield was 33%, and with 1.05 equivalents the yield was 11%.

SUMMARY

There is described a method for obtaining 1,8-naphthalide by hydrogenation of 1,8-naphthalic anhydride. Certain other products obtained from this hydrogenation have been characterized. 8-Methyl-1-naphthoic acid has been prepared by hydrogenation of naphthalide in aqueous alkali.

BERKELEY, CALIFORNIA

REFERENCES

(1) ERRERA AND AJON, *Gazz. chim. ital.* **44**, II, 92 (1914).
(2) GHIGI, *Ber.*, **73**, 677 (1940).
(3) GHIGI, *Gazz. chim. ital.* **76**, 352 (1946).

(4) Huang-Minlon, *J. Am. Chem. Soc.*, **68,** 2487 (1946).
(5) Fuson and Munn, *J. Am. Chem. Soc.*, **71,** 1870 (1949).
(6) Maxwell and Allen, *Org. Syntheses*, **24,** 1 (1944).
(7) Graebe and Gfeller, *Ann.* **276,** 1 (1893).
(8) Zink, *Monatsh.*, **22,** 986 (1901).
(9) Austin, Bousquet, and Lazier, *J. Am. Chem. Soc.*, **59,** 864 (1937).
(10) Willstätter and Jaquet, *Ber.*, **51,** 767 (1918).
(11) Gardner and Naylor, *Org. Syntheses*, Coll. Vol. II, 526 (1943).
(12) Fieser and Cason, *J. Am. Chem. Soc.*, **62,** 1296 (1940).
(13) Fieser and Cason, *J. Am. Chem. Soc.*, **62,** 432 (1940).
(14) Adkins, *Org. Syntheses*, Coll. Vol. II, 144 (1943).