[Contribution from the Chemistry Department of the University of Missouri]

# THE ANOMALOUS ACYLATION OF SOME MONOALKYLBENZENES[1]

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The chance acylation in this laboratory of 3-phenylpentane with propionyl chloride and aluminum chloride in carbon disulfide solution at reflux temperature rather than at ice-bath temperature yielded three compounds: propiophenone, 4-(1-ethylpropyl)propiophenone, and a diamylpropiophenone.

When isopropylbenzene, *sec*-butylbenzene, and 2-phenylpentane were acetylated with acetyl chloride under the same conditions, the reaction products in each case were acetophenone, a *p-sec*-alkylacetophenone, and a dialkylacetophenone. *tert*-Butylacetophenone and *tert*-amylacetophenone were the only ketones obtained from *tert*-butylbenzene and *tert*-amylbenzene. More unchanged hydrocarbon was recovered and there was a larger amount of tarry residue from these *tert*-alkylbenzenes than from the other alkylbenzenes. *n*-Propylbenzene yielded *n*-propylacetophenone and a dipropylacetophenone. If all of these alkylbenzenes were acylated at ice-bath temperatures, there was little or no rearrangement of the alkyl groups.

These results are not surprising in view of the well established fact that toluene, ethylbenzene, *n*-propylbenzene, and *n*-butylbenzene yield *m*- and *p*-dialkylbenzenes when heated with aluminum chloride (1).

The diisopropylacetophenone appears to be the 2,4-isomer on the basis of the following data: Newton (2) has proved that the acetylation of both 1,3- and 1,4-diisopropylbenzene in carbon disulfide solution at 30–40° yielded 2,4-diisopropylacetophenone. Its semicarbonazone melted at 195.7–196.5°. The semicarbazone of the diisopropylacetophenone obtained from isopropylbenzene in the present investigation melted at 195–196°.

The dibutylacetophenone was identified as 2,5-di-*sec*-butylacetophenone. It formed a semicarbazone, m.p. and mixture m.p. with an authentic sample of 2,5-di-*sec*-butylacetophenone semicarbazone, 165.5–166.5°.

The diamylacetophenone obtained from 2-phenylpentane is either a 2,4-diamylacetophenone or a mixture of isomeric ketones. Authentic 2,5-di-(1-methylbutyl)acetophenone was prepared from *p*-di-(1-methylbutyl)benzene and acetyl chloride at 0° to 5° as described in Organic Syntheses (3). Its semicarbazone melted at 147–148°. The semicarbazone of the diamylacetophenone obtained from 2-phenylpentane at reflux temperature melted at 126–127° and a mixture of the two derivatives melted at 127–141°. The structure of the migrating amyl groups could not conveniently be determined, but it is probable that they were isomerized. It is also probable that the migrating *n*-propyl radical was isomerized when *n*-propylbenzene was acetylated at reflux temperature.

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[1] Abstract of a portion of the Ph.D. dissertation of Oscar L. Wright, 1949, and of the Ph.D. dissertation to be presented by Howard B. Hucker.

There are no reports in the literature of anomalous acylation products from the acylation of monoalkylbenzenes, and Thomas (4) states that the acylation of alkylbenzenes involves no migration of the alkyl groups present. However, Crounse (5) and Niedzielski and Nord (6) have reported the formation of benzaldehyde and dialkylbenzaldehydes as by products from the formylation of alkylbenzenes under conditions comparable to those used in the present investigation. A British patent (7) describes the preparation of diisopropylbenzaldehyde from isopropylbenzene and carbon monoxide, using aluminum chloride and cuprous chloride as the catalyst.

The results from the present investigation indicate that the acylation of alkylbenzenes should be carried out at as low a temperature as possible to avoid both dealkylation and realkylation by the liberated radical.

## EXPERIMENTAL[2]

*Hydrocarbons.* The isopropylbenzene was from the Dow Chemical Company. The *sec*-butylbenzene and 2-phenylpentane were prepared by the procedure of Welsh and Hennion (8). 3-Phenylpentane and *n*-propylbenzene were prepared by the reduction of diethylphenylcarbinol and propiophenone respectively with hydrogen and copper-chromium oxide catalyst. The physical constants of the hydrocarbons agreed with those reported in the literature (9).

*Acylation procedure.* The acylation of 3-phenylpentane is typical. The hydrocarbon (177 g., 1.2 moles) and 175 g. (1.4 moles) of aluminum chloride were dissolved in 500 cc. of carbon disulfide in the usual apparatus. The propionyl chloride (175 g., 1.4 moles) was added with stirring at such a rate that the carbon disulfide refluxed gently. After the acyl halide had been added, the solution was refluxed for three hours. The complex was decomposed with iced hydrochloric acid.

The reaction product (180 cc.) was fractionated at reduced pressure through a column of approximately 15 theoretical plates at a reflux ratio of 30:1 and the distillate collected in three main portions, each of which was in turn re-fractionated to yield the following products: (a) 36 g. of propiophenone, b.p. 98–104° (20 mm.); (b) 87 g. of 4-(1-ethylpropyl)-propiophenone, b.p. 161–165° (20 mm.), $n_D^{20}$ 1.5162; (c) 29 g. of x-amyl-x-(1-ethylpropyl)-propiophenone b.p. 132–134° (1 mm.), $n_D^{20}$ 1.4997; (d) 7 g. of residue. Center cuts from these fractions were used for the physical constants, analyses, and derivatives listed in Tables II and III. The yields of ketone fractions from the acylations of the *sec*-alkylbenzenes are listed in Table I. Acetophenone and propiophenone were identified by their semicarbazones and 2,4-dinitrophenylhydrazones.

*tert-Butylbenzene.* The acetylation of 84 g. of hydrocarbon yielded 47 g. of crude *p-tert*-butylacetophenone, b.p. 119–126° (7–8 mm.), $n_D^{20}$ 1.5220. The recorded constants are b.p. 133–134° (11 mm.), $n_D^{20}$ 1.5199 (10) and b.p. 97–98° (0.8–0.9 mm.) (11). The ketone formed a semicarbazone, m.p. 230–231° (dec.), literature values 231–232° (11) and 220–221° (10).

An authentic sample of *p-tert*-butylacetophenone, prepared by acetylation of *tert*-butylbenzene at 0°, formed a semicarbazone which melted at 231–232° (dec.) and did not depress the melting point of the derivative of the above ketone.

*tert-Amylbenzene.* The acetylation of 84 g. of *tert*-amylbenzene yielded 50 g. of crude

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[2] The acylations of the *sec*-alkylbenzenes were done by O. L. Wright and most of the carbon and hydrogen analyses of these ketones and their 2,4-dinitrophenylhydrazones were done by him. The determination of the orientation of the dialkylacetophenones and the remainder of the experimental work was done by H. B. Hucker, who also did many of the carbon and hydrogen analyses. A few of the analyses were done by P. D. Strickler and Y. C. Lee.

ketone. This product was separated into the following fractions: (a) 7.8 g. b.p. 87–121° (2–3 mm.), $n_D^{20}$ 1.5203; (b) 10.5 g. b.p. 122–125° (2–3 mm.), $n_D^{20}$ 1.5198; (c) 21 g. b.p. 125–134° (3–5 mm.), $n_D^{20}$ 1.5189.

Each of these fractions formed a semicarbazone which melted at 209–210° (dec.) and did not depress the melting point of an authentic sample of *p*-*tert*-amylacetophenone semicarbazone.

TABLE I

ACYLATIONS OF ALKYLBENZENES AT REFLUX TEMPERATURE

| HYDROCARBON | ACID CHLORIDE | YIELD OF KETONE FRACTIONS, % | | |
|---|---|---|---|---|
| | | Acetophenone | *p*-Alkyl-acetophenone | Dialkyl-acetophenone |
| Isopropylbenzene | Acetyl | 30 | 23 | 40 |
| *sec*-Butylbenzene | Acetyl | 7 | 22 | 27 |
| 2-Phenylpentane | Acetyl | 27 | 13 | 35 |
| 3-Phenylpentane | Propionyl | 27 | 12 | 36 |
| *tert*-Butylbenzene | Acetyl | | 25 | |
| *tert*-Amylbenzene | Acetyl | | 14 | |
| *n*-Propylbenzene | Acetyl | | 40 | 18 |

TABLE II

KETONES FROM THE *sec*-ALKYLBENZENES

| KETONES | B.P., °C. | MM. | $n_D^{20}$ | FORMULA | ANALYSES | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Calc'd | | Found | |
| | | | | | C | H | C | H |
| *p*-Isopropylacetophenone | 137–138 | 10–11 | 1.5204[a] | | | | | |
| Diisopropylacetophenone | 147–148 | 10–11 | 1.5123[b] | $C_{14}H_{20}O$ | 82.30 | 9.86 | 82.19 | 9.90 |
| *p*-sec-Butylacetophenone | 130–131 | 7–8 | 1.5182[c] | | | | | |
| 2,5-Di-*sec*-butylacetophenone | 148–149 | 7–8 | 1.5061[f] | $C_{16}H_{24}O$ | 82.70 | 10.41 | 82.47 | 10.44 |
| 4-(1-Methylbutyl)acetophenone | 119–120 | 1–2 | 1.5140[d] | | | | | |
| Diamylacetophenone | 127–129 | 1–2 | 1.5015[e] | $C_{18}H_{28}O$ | 83.08 | 10.84 | 83.04 | 10.78 |
| 4-(1-Ethylpropyl)propiophenone | 108–109 | 1–2 | 1.5149 | $C_{14}H_{20}O$ | 82.30 | 9.86 | 82.36 | 9.98 |
| Diamylpropiophenone | 129–130 | 1–2 | 1.4990 | $C_{19}H_{30}O$ | 85.15 | 11.01 | 83.33 | 11.12 |

[a] Literature value (2) $n_D^{20}$ 1.5206. [b] Literature value (2) $n_D^{20}$ 1.5109. [c] Literature value (10) $n_D^{20}$ 1.5195. [d] Literature value (10) $n_D^{20}$ 1.5150. [e] Literature value (10) $n_D^{20}$ 1.5052 for 2,5-di-(1-methylbutyl)acetophenone. [f] Literature value (10) $n_D^{20}$ 1.5056.

The authentic sample of *p*-*tert*-amylacetophenone was obtained in 14% yield by the acetylation of *tert*-amylbenzene at 0° and had the following constants: b.p. 91–96° (1–2 mm.), $n_D^{20}$ 1.5207.

*Anal.* Calc'd for $C_{13}H_{18}O$: C, 82.06; H, 9.53.
Found: C, 81.87; H, 9.46.

The semicarbazone melted at 209–210° (dec.).

*Anal.* Calc'd for $C_{14}H_{21}N_3O$: C, 67.98; H, 8.56.
Found: C, 68.03; H, 8.55.

*n-Propylbenzene.* The acetylation of 90 g. of hydrocarbon yielded 51 g. of crude ketone which was separated into the following fractions: (a) 24.8 g. b.p. 128–133° (15–16 mm.), $n_D^{20}$ 1.5162; (b) 5.9 g. b.p. 133–137° (15–16 mm.), $n_D^{20}$ 1.5234; (c) 6.2 g. b.p. 102–109° (1–2 mm.), $n_D^{20}$ 1.5158; (d) 7.2 g. b.p. 111–116° (1–2 mm.), $n_D^{20}$ 1.5083.

Fractions (a) and (b) were identified as *n*-propylacetophenone by their semicarbazones, m.p. 186–187°, literature value 187.3–188.5° (12). The melting point of a mixture of these semicarbazones and authentic *p*-isopropylacetophenone semicarbazone (m.p. 192–193°) was 182–189°.

TABLE III

DERIVATIVES OF THE KETONES

| KETONE | M.P., °C. | FORMULA | ANALYSES | | | |
|---|---|---|---|---|---|---|
| | | | Calc'd | | Found | |
| | | | C | H | C | H |
| | | 2,4-DINITROPHENYLHYDRAZONES | | | | |
| *p*-Isopropylacetophenone | 176–177 | $C_{17}H_{18}N_4O_4$ | 59.64 | 5.30 | 59.60 | 5.55 |
| *p*-*sec*-Butylacetophenone | 146–147 | $C_{18}H_{20}N_4O_4$ | 60.65 | 5.66 | 60.60 | 5.86 |
| 4-(1-Methylbutyl)acetophenone | 147–148[a] | $C_{19}H_{22}N_4O_4$ | 61.60 | 5.98 | 61.62 | 6.07 |
| 4-(1-Ethylpropyl)propiophenone | 144–145 | $C_{20}H_{24}N_4O_4$ | 62.50 | 6.29 | 62.77 | 6.81 |
| x-Amyl-x-(1-ethylpropyl)propiophenone | 123–124 | $C_{25}H_{34}N_4O_4$ | 66.05 | 7.54 | 65.85 | 7.47 |
| | | SEMICARBAZONES | | | | |
| 2,4-Diisopropylacetophenone | 195–196[b] | | | | | |
| x-Amyl-x-(1-methylbutyl)acetophenone | 127–128 | $C_{19}H_{31}N_3O$ | 71.88 | 9.84 | 71.96 | 9.84 |
| x-Isopropyl-x-*n*-propylacetophenone | 112–113 | $C_{15}H_{23}N_3O$ | 68.93 | 8.67 | 68.84 | 8.68 |
| 2,5-Di-*sec*-Butylacetophenone | 166–167[c] | $C_{17}H_{27}N_3O$ | 70.54 | 9.40 | 70.70 | 9.58 |

[a] Pines, Huntsman, and Ipatieff, *J. Am. Chem. Soc.*, **73**, 4343 (1951) report m.p. 149–149.5°.

[b] Literature value, 195.7–196.5 (2).

[c] Hennion and McLeese (10) report m.p. 160–161° for their derivative but no carbon and hydrogen analyses.

Fraction (c) contained a dipropylacetophenone.

*Anal.* Calc'd for $C_{14}H_{20}O$: C, 82.30; H, 9.87.

Found: C, 82.45; H, 9.97.

The semicarbazone of (c) melted at 112–113°.

Carbon and hydrogen analyses of (d) indicated that it contained impurities.

## SUMMARY

The Friedel-Crafts acylation of one primary alkylbenzene and four secondary alkylbenzenes in carbon disulfide solution at reflux temperature yielded a mixture of acetophenone, a *p*-alkylacetophenone, and a 2,4-dialkylacetophenone. *tert*-Butylbenzene and *tert*-amylbenzene yielded only the *p*-*tert*-alkylacetophenone under these conditions.

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