

weight of non-radioactive olefin. The mixture then was usually subjected to some preliminary purification and the derivative was prepared as previously described. In the case of olefin III, the crude mixture was partially purified by the use of a column of alumina; for olefins IV, V and VI, the crude mixture of olefins was distilled, and for olefin VII, the derivative was prepared without preliminary purification. In Table V are summarized the details of the above-described experiments.

The calculation of the yields of the olefins may best be illustrated by a sample calculation for 1-phenylcyclohexene in experiment 1 (Table V). In the equation<sup>6</sup>  $A_1(D_1 + X) = A_0X$

$A_0$  = specific act. of undiluted IIIa = spec. act. of starting material [Ia] = 1.330 mc./mole

$A_1$  = measd. spec. act. of deriv. = 0.3401 mc./mole (column V)

$D_1$  = wt. of non-radioactive 1-phenylcyclohexene (III) added = 0.6606 g. (column III)

$X$  = wt. of 1-phenylcyclohexene-1-C<sup>14</sup> (IIIa) of specific act. 1.330 mc./mole

then

$$(0.3401)(0.6606 + X) = 1.330(X)$$

$$X = \frac{(0.3401)(0.6606)}{0.990} = 0.227 \text{ g. of III in } 10\% \text{ of the reacn. mixt. (col. IV) or } 2.27 \text{ g. of III in total reacn. mixt.}$$

Theoretical yield of olefins = 2.59 g.

$$(2.27/2.59) \times 100 = 87.7\% \text{ yield of III}$$

**Determination of Phenyl Migration Occurring during the Dehydration of *cis*- and *trans*-2-Phenylcyclohexanol-2-C<sup>14</sup> (Ia and IIa).**—The derivatives of 1-phenylcyclohexene (III) obtained from the dehydration of Ia and IIa (Table V) were oxidized to benzoic acid by one of the methods previously described. The radiochemical data are given in Table V. The latter calculations are straightforward, and are thus not included in the present write-up.

**Isomerization of 3-Phenylcyclohexene (IV) and Mixtures of 1- and 3-Phenylcyclohexene (III and IV).**—The isomerization experiments of the olefins III and IV were performed under the same conditions that were used for the dehydration. Equal weights of the olefin and phosphoric acid were refluxed for 4 hours. The isolation and the derivative preparation of the olefins was accomplished as previously described in this section for the dehydration reactions. The radiochemical and dilution data are summarized in Table VI.

**Determination of Purity of 1- and 3-Phenylcyclohexene (III and IV).**—In order to ensure that the derivatives pre-

pared from the various olefins were not contaminated with "spurious" radioactivity, it was necessary to prepare a number of synthetic mixtures of radioactive and non-radioactive olefins, convert them into the corresponding derivatives, and prove that contamination was not a source of error. The results of these experiments are listed in Table VII and signify that these derivatives are almost certainly radiochemically pure.

TABLE VII

RADIOCHEMICAL DATA ON THE PURITY OF 1- AND 3-PHENYL-CYCLOHEXENE AND THEIR DERIVATIVES

Expt.	Reactant and wt.	Deriv.	Radioactivity assay of deriv., mc./mole	Calcd. radioactivity of deriv., mc./mole
14	IIIa 4.0 g. 1.004 mc./mole	VIII	0.9955 ± 0.0016	1.004
15	IIIa 0.9931 g. 1.004 mc./mole III 1.0139 g.	VIII	0.4953 ± .0011	0.4968
16	IIa 0.8624 g. 1.004 mc./mole IV 0.3252 g.	X	1.004 ± .000	1.004
17	IIIa 0.8665 g. 1.334 mc./mole IV 0.3201 g.	VIII	1.320 ± .0015	1.334
18	IVa 0.2198 g. 2.293 mc./mole IV 0.1707 g.	XII	1.286 ± .009	1.291
19	IIIa 1.8946 g. 1.004 mc./mole IV 2.0852 g.	XII	0.0004	0.000

The radioactivity assays reported in this paper were performed with a vibrating reed electrometer using a modification of the wet combustion procedure as described by Neville.<sup>25</sup>

The elemental analyses reported herein were performed by the Huffman Microanalytical Laboratories, Wheatridge, Colorado.

(25) O. K. Neville, *THIS JOURNAL*, **70**, 3501 (1948).

OAK RIDGE, TENNESSEE

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF MISSOURI]

## The Acetylation of Some Dialkylbenzenes. II

BY DOROTHY V. NIGHTINGALE AND JAMES M. SHACKELFORD<sup>1</sup>

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When *m*- and *p*-cymene, *m*- and *p*-*sec*-butyltoluene are acetylated in the presence of aluminum chloride at 0 to +5°, the product in each case is a mixture of 2,4- and 2,5-dialkylacetophenones. If the acetylation of these hydrocarbons and of *p*-di-*sec*-butylbenzene is carried out with anhydrous ferric chloride as the catalyst, there is little or no migration of the *sec*-alkyl group.

In a previous publication,<sup>2</sup> it was established that the acetylation of *p*-di-*sec*-butylbenzene in the presence of aluminum chloride yielded 2,4-di-*sec*-butylacetophenone as the principal product. This was true even though the acetylation was carried out at -10 to -15°. Since this reaction was carried out according to a described procedure<sup>3</sup> for the

(1) Abstracted from a portion of the dissertation to be submitted by J. M. Shackelford for the degree of Doctor of Philosophy.

(2) D. V. Nightingale and H. B. Huckler, *J. Org. Chem.*, **18**, 1529 (1953).

(3) "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 3.

preparation of aceto-*p*-cymene, it seemed desirable to examine the acetylation product of *p*-cymene.

The procedure described in "Organic Syntheses" is essentially the low temperature acetylation of *p*-cymene as described by Lacourt,<sup>4</sup> who also acetylated *m*-cymene.<sup>5</sup> She found that although the ketones obtained from both *m*- and *p*-cymene formed semicarbazones having different melting points, the melting points of their oximes were the same but no mixture melting points of the oximes were recorded.

(4) A. Lacourt, *Bull. soc. chim. Belg.*, **38**, 1 (1929).

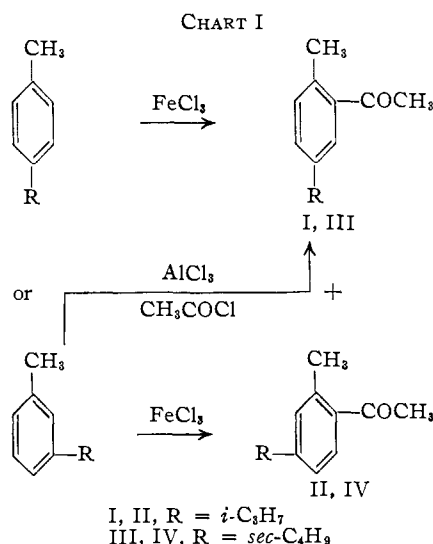
(5) A. Lacourt, *ibid.*, **39**, 374 (1930).

Lacourt established the structure of the ketone isolated from the acetylation of *m*-cymene as 2-methyl-4-isopropylacetophenone by oxidation to methylterephthalic acid, m.p. 326–330°, which did not depress the melting point of an authentic sample. The oxidation of the ketone from *p*-cymene yielded an acid, m.p. 332°, which she designated as 4-methylisophthalic acid, but with no reported comparison of this acid with either authentic 4-methylisophthalic acid or methylterephthalic acid.

In the present investigation (Chart I), it was established that the acetylation of both *p*-cymene and *m*-cymene with aluminum chloride as the catalyst at a temperature not higher than 5° gave a mixture of 2-methyl-5-isopropylacetophenone (I) and 2-methyl-4-isopropylacetophenone (II) with II as the predominating component of the mixture from both hydrocarbons. *p*-Cymene also yielded a small amount of *p*-methylacetophenone. When the temperature was held at –5 to –10°, no derivative of II was isolated.

The mixture of ketones I and II obtained in this investigation from the acetylation of *p*-cymene yielded a semicarbazone, m.p. 168°, of II and an oxime, m.p. 94°, of II which were identical with the same derivatives of II obtained from the acetylation of *m*-cymene; the melting points of the derivatives agreed with those reported by Lacourt for the derivatives of II from *m*-cymene. The acetylation product of each hydrocarbon yielded two isomeric 2,4-dinitrophenylhydrazones: a yellow derivative of I, m.p. 144°, and a red derivative of II, m.p. 130°, with the latter predominating.

*p*-Cymene was acetylated with ferric chloride as the catalyst to yield I. This ketone formed a yellow 2,4-dinitrophenylhydrazone, m.p. 144°, and a semicarbazone, m.p. 147°, the temperature reported by Lacourt and recently by Pines and Shaw,<sup>6</sup> but no oxime could be obtained by the usual procedures. Oxidation of I with dilute nitric acid yielded 4-methylisophthalic acid which was identical with an authentic sample.



*m*-Cymene was acetylated with ferric chloride as the catalyst to yield II. This ketone formed a

(6) H. Pines and A. W. Shaw, *J. Org. Chem.*, **20**, 373 (1955).

red 2,4-dinitrophenylhydrazone, m.p. 130°, an oxime, m.p. 92°, and a semicarbazone, m.p. 168°. These melting points agree with those reported by Lacourt<sup>5</sup> and by Pines and Shaw<sup>6</sup> for these derivatives of II.

It appears that Lacourt's acetylation product from *p*-cymene may have been a mixture of I and II from which she isolated the oxime of II and the semicarbazone of I.<sup>7</sup>

In the same way it was established that the acetylation of *p*-*sec*-butyltoluene and *m*-*sec*-butyltoluene with aluminum chloride as the catalyst gave a mixture of 2-methyl-5-*sec*-butylacetophenone (III) and 2-methyl-4-*sec*-butylacetophenone (IV). The ketone III obtained from the acetylation of *p*-*sec*-butyltoluene with ferric chloride as the catalyst formed a yellow 2,4-dinitrophenylhydrazone. The same derivative of IV from the acetylation of *m*-*sec*-butyltoluene in the presence of ferric chloride was red. Oxidation of III and IV with dilute nitric acid yielded 4-methylisophthalic acid and methylterephthalic acid, respectively, which did not depress the melting points of the authentic acids.

Acetylation of *p*-*di-sec*-butylbenzene at a temperature not higher than 5° or at 20–30° with ferric chloride as the catalyst gave 2,5-*di-sec*-butylacetophenone in poor yield. This ketone formed a semicarbazone, m.p. 161°. A mixture melting point of this derivative and the derivative, m.p. 167°, of 2,4-*di-sec*-butylacetophenone was 138–141°.

A comparison of the infrared spectrograms of the three 2,5-dialkylacetophenones shows similar major absorption bands in the 6.4, 6.7, 8.4 and 13.8  $\mu$  region which are not present in the spectrograms of the three 2,4-dialkylacetophenones. In the spectrograms of the 2,4-dialkylacetophenones, there are bands in the 6.2 and 13.5  $\mu$  regions which are not present in the spectrograms of the 2,5-dialkylacetophenones.

### Experimental<sup>8</sup>

*p*-Cymene was obtained from Distillation Products Industries. *p*-*sec*-Butyltoluene was synthesized from *p*-methylacetophenone and ethylmagnesium bromide followed by the reduction of the *t*-carbinol with hydrogen and copper-chromium oxide catalyst. *m*-Cymene and *m*-*sec*-butyltoluene were synthesized in the same way from *m*-tolylmagnesium bromide and acetone and methyl ethyl ketone, respectively. *p*-*Di-sec*-butylbenzene was synthesized as previously described.<sup>2</sup>

Unless otherwise specified, the acetylation products were distilled directly on a medium bore Todd column at a reflux ratio of 8:1. A center cut was used for the refractive index and the infrared spectrograms. The center cut was redistilled for an analytical sample.

**Acetylation of *p*-Cymene with Aluminum Chloride as Catalyst.**—All acetylations were carried out as described in reference 3. One mole of *p*-cymene yielded 88 g. (43%) of ketone, b.p. 130–133° (19 mm.),  $n_D^{20}$  1.5211. This product yielded a semicarbazone, m.p. 168°, and an oxime, m.p. 94°, the literature values<sup>5</sup> for these derivatives of II. This product yielded two isomeric 2,4-dinitrophenylhydrazones: a yellow one, m.p. 144°, and a red one, m.p. 130°.

(7) Pines and Shaw (ref. 6) report that the acetylation of *p*-cymene in the presence of aluminum chloride at room temperature yields only derivatives of toluene and *m*-cymene when the aluminum chloride is added to the *p*-cymene 15–20 minutes prior to the addition of the acetyl chloride. If the aluminum chloride was first complexed with acetyl chloride before adding the hydrocarbon, isomerization did not occur.

(8) The carbon and hydrogen analyses were by R. E. Bolin and R. L. Elliot.

The red derivative separated first. These two derivatives did not depress the melting point of the corresponding derivatives of I and II obtained by the acetylation of *p*- and *m*-cymene with ferric chloride as the catalyst.

**The Acetylation of *m*-Cymene with Aluminum Chloride as the Catalyst.**—Thirty-four grams of *m*-cymene yielded 29 g. (63%) of ketone, b.p. 128–133° (17 mm.),  $n_D^{25}$  1.5210. This product yielded a semicarbazone, m.p. 167°, literature value 168° (172° for the derivative of a highly purified sample of ketone).<sup>5</sup> The ketone formed an oxime, m.p. 94°, literature value<sup>5</sup> 93°, and two isomeric 2,4-dinitrophenylhydrazones, a yellow one, m.p. 143°, and a red one, m.p. 130°. These two derivatives were identical with the same derivatives of I and II obtained from the acetylation of *p*- and *m*-cymene with ferric chloride as the catalyst.

**The Acetylation of *p*-Cymene with Ferric Chloride as the Catalyst.**—All acetylations with ferric chloride were carried out as follows: Into a well-cooled 1000-ml. three-necked round-bottom flask with the usual equipment was placed 300 ml. of carbon disulfide and 220 g. (1.3 moles) of anhydrous sublimed ferric chloride. A mixture of 78 g. (1.0 mole) of acetyl chloride and 132 g. (1.0 mole) of *p*-cymene was added at such a rate that the temperature never rose above 5°. After the addition was completed, the mixture was allowed to stand overnight at room temperature, and then poured onto iced hydrochloric acid and extracted with ether. The ether extracts were combined, washed with water until neutral, dried and distilled to yield 85 g. (41%) of 2-methyl-5-isopropylacetophenone (I), b.p. 125–128° (17 mm.),  $n_D^{25}$  1.5255, and considerable tarry residue.

*Anal.* Calcd. for  $C_{12}H_{18}O$ : C, 81.77; H, 9.15. Found: C, 81.71; H, 9.53.

The ketone formed a semicarbazone, m.p. 147°, literature value 148°, but it would not form an oxime. The yellow 2,4-dinitrophenylhydrazone melted at 143.5–144°, literature value<sup>6</sup> 152°.

*Anal.* Calcd. for  $C_{18}H_{20}N_4O_4$ : C, 60.66; H, 5.66. Found: C, 60.81; H, 6.07.

Oxidation of this ketone with dilute nitric acid yielded 4-methylisophthalic acid.

**The Acetylation of *m*-Cymene with Ferric Chloride as the Catalyst.**—Eighteen grams of the hydrocarbon yielded 9.5 g. (31%) of 2-methyl-4-isopropylacetophenone (II), b.p. 140–143° (25 mm.),  $n_D^{25}$  1.5198. The ketone formed a semicarbazone, m.p. 168°, literature value 172°, an oxime, m.p. 94°, literature value 93°, and a red 2,4-dinitrophenylhydrazone, m.p. 130°, literature value 131°.

**The Acetylation of *p*-*sec*-Butyltoluene with Aluminum Chloride as the Catalyst.**—Eighty-five grams of hydrocarbon yielded 59 g. (54%) of ketone, b.p. 135–142° (16 mm.). This product yielded two 2,4-dinitrophenylhydrazones, a yellow one, m.p. 125–126°, and a red one, m.p. 139–140°, in nearly equal quantities. These derivatives did not depress the melting points of the corresponding yellow and red 2,4-dinitrophenylhydrazones of III and IV obtained from *p*-*sec*-butyltoluene and *m*-*sec*-butyltoluene, respectively, by acetylation with ferric chloride as the catalyst.

**The Acetylation of *m*-*sec*-Butyltoluene with Aluminum Chloride as the Catalyst.**—Forty-nine grams of hydrocarbon yielded 41 g. (65%) of ketone, b.p. 137–139° (16 mm.),  $n_D^{25}$  1.5190. This product yielded two isomeric 2,4-dinitrophenylhydrazones: a small amount of a yellow one, m.p. 118–120°, and a red one, m.p. 139–140°. The latter did not depress the melting point of the red derivative of IV obtained from the acetylation of *m*-*sec*-butyltoluene with ferric chloride as the catalyst.

**The Acetylation of *p*-*sec*-Butyltoluene with Ferric Chloride as the Catalyst.**—Forty-five grams of hydrocarbon

yielded 17 g. (29%) of 2-methyl-5-*sec*-butylacetophenone (III), b.p. 135–137° (15 mm.),  $n_D^{25}$  1.5209.

*Anal.* Calcd. for  $C_{13}H_{18}O$ : C, 82.06; H, 9.54. Found: C, 81.96; H, 9.67.

The ketone formed a yellow 2,4-dinitrophenylhydrazone, m.p. 126°.

*Anal.* Calcd. for  $C_{19}H_{22}N_4O_4$ : C, 61.61; H, 5.99. Found: C, 61.87; H, 5.70.

**The Acetylation of *m*-*sec*-Butyltoluene with Ferric Chloride as the Catalyst.**—Forty-five grams of hydrocarbon yielded 31 g. (54%) of 2-methyl-4-*sec*-butylacetophenone (IV), b.p. 141–142° (16 mm.),  $n_D^{25}$  1.5201.

*Anal.* Calcd. for  $C_{13}H_{18}O$ : C, 82.06; H, 9.54. Found: C, 82.10; H, 9.55.

The ketone formed a red 2,4-dinitrophenylhydrazone, m.p. 140.5–141°.

*Anal.* Calcd. for  $C_{19}H_{22}N_4O_4$ : C, 61.61; H, 5.99. Found: C, 61.73; H, 5.95.

**The Acetylation of *p*-*Di*-*sec*-butylbenzene with Ferric Chloride as the Catalyst.**—It was necessary to raise the reaction temperature to 25–30° for this acetylation. Eighty-one grams of hydrocarbon yielded 2 g. of 2,5-*di*-*sec*-butylacetophenone, b.p. 100–105° (1 mm.),  $n_D^{25}$  1.5050, purified by distillation through a Podbielniak column.

*Anal.* Calcd. for  $C_{18}H_{24}O$ : C, 82.70; H, 10.41. Found: C, 82.89; H, 10.13.

The ketone formed a semicarbazone, m.p. 161°.

*Anal.* Calcd. for  $C_{17}H_{27}N_3O$ : C, 70.54; H, 9.40. Found: C, 70.47; H, 9.60.

**Oxidation of the Dialkylacetophenones.**—The ketones were oxidized with dilute nitric acid by the procedure of Hennion and McLeese.<sup>9</sup>

2,4-Dimethylacetophenone yielded methylterephthalic acid, m.p. 332°, literature value 324<sup>10</sup> and 330<sup>11</sup>.

2,5-Dimethylacetophenone yielded 4-methylisophthalic acid, m.p. 330°, literature value 320<sup>12</sup> and 330<sup>13</sup>. A mixture of methylterephthalic acid and 4-methylisophthalic acid melted at 305–315°.

2-Methyl-5-isopropylacetophenone yielded 4-methylisophthalic acid, m.p. 332°, with softening at 305°. This acid did not depress the melting point of the 4-methylisophthalic acid obtained from 2,5-dimethylacetophenone.

2-Methyl-5-*sec*-butylacetophenone yielded 4-methylisophthalic acid, m.p. 327°, with softening at 320°, which did not depress the melting point of 4-methylisophthalic acid obtained from 2,5-dimethylacetophenone. A mixture of this acid and methylterephthalic acid melted at 297–303°.

2-Methyl-4-*sec*-butylacetophenone yielded methylterephthalic acid, m.p. 323–327° with softening at 320°, which did not depress the melting point of methylterephthalic acid from 2,4-dimethylacetophenone. A mixture of this acid and 4-methylisophthalic acid melted at 300–305°.

**Infrared Spectrograms.**—These were determined by Dr. E. E. Pickett of the spectrographic laboratory of the University of Missouri and by J. M. Shackelford, on a Beckman Infrared Spectrophotometer, Model IR-2, cell length 0.025 mm.

#### COLUMBIA, MISSOURI

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