in vacuo. The residue was crystallized from acetone–petroleum ether (b.p. 30–60°) giving 2′,3′-dideoxyuridine (375 mg., 83%) of m.p. 115°. This product contained 4% uracil which was difficult to remove by crystallization. A completely pure product was, however, readily obtained by preparative paper chromatography in solvent I which gave material of m.p. 116–117° after crystallization from acetone–ether, $\lambda_{\max}^{0.01\,N\ \mathrm{HCl}}$ 263 mμ ($\epsilon_{\max}$ 10,050), $\lambda_{\max}^{0.01\,N\ \mathrm{NaOH}}$ 263 mμ ($\epsilon_{\max}$ 7220).

Anal. Calcd. for $C_9H_{12}N_2O_4$: C, 50.90; H, 5.70; N, 13.20. Found: C, 50.81; H, 5.75; N, 13.22.

3′-**Deoxythymidine.**—This compound was prepared *via* the same sequence of steps as described above for 2′,3′-dideoxyuridine, except that the starting material was 5′-O-tritylthymidine.[8] The procedure is a direct adaptation of that described by Michelson and Todd[5] and the intermediates prepared were as follows: 3′-O-methanesulfonyl-5′-O-tritylthymidine (100%, amorphous), 3′-deoxy-3′-iodo-5′-O-tritylthymidine (70%, m.p. 147–148°), 3′-deoxy-3′-iodothymidine (79%, m.p. 166° dec., 3′-deoxythymidine (61%, m.p. 147–149°).

2′3′-Dideoxyuridine 5′-Phosphate (VII, R = H).—A mixture of pyridinium cyanoethyl phosphate[11] (0.2 mmole) and 2′,3′-dideoxyuridine (0.1 mmole) was rendered anhydrous by three evaporations with 2-ml. portions of dry pyridine. The final residue was dissolved in anhydrous pyridine (1 ml.) and dicyclohexylcarbodiimide (124 mg., 0.6 mmole) was added. After 24 hr. at room temperature, a small amount of water (0.5 ml.) was added and, after a further 30 min., the solvent was evaporated *in vacuo*. The residue was well stirred with water (5 ml.) and ether (5 ml.) and filtered to remove crystalline dicyclohexylurea. The water layer was extracted once more with ether, made 0.5 *M* with lithium hydroxide, and heated at 100° for 1 hr. After cooling in ice, the precipitated lithium phosphate was removed and the filtrate and washings (with 0.01 *M* LiOH) were passed through a column containing 3 ml. of Dowex-50 (H^+) resin. The eluates gave a single spot on paper with solvent I (R_f 0.11, while dideoxyuridine itself had R_f 0.63) and, based upon the ultraviolet spectrum, the yield was 80%. The pH of the solution was brought to 8.0 with barium hydroxide and after removal of a trace of barium phosphate the volume was reduced to 3–4 ml. The addition of three volumes of ethanol gave a white precipitate which was washed with ethanol and dried *in vacuo*. The barium salt of 2′,3′-dideoxyuridine 5′-phosphate thus obtained was spectrally shown to be a tetrahydrate and was poorly soluble in water, $\lambda_{\max}$ 263 (pH 2) and 263 mμ (1 *N* lithium hydroxide).

Anal. Calcd. for $C_9H_{11}BaN_2O_7P \cdot 4H_2O$: P, 6.20, P/dideoxyuridine, 1.0. Found: P, 6.51; P/dideoxyuridine, 1.05.

3′-Deoxythymidine 5′-Phosphate (VII, R = Me).—Phosphorylation of 3′-deoxythymidine (0.1 mmole) was carried out in identical manner to that of 2′,3′-dideoxyuridine above. The yield of chromatographically pure product (R_f 0.14; *cf.* 3′-deoxythymidine, R_f 0.72 in solvent I) was 85% and the barium salt was an octahydrate.

Anal. Calcd. for $C_{10}H_{13}BaN_2O_7 \cdot 8H_2O$: P, 5.30; P/deoxythymidine, 1.0. Found: P, 5.70; P/deoxythymidine, 1.08.

Kinetics of Acid Hydrolyses. A. Uracil Nucleosides.—Samples of uridine, 2′-deoxyuridine, and 2′,3′-dideoxyuridine (2.0 mg.) were separately dissolved in 0.5-ml. portions of cold, 1.0 *N* hydrochloric acid. Approximately 20-μl. aliquots of these solutions were sealed in capillary tubes and placed in a boiling water bath. At intervals the tubes were removed and, if necessary, stored in Dry Ice. The tubes were then broken and the contents were mixed directly with approximately 1.5 ml. of 1 *N* lithium hydroxide in a quartz spectrophotometer cell. The extent of the hydrolysis was followed by the ratio of the optical densities at 276 and 263 mμ: O.D. 276/263 = 0.556 for uracil nucleosides, 276/263 = 1.29 for uracil in 1 *N* lithium hydroxide.

B. Thymine Nucleosides.—The procedure in A was repeated exactly, except that thymidine and 3′-deoxythymidine were used in place of the uracil nucleosides. The extent of hydrolysis was determined from the optical density ratios at 281 and 267 mμ: 281/267 = 0.596 for thymidine and 3′-deoxythymidine, and 1.184 for thymine in 1 *N* lithium hydroxide. The results are shown in Fig. 1, the various deoxynucleosides all obeying first-order kinetics until 60–75% hydrolysis had occurred.

Alkylbenzenes. XIII. Rearrangements and Reorientations of C^{14}-Labeled *n*-Propyltoluenes and *n*-Propylxylenes

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The reactions of *p*-*n*-propyl-α-C^{14}-toluene and 1,3-dimethyl-4-*n*-propyl-β-C^{14}-benzene with aluminum chloride at temperatures from 23 to 98° were studied. At lower temperatures the main reactions were reorientation to *m*-*n*-propyltoluene and 1,3-dimethyl-5-*n*-propylbenzene, respectively; at higher temperatures a complex mixture of products was formed by competing reactions which included reorientation of methyl as well as propyl groups, and rearrangements of *n*-propyl groups to isopropyl groups and to *n*-propyl groups in which C^{14} was interchanged between α- and β-positions of the side chains. The results of the present work and previous work lead to the conclusion that the susceptibility toward aluminum chloride-induced rearrangement of *n*-propyl side chains decreases in the series *n*-propylbenzene, *n*-propyltoluene, and *n*-propylxylene. An explanation for this order is suggested.

Reorientation reactions of the type *p*-xylene → *m*-xylene[1,2] and *p*-ethyltoluene → *m*-ethyltoluene[3] take place under milder conditions than those which produce rearrangements of side chains in propyl-[4] and butylbenzenes.[5] However, in some studies of reorientation reactions,[6,7] conditions were similar to those which produce rearrangement; it thus seemed worthwhile to determine the extent to which rearrangements may occur in these systems.

Nightingale and Shackelford[7] reported that the major products of reaction of 1,3-dimethyl-4-*n*-propylbenzene and 1,3-dimethyl-4-*n*-butylbenzene were 1,3-dimethyl-5-*n*-propylbenzene and 1,3-dimethyl-5-*n*-butylbenzene, respectively, but they stated that it was quite possible that their products contained minor amounts of side chain-rearranged isomers. We particularly were interested in investigating the C^{14}-labeled *n*-propyl case, since rearrangements could be detected with more precision in this system than the butyl. This paper reports the results of investigation of the reaction of 1,3-dimethyl-4-*n*-propyl-β-C^{14}-benzene and of the structurally related *p*-*n*-propyl-α-C^{14}-toluene with aluminum chloride.

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(1) G. Baddeley, G. Holt, and D. Voss, *J. Chem. Soc.*, 100 (1952).

(2) (a) D. A. McCaulay and A. P. Lien, *J. Am. Chem. Soc.*, **74**, 6246 (1952); (b) H. C. Brown and H. Jungk, *ibid.*, **77**, 5579 (1955).

(3) R. H. Allen, *ibid.*, **82**, 4856 (1960).

(4) R. M. Roberts and J. E. Douglass, *J. Org. Chem.*, **28**, 1225 (1963); *cf.* references to previous papers.

(5) R. M. Roberts, Y. W. Han, C. H. Schmid, and D. A. Davis, *J. Am. Chem. Soc.*, **81**, 640 (1959).

(6) G. Baddeley and J. Kenner, *J. Chem. Soc.*, 303 (1935).

(7) (a) D. V. Nightingale and J. M. Shackelford, *J. Am. Chem. Soc.*, **76**, 5767 (1954); (b) **78**, 1225 (1956).

TABLE I

REACTIONS OF 1,3-DIMETHYL-4-*n*-PROPYLBENZENE WITH ALUMINUM CHLORIDE

Temp., °C.	30 ± 2	30 ± 2	30 ± 2[a]	80 ± 2	98 ± 2[a]	98 ± 2[a]
Time, hr.	4	4	8	2.5	4	4
$AlCl_3$/hc[b]	0.24	0.48	0.48	0.24	0.24	0.48
$AlCl_3/H_2O$	...	...	...	...	...	2
Products[c]						
Toluene	Tr.	Tr.	Tr.	1	2	4
Xylenes	18	18	13	8	11	19
Mesitylene	tr.	tr.	tr.	5	9	12
Pseudocumene	2	3	5	10	13	17
n-Propyltoluenes	5	5	8	18	17	17
1,3-Dimethyl-4-*n*-propylbenzene	57	38	28	21	...[d]	...[d]
1,2-Dimethyl-4-*n*-propylbenzene	...[d]	...[d]	...[d]		18	12
1,3-Dimethyl-5-*n*-propylbenzene	18	36	46	34	25	13
1,3-Dimethyl-5-isopropylbenzene	...	...	...	3[e]	5[e]	6[e]
Residue[f]	...	...	25	...	20	32
Per cent C^{14} in α-carbon of 1,3-dimethyl-5-*n*-propylbenzene			0		4.5 ± 0.2[g]	36 ± 1[g]

[a] 1,3-Dimethyl-4-*n*-propyl-β-C^{14}-benzene was the starting material. See Experimental section for details. [b] Molar ratio of $AlCl_3$/hydrocarbon. [c] Mole %, determined by integration of v.p.c. recordings of crude product mixtures. [d] These isomers were not resolved on the v.p.c. column, but their infrared spectra were sufficiently distinctive to indicate the absence of any more than trace amounts of the 1,2-dimethyl isomer in the first three experiments and of the 1,3-dimethyl isomer in the last two. [e] Estimated within ±5% from shoulder peaks, since this isomer was not completely resolved from 1,3-dimethyl-5-*n*-propylbenzene by the v.p.c. column. [f] Distillation residues, b.p. >210°, are given in wt. % of starting material for three experiments. [g] Confidence limits based on a maximum error of 4% in radioassays.

Results and Discussion

In preparation for the work with the C^{14}-labeled molecules, several experiments were carried out with ordinary 1,3-dimethyl-4-*n*-propylbenzene at different temperatures and with different proportions of catalysts. These experiments and their results, as well as those with radioactive materials, are summarized in Table I. At 30° a complex mixture resulted from reorientation and disproportionation reactions. The major products were 1,3-dimethyl-5-*n*-propylbenzene and xylenes (probably mainly the *meta* isomer[8]) as reported previously.[7b] Reorientation was incomplete, considerable starting material remaining even after 8 hr. No rearrangement of the *n*-propyl side chain to isopropyl was found.

The experiment of column five, Table I, duplicated the one reported by Nightingale and Shackelford.[7b] In addition to those found in the lower temperature experiments, several new products appeared in appreciable amounts: toluene, mesitylene, psuedocumene, *n*-propyltoluenes, 1,2-dimethyl-4-*n*-propylbenzene, and 1,3-dimethyl-5-isopropylbenzene. It is to be noted that several of these result from removal and reorientation of methyl groups, as well as propyl groups. Some rearrangement of *n*-propyl to isopropyl side chains occurred.

In order to determine the amount of rearrangement of C^{14} in the *n*-propyl groups in the experiments utilizing labeled starting material, the crude reaction mixtures were subjected to fractional distillation, and dimethylpropylbenzene cuts were taken for degradation to trimesic acid. These cuts were shown by v.p.c. analysis to be free of 1,3-dimethyl-5-isopropyl benzene (see below); they contained 1,3-dimethyl-5-*n*-propylbenzene and 1,3-dimethyl-4-*n*-propylbenzene (experiment of column three) or 1,2-dimethyl-4-*n*-propylbenzene (experiments of columns five and six). The trimellitic acid resulting from oxidation of the latter two isomers was easily separated from trimesic acid by recrystallization. In order to ensure that the radioactivity of the trimesic acid arose from oxidation of 1,3-dimethyl-5-*n*-propyl-α-C^{14}-benzene only and *not* 1,3-dimethyl-5-isopropyl-α-C^{14}-benzene, the latter labeled isomer was synthesized and mixed with nonradioactive 1,3-dimethyl-5-*n*-propylbenzene, and the mixture was oxidized to trimesic acid. Radioassay of the purified trimesic acid showed that only 6% of the 1,3-dimethyl-5-isopropyl-α-C^{14}-benzene was oxidized to trimesic acid. Since the v.p.c. analysis of the dimethylpropylbenzene cuts would have detected as much as 5% of the isopropyl isomer, the error in radioassay produced by the presence of the isopropyl isomer in trace amounts and its oxidation to trimesic acid would have been insignificant. The extent of rearrangement of C^{14} calculated from the radioassays of trimesic acid is shown at the bottom of Table I.

p-*n*-Propyl-α-C^{14}-toluene also was synthesized and its reactions with Lewis acids were studied. In toluene solution at 23°, with aluminum bromide–hydrogen bromide, complete reorientation to the *meta* isomer occurred in 30 min. The same reactants in a sealed tube at 100° for 30 min. gave a mixture so complex that recovery of pure propyltoluene was impossible. A third experiment carried out with aluminum chloride and water cocatalysts gave a mixture somewhat more amenable to separation and analysis.

The *m*-*n*-propyltoluene recovered from the first experiment was oxidized to isophthalic acid and this was converted to the dimethyl ester for radioassay. The radioassay indicated loss of only 1.9 ± 0.5% of C^{14} from the α-carbon of the *n*-propyl side chain. The propyltoluene distillation fraction from the third experiment was not pure *m*-*n*-propyltoluene (infrared analysis), but it gave isophthalic acid upon oxidation, as did a higher boiling fraction which contained *m*-di-*n*-propylbenzene. At the time these experiments with

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[8] Nightingale and Shackelford[7b] identified *m*-xylene by means of a derivative. *p*-Xylene would not have been resolved from *m*-xylene by our v.p.c. column, but *o*-xylene was; it made up 10–20% of the xylene mixtures produced.

p-*n*-propyl-α-C^{14}-toluene were carried out, v.p.c. analysis of the products was not feasible. When the experiments with *n*-propyldimethylbenzenes were carried out at a later date, a sample of the dipropylbenzene distillation fraction (e) was still available and was analyzed by v.p.c., but none of the propyltoluene fraction (c) remained. Since the v.p.c. analysis of the higher boiling fraction showed that it contained *m*-*n*-propyltoluene, it is reasonable to assume that the lower boiling cut contained some *m*-di-*n*-propylbenzene. From the proportions of *m*-*n*-propyltoluene and *m*-di-*n*-propylbenzene determined in the higher boiling fraction by v.p.c. and the radioassay of the dimethyl isophthalate obtained from this fraction, the per cent loss of C^{14} from the α-positions of the *n*-propyl side chains was calculated to be about 17%.[9] Making the reasonable assumption that the lower boiling fraction contained 10 mole % *m*-di-*n*-propylbenzene, and, using the radioassay of the dimethyl isophthalate obtained from this fraction, the per cent loss of C^{14} from the α-positions of the *n*-propyl side chains also was calculated to be about 17%.

In view of the complexity of the mixture obtained from reaction of *p*-*n*-propyl-α-C^{14}-toluene with aluminum chloride at 98° and the assumption necessitated by the fragmentary data, the extent of isotopic rearrangement calculated for this hydrocarbon must be considered indicative rather than conclusive.

Although accurate comparisons can not be made with the data available, we are tempted to comment on the apparent relative susceptibility of an *n*-propyl side chain toward rearrangement by aluminum chloride in an aromatic hydrocarbon having it as the only side chain with ones having in addition one or two methyl groups attached to the same benzene ring. Under similar conditions of time, temperature, and catalyst to hydrocarbon ratio, the approximate extent of rearrangement of *n*-propyl groups is in *n*-propylbenzene about 30%,[4] in *p*-*n*-propyltoluene about 17%, and in 1,3-dimethyl-4-*p*-propyltoluene about 5%. We have pointed out in previous papers[4,10] that rearrangements of alkylbenzene side chains induced by aluminum chloride and similar catalysts are subject to inhibition by disproportionation products such as polyalkylbenzenes, owing to the deactivation of the Lewis acid catalyst by complex formation with these products, which are stronger Lewis bases than the original monoalkylbenzene.[11] A reasonable explanation of the decreasing extent of rearrangement of *n*-propyl side chains in the series *n*-propylbenzene, *p*-*n*-propyltoluene, and 1,3-dimethyl-4-*n*-propylbenzene appears to lie in the fact that the catalyst would be progressively less active toward rearrangement of the di- and trialkylbenzenes, particularly after reorientation to the 1,3 and 1,3,5 isomers has occurred. The reorientation and rearrangement reactions are probably entirely independent of one another (the reorientation of *p*-*n* propyltoluene to *m*-*n*-propyltoluene was complete in 30 min. at room temperature with no accompanying side chain rearrangement) so that the rearrangements observed are probably subsequent rearrangements of the rapidly formed reorientation products, *m*-*n*-propyltoluene and 1,3-dimethyl-5-*n*-propylbenzene.

The greater extent of rearrangement in the experiment of column six, Table I, also is understandable in terms of (lesser) deactivation of the catalyst by the trialkylbenzene, since in this experiment the ratio of aluminum chloride to hydrocarbon was twice that of the experiment of column five. The effect of water as a cocatalyst[4,5] was an additional factor favoring rearrangement, of course.

The mechanisms of rearrangement of the *n*-propyl side chains of *m*-*n*-propyltoluene and 1,3-dimethyl-5-*n*-propylbenzene to isopropyl side chains and to *n*-propyl side chains in which the α- and β-carbon atoms have been interchanged are undoubtedly the same as those of *n*-propylbenzene, which have been considered previously.[4]

The reorientation of the methyl groups (production of 1,2-dimethyl-4-*n*-propylbenzene) is interesting. Additional examples of methyl shifts of this type will be discussed in a forthcoming publication.[12] We note that Nightingale and Shackelford reported their products from 1,3-dimethyl-4-*n*-propylbenzene contained 28% of "1,3,4-trialkylbenzene."[7b] It now appears, from our results, that the "1,3,4-trialkylbenzene" was mainly 1,2-dimethyl-4-*n*-propylbenzene.

Experimental

Materials.—Ethyl-1-C^{14} iodide was purchased from Tracerlab, Inc.[13] Aluminum chloride was commercial anhydrous sublimed reagent grade, taken from freshly opened bottles. The following authentic hydrocarbons used for v.p.c. and infrared identification and analysis were prepared by standard, unequivocal syntheses by Dep Shiengthong, in connection with another problem[12]: 1,3-dimethyl-4-*n*-propylbenzene, 1,3-dimethyl-5-*n*-propylbenzene, 1,2-dimethyl-4-*n*-propylbenzene, 1,3-dimethyl-5-isopropylbenzene, 1,3-dimethyl-4-isopropylbenzene, and 1,2-dimethyl-4-isopropylbenzene. Authentic *p*- and *m*-*n*-propyltoluene were prepared by standard, unequivocal syntheses from *p*- and *m*-toluidines (recrystallized in the free amine and hydrochloric acid salt forms, respectively). *m*- and *p*-di-*n*-propylbenzene were produced by low temperature disproportionation of *n*-propylbenzene.

Analytical Procedures.—Radioassays were made as described previously.[4] Infrared analysis was done with Beckman IR5A and Baird Model 4-55 double-beam instruments, using sodium chloride cells. Vapor-phase chromatographic (v.p.c.) analysis was made using a Beckman GC2A instrument with a 12-ft. silicone gum rubber-on-firebrick column.

Synthesis of Radioactive Materials.—1,3-Dimethyl-4-*n*-propyl-β-C^{14}-benzene was synthesized from ethyl-1-C^{14} iodide *via* sodium propionate-2-C^{14} and 2,4-dimethylpropiophenone-2′-C^{14}, in a manner analogous to that used for *n*-propyl-β-C^{14}-benzene.[14] The 2,4-dimethylpropiophenone-2′-C^{14}, after fractional distillation (b.p. 102–103° at 6 mm.), was pure according to v.p.c. analysis. It was radioassayed in the form of its semicarbazone derivative, 0.86 μc./mmole. The ketone was hydrogenated to 1,3-dimethyl-4-*n*-propyl-β-C^{14}-benzene in glacial acetic acid containing a little perchloric acid using 5% palladium-on-carbon catalyst[15]; the hydrocarbon was pure by v.p.c. and infrared analysis, b.p. 204–207°, n^{22}_{D} 1.4972.

1,3-Dimethyl-5-isopropyl-α-C^{14}-benzene was synthesized from 2-propanol-2-C^{14} *via* 2-chloro-2-C^{14}-propane, which was used to alkylate *m*-xylene by standard procedures.[16] The product was fractionally distilled and a cut boiling at 195.5–197.5° was shown (infrared and v.p.c. analysis) to contain less than 2% of 1,3-

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[9] See Experimental.

[10] R. M. Roberts, E. K. Baylis, and G. J. Fonken, *J. Am. Chem. Soc.*, **85**, 3454 (1963).

[11] D. A. McCaulay and A. P. Lien, *ibid.*, **73**, 2013 (1951).

[12] R. M. Roberts and D. Shiengthong, paper in preparation.

[13] On allocation from the U. S. Atomic Energy Commission.

[14] R. M. Roberts and S. G. Brandenberger, *J. Am. Chem. Soc.*, **79**, 5484 (1957).

[15] R. M. Roberts, G. A. Ropp, and O. K. Neville, *ibid.*, **77**, 1764 (1955).

[16] D. Nightingale and B. Carton, Jr., *ibid.*, **62**, 280 (1940).

dimethyl-4-isopropylbenzene. The hydrocarbon was radioassayed in the form of the trinitro derivative, m.p. 116–117°,[7b] 0.75 μc./mmole.

***p*-*n*-Propyl-α-C^{14}-toluene** was synthesized from $BaC^{14}O_3$ (Oak Ridge National Laboratory[13]) *via* sodium propionate-1-C^{14} and *p*-methylpropiophenone-1-C^{14} in a manner analogous to that previously reported for *n*-propyl-α-C^{14}-benzene.[4] Infrared analysis showed that no *ortho* isomer was present in the product. The hydrocarbon was radioassayed in the form of dimethyl terephthalate, m.p. 139–140.5°, produced by permanganate oxidation to the acid, conversion to the acid chloride with phosphorus pentachloride, followed by reaction with methanol; 0.614 μc./mmole.

Reactions of 1,3-Dimethyl-4-*n*-propylbenzene with Aluminum Chloride.—All reactions were carried out on 10 g. (0.068 mole) of hydrocarbon and either 2.15 g. (0.0161 mole) or 4.30 g. (0.0322 mole) of aluminum chloride. In one experiment 0.29 g. (0.016 mole) of water also was added. The reactants were stirred by a Teflon-covered magnet in a flask equipped with a reflux condenser protected by a calcium chloride tube. The temperature of the reaction was controlled by an electrically heated oil bath. The conditions for six experiments are given in Table I. After the reaction period was completed, the contents of the flask were cooled in an ice bath and decomposed with 6 *N* hydrochloric acid. The organic products were extracted into ether; the ether solution was washed with 5% sodium bicarbonate solution and water and then dried over calcium chloride. The crude organic mixture was analyzed by v.p.c. with the results shown in Table I.

In the case of the experiments with radioactive materials, the reaction mixture was subjected to fractional distillation through a 100-cm. Nichrome spiral column using a reflux ratio of 99:1. The dimethylpropylbenzene fractions were analyzed by infrared and v.p.c. The fractionations were apparently effective in separating 1,3-dimethyl-5-isopropylbenzene (b.p. 194.5°[17]) from 1,3-dimethyl-5-*n*-propylbenzene (b.p. 202.2°[17]) and 1,2-dimethyl-4-*n*-propylbenzene (b.p. 208.9°[17]) because the shoulder or peak corresponding to the first isomer disappeared from the v.p.c. recordings of the fractions from the 98° reactions which were taken for degradation to trimesic acid.

Reactions of *p*-*n*-Propyl-α-C^{14}-toluene with Aluminum Bromide and Aluminum Chloride.—A mixture of 15.7 g. (0.0292 mole, as Al_2Br_6) of aluminum bromide and 15.7 ml. of dry toluene were shaken until all the solid had disappeared. Hydrogen bromide was bubbled through the mixture until a homogeneous solution was obtained. *p*-*n*-Propyl-α-C^{14}-toluene, 4.0 g. (0.030 mole), was added; the vessel was capped, inverted several times to ensure complete mixing, and placed in a water bath at 23° for 30 min. The reaction mixture was then decomposed with water and worked up in the usual way. A fraction which boiled at 178–181° had an infrared spectrum identical with that of authentic *m*-*n*-propyltoluene.

A mixture of 15.9 g. (0.119 mole) of *p*-*n*-propyl-α-C^{14}-toluene, 3.9 g. (0.030 mole) of aluminum chloride, and 0.13 g. (0.0071 mole) of water was heated with stirring at 98 ± 2° for 4 hr. The reaction mixture was worked up as before and distilled through a 75-cm. Nichrome spiral column. The following fractions were collected: (a) b.p. 109–114°, 0.76 g.; (b) b.p. 114–181°, 2.00 g.; (c) b.p. 181–185°, 1.35 g.; (d) b.p. 185–196°, 0.61 g.; b.p. 196–221°, 3.75 g. Fractions c and e were degraded for radioassay, as described below.

Degradations for Radioassays. 1,3-Dimethyl-4-*n*-propyl-β-C^{14}-benzene (starting material) was shown to have no C^{14} in the α-position of the side chain by oxidation (basic permanganate at reflux for 10 hr., followed by acidification and reflux for 2 hr.) to trimellitic acid. Recrystallized from aqueous ethanol, it melted at 237–238°; it gave no radioactivity above background. (Mixture of this product with trimellitic acid prepared by oxidation of pseudocumene gave no melting point depression.)

A. **Dimethylpropylbenzenes.**—A distillation fraction, b.p. 201–209°, obtained from the reaction at 30° (column three, Table I) was shown by v.p.c. and infrared analysis to consist of 1,3-dimethyl-4-*n*-propylbenzene, 35 ± 5%, and 1,3-dimethyl-5-*n*-propylbenzene, 65 ± 5%. Oxidation with basic and acidic permanganate, as described above, gave trimesic acid, m.p. 364–370°; a mixture with authentic trimesic acid obtained by oxidation of mesitylene had the same melting point. This product showed no radioactivity above background.

A distillation fraction, b.p. 195–205°, obtained from the reaction at 98° (column five, Table I) was shown by v.p.c. and infrared analysis to consist of 1,3-dimethyl-5-*n*-propylbenzene, 67 ± 5%, and 1,2-dimethyl-4-*n*-propylbenzene, 33 ± 5%. Oxidation gave trimesic acid, m.p. 365–370°; recrystallized from water, m.p. 365–368°. Radioassay gave 0.039 μc./mmole, corresponding to 4.5 ± 0.2% rearrangement of C^{14} to the α-position of the *n*-propyl side chain (Table I).

A distillation fraction, b.p. 198–208°, obtained from the reaction at 98° (column six, Table I) was shown by v.p.c. and infrared analysis to consist of 1,3-dimethyl-5-*n*-propylbenzene, 60 ± 5%, and 1,2-dimethyl-4-*n*-propylbenzene, 40 ± 5%. Oxidation gave trimesic acid, m.p. 364–370°; after recrystallization from water, radioassay gave 0.31 μc./mmole, corresponding to 36 ± 1% rearrangement of C^{14} to the α-position of the *n*-propyl side chain (Table I).

A prepared mixture of 1,3-dimethyl-5-isopropyl-α-C^{14}-benzene (0.636 g., 0.753 μc./mmole), 1,3-dimethyl-5-*n*-propylbenzene (1.80 g.), and 1,3-dimethyl-4-*n*-propylbenzene (1.20 g.) was oxidized in the usual way. The crude acid was recrystallized from water to give 600 mg. of trimesic acid, m.p. 365–368°. Recrystallization to constant radioactivity gave 0.012 μc./mmole; this corresponded to 6.0 ± 0.2% of the molecular radioactivity which could have been obtained by complete oxidation of the α-C^{14}-labeled isopropyl side chain.

B. ***m*-*n*-Propyltoluene.**—The *m*-*n*-propyltoluene fraction, b.p. 178–181°, from the reaction of *p*-*n*-propyl-α-C^{14}-toluene with aluminum bromide–hydrogen bromide at 23° was oxidized by permanganate to isophthalic acid. This was converted to the dimethyl ester as described for the *para* isomer (starting material) and recrystallized from 30% aqueous methanol, m.p. 66–67°. Recrystallization to constant melting point (67°) and radioactivity gave 0.602 μc./mmole. This corresponded to a loss of 1.9 ± 0.5% of the C^{14} from the α-position of the *n*-propyl side chain.

Fraction c, b.p. 181–185°, from the reaction of *p*-*n*-propyl-α-C^{14}-toluene with aluminum chloride at 98°, gave upon oxidation isophthalic acid which was converted to dimethyl isophthalate (m.p. 67°), recrystallized to a constant radioactivity of 0.562 μc./mmole. The infrared spectrum of fraction c was not identical with that of authentic *m*-*n*-propyltoluene. The impurities present were probably *m*-di-*n*-propylbenzene, unchanged *p*-*n*-propyltoluene, and isopropyltoluene isomers, judging from the v.p.c. analysis of fraction e (see below). The latter two would not interfere with the radioactivity analysis, since they would not oxidize appreciably to isophthalic acid.[18] Assuming 10 mole % *m*-di-*n*-propylbenzene and 90 mole % *m*-*n*-propyltoluene responsible for the dimethyl isophthalate radioassayed, the extent of rearrangement away from the α-position of the *n*-propyl side chains was calculated to be about 17%.[19]

Fraction e from the same reaction was also oxidized to isophthalic acid and converted to dimethyl isophthalate which was recrystallized to constant radioactivity, 0.763 ± 0.003 μc./mmole. Analysis of fraction e by v.p.c. showed it to contain *m*-*n*-propyltoluene and *m*-di-*n*-propylbenzene in about a 1:1 ratio.[19] Other products (three peaks) such as *m*- and *p*-diisopropylbenzene, *m*- and *p*-propylisopropylbenzene, and dipropyltoluenes also were present, but none of these would oxidize appreciably to isophthalic acid.[18] From the radioactivity of the dimethyl isophthalate and the proportion of *m*-*n*-propyltoluene and *m*-di-*n*-propylbenzene, the extent of rearrangement of C^{14} from the α-positions of the *n*-propyl side chains was calculated to be about 17%.[19]

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[17] F. R. Rossini, K. S. Pitzer, R. L. Arnett, R. M. Braun, and G. C. Pimentel, "Selected Values of Physical and Thermodynamic Properties of Hydrocarbons and Related Compounds," Carnegie Press, Pittsburgh, Pa., 1953, p. 74.

[18] The *para* isomers, of course, could not oxidize to isophthalic acid. The failure of isopropyl groups to oxidize to an appreciable extent was demonstrated in the case of 1,3-dimethyl-5-isopropylbenzene, as described earlier in Experimental.

[19] The precision of the v.p.c. analysis was not better than ±5%; this is responsible for the approximate value indicated for the extent of C^{14} rearrangement in this experiment.