

which are bracketed, arguments which have been given for centralite and methyl centralite apply, but broader generalizations on the basis of steric hindrance are more difficult to defend.

### Experimental<sup>10</sup>

**Materials.**—A mixture of Merck and Co., Inc., Reagent Silicic Acid and Celite 535 (2:1 by weight) which had been prewashed with  $V$  ml.<sup>11</sup> of ether and 2  $V$  ml. of ligroin (60–70°) was used as the adsorbent in all experiments; the size of the column usually was  $19 \times 150$  mm. Further information about the adsorbent, the solvents, most of the compounds which were chromatographed, and the reagents for the detection of colorless zones has already been presented.<sup>2,3,4</sup>

**Methods.**—The adsorption sequences were obtained by the following general method. A compound was placed on the column in a solvent whose developing properties were as weak as possible and then was developed with a developer which was expected to be satisfactory. On the basis of the results, other chromatograms were run in which the composition of the developer was changed until the most satisfactory one of each of several solvent mixtures had been found. Mixed chromatograms with similarly adsorbed compounds were then made in order to determine the exact sequence. Sometimes separation of two similarly adsorbed compounds into discrete zones could not be achieved with the developers which were used to establish the sequences given. When such was the case, the sequence was determined by running separate chromatograms of each compound and measuring the position of the zone after the passage of a given quantity of developer. Unless the column was overloaded, all evidence showed that a zone moved in the same manner when a mixture was present as it did when the compound was chromatographed alone.

(10) The experimental work was done for the Office of Scientific Research and Development under Contracts OEMsr-702 and OEMsr-881 with the California Institute of Technology.

(11)  $V$  ml. is the volume of solvent which is required to wet completely the column of adsorbent.

**Developing Mixtures.**—Table V gives the solvent mixtures which develop compounds in the same series at similar rates. It should be mentioned again that these mixtures must only be considered approximate because silicic acid shows variations from lot to lot as was amply found in these experiments and further studied by Trueblood and Malmberg.<sup>12</sup>

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### Summary

The unexpected relative adsorption affinities which are shown by nitro and nitroso derivatives of diphenylamine and *N*-ethylaniline on silicic acid columns have been correlated with the strength of the hydrogen bonds between the adsorbed compound and the adsorbent. The strength of the hydrogen bonds is conditioned by such features as intramolecular hydrogen bonding, the contribution of various resonance structures of the molecule and the effect of other groups upon such resonance structures.

Some of the applications and limitations of this theory are illustrated and discussed.

(12) K. N. Trueblood and E. W. Malmberg, *Anal. Chem.*, **21**, 1055 (1949).

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[CONTRIBUTION FROM THE CHEMISTRY DEPARTMENT OF EMORY UNIVERSITY]

## Rate of Oxime Formation of Isomeric Ketones from *p*-Cymene<sup>1</sup>

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In a previous communication<sup>4</sup> we have described the medium and method for measuring the rate of oxime formation of alkyl phenyl and alkyl *p*-xylyl ketones. We have extended this method to include the isomeric ketones containing the carvacryl (2-methyl-5-isopropylphenyl) and the thymyl (3-methyl-6-isopropylphenyl) groups.

**Preparation of Carvacryl Ketones.**—These ketones were prepared on a 1 molar scale according to a standard procedure.<sup>5</sup> They are unusually difficult to purify due to a pronounced tendency to superheat. Some samples were fractionally distilled as many as four times. The ketones are listed in Table I. The physical properties are those of samples used in the rate determinations.

**Preparation of Thymyl Ketones.**—These ketones were prepared on a 0.3 molar scale by the reaction of 3-methyl-6-isopropylbenzoyl chlo-

ride with a suitable dialkylcadmium compound.<sup>6</sup> The 3-methyl-6-isopropylbenzoyl chloride was prepared from thymol as previously described.<sup>7</sup> The ketones were purified by two fractional distillations. The properties listed in Table II are those of the center cut fractions used in the rate determinations.

**Determination of Rates of Reaction.**—The medium and method is that previously described. Glass electrode readings of *pH* values indicated that the medium had been properly buffered to correspond to previous conditions. The carvacryl ketones were measured in a solution 0.1 *M* in ketone and 0.1 *M* in hydroxylamine hydrochloride; the thymyl ketones were measured in a solution 0.1 *M* in ketone and 0.2 *M* in hydroxylamine hydrochloride. Duplicate values were determined and checked within 5% in all cases. The reactions were carried to 70% completion or better and the *k* values calculated by the method of least squares. The rates were measured in a bath with a temperature variation of  $\pm 0.05^\circ$ . The results obtained at 30, 35 and  $40^\circ$  are included in Table III.

(1) This work was made possible by a contract with the Office of Naval Research.

(2) Taken from the Ph.D. Thesis of Mary J. Craft, Emory University, 1950.

(3) Responsible co-author.

(4) Suratt, Proffitt and Lester, *THIS JOURNAL*, **72**, 1561 (1950).

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

(6) Gilman and Nelson, *Rec. trav. chim.*, **55**, 518 (1936).

(7) Lester and Bailey, *THIS JOURNAL*, **68**, 375 (1946).

TABLE I  
CARVACRYL ALKYL KETONES

Alkyl	°C.	B.p., Mm.	$n_D^{20}$	$d_4^{25}$	Carbon, %		Hydrogen, %	
					Calcd.	Found	Calcd.	Found
Methyl <sup>a,b</sup>	80	1	1.5188	0.9615	81.76	81.94	9.16	9.24
Ethyl <sup>a</sup>	82	0.5	1.5130	.9516	82.04	81.86	9.54	9.64
Propyl <sup>a</sup>	102	1	1.5076	.9404	82.27	82.28	9.87	10.00
Butyl	108	0.5	1.5054	.9346	82.50	82.52	10.16	10.09
Amyl	124	1	1.5030	.9299	82.69	82.60	10.42	10.51
Hexyl	137	1	1.5004	.9208	82.86	82.97	10.64	10.73
Heptyl	148	1	1.4983	0.9183	83.01	83.20	10.84	10.88

<sup>a</sup> Claus, *J. prakt. Chem.*, [2] **46**, 474 (1893); [*J. Chem. Soc., Abstracts*, **64**, [1] 162 (1893)]. <sup>b</sup> Klages and Lickroth, *Ber.*, **32**, 1549 (1899).

TABLE II  
THYMYL ALKYL KETONES

Alkyl	°C.	B.p., Mm.	$n_D^{20}$	$d_4^{25}$	Carbon, %		Hydrogen, %	
					Calcd.	Found	Calcd.	Found
Methyl	113	6	1.5123	0.9588	81.76	81.46	9.16	9.19
Ethyl	119	5	1.5073	.9495	82.04	81.84	9.54	9.62
Propyl	130	7	1.5034	.9373	82.27	82.56	9.97	10.06
Butyl	129	4	1.5006	.9303	82.50	82.23	10.16	10.25
Amyl	139	5	1.4987	.9271	82.69	82.54	10.42	10.66
Hexyl	160	9	1.4965	.9225	82.86	82.80	10.64	10.57
Heptyl	164	5	1.4947	.9153	83.01	83.00	10.84	10.86

TABLE III  
RATES OF REACTION OF KETONES WITH HYDROXYLAMINE  
HYDROCHLORIDE

RATE CONSTANTS IN LITERS/MOLE/SEC. $\times 10^3$						
Alkyl	30°	Carvacryl 35°	40°	30°	Thymyl 35°	40°
Methyl	1.83	2.47	3.27	1.03	1.24	1.65
Ethyl	0.575	0.790	1.02	0.232	0.286	0.366
Propyl	.507	.697	0.891	.172	.203	.344
Butyl	.483	.681	.889	.200 <sup>a</sup>	.218	.355 <sup>a</sup>
Amyl	.493	.655	.855	.159	.240	.292
Hexyl <sup>b</sup>	.469	...	.860	.147	.192	.229
Heptyl <sup>b</sup>	.456	.580	.781	.172	.220	.287

<sup>a</sup> Identical duplicate value was obtained when ketone and hydroxylamine hydrochloride were 0.2 and 0.1 *M*, respectively. <sup>b</sup> The rate curve was displaced upward on the *y*-axis. By the method of least squares an appreciable intercept value was obtained. Points obtained below 25% reaction indicated some compound which reacted rapidly with hydroxylamine. If allowed to sit for three days, reaction in excess of 98% was realized. The rate curve showed no sign of falling off between 25 and 75% reaction. Repeated fractional distillation had no effect on the behavior of the ketone. These observations, coupled with the C and H analysis, suggest the presence of an isomeric ketone, presumably without a substituent in the ortho-position.

The *k* values obtained have been used to determine the energy of activation and log *PZ* value for each ketone.<sup>8</sup> These values are listed in Table IV.

TABLE IV  
ENERGIES OF ACTIVATION IN KCAL. AND LOG *PZ* VALUES

Alkyl	Carvacryl <i>E</i>	Thymyl <i>E</i>	Carvacryl log <i>PZ</i>	Thymyl log <i>PZ</i>
Me	10.9	8.9	4.54	3.43
Et	10.6	8.7	4.40	2.64
Prop	10.6	11.5	4.35	4.53
Bu	11.3	10.1	4.64	3.58
Am	10.3	10.9	4.11	4.06
Hex <sup>a</sup>	11.4	8.6	4.89	2.40
Hept	9.9	9.2	3.80	2.87

<sup>a</sup> Calculated from the equation  $E = 2.3R \log k_2/k_1 \cdot (T_1T_2/T_2 - T_1)$ .

(8) *E* was determined by plotting log *k* vs. 1/*T* and obtaining the

An examination of these values leads to the conclusion that the difference between the two series is due to the difference in the "ortho effect" of a methyl and an isopropyl group. Except for the propyl ketones, if one compares the corresponding members of each series, there is a decided trend toward more negative entropy of activation for the thymyl series.<sup>9</sup> With the inaccuracy inherent in the use of a standard curve, fluctuations within a series can be expected. An accuracy of 5% is the best we have been able to realize.<sup>10</sup> In a refined study of semicarbazone formation, Price and Hammett<sup>11</sup> present evidence that suggests a rigid structure in the transition state. This indicates that in our reactions a ketone possessing an ortho-isopropyl group must lose more of its possible random motion in the activated state than a ketone possessing an ortho-methyl group. In short the differences in rates in the carvacryl and thymyl series is primarily an entropy rather than a potential energy effect.<sup>12</sup>

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### Summary

1. The synthesis of seven alkyl carvacryl and seven alkyl thymyl ketones are reported.
2. The rate constants for the reaction of these ketones with hydroxylamine are reported at 30, 35 and 40°.
3. *E* and log *PZ* values have been calculated.
4. It has been suggested that the difference in rate constants between the two series is primarily an entropy effect.

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slope of the best straight line as calculated by the method of least squares. log *PZ* was calculated at 30° from the equation  $\log PZ = E/2.3RT - \log k$ .

(9) By assuming that the entropy of activation for each member of the carvacryl series is zero, the differences between corresponding members of each series may be calculated, using  $\Delta S^* \text{ for carvacryl} = \Delta S^*_1 = 0$  and  $\Delta S^* \text{ for thymyl} = \Delta S^*_2$ . The expression  $\Delta S^*_1 - \Delta S^*_2 = 2.3R \log P_1Z_1/P_2Z_2$ , will then give negative values except for the propyl ketones.

(10) If the 40° value of *k* for the propyl thymyl ketone was 5% lower, the value of *E* would be 10.8 kcal. and log *PZ* would be 4.02.

(11) Price and Hammett, *This Journal*, **63**, 2387 (1941).

(12) Hammett, "Physical Organic Chemistry," McGraw-Hill Book Co., Inc., New York, N. Y., 1940, pp. 118-124.