12, 2498-77-3; **13**, 2498-76-2; **14**, 2498-75-1; **15**, 316-49-4; **16**, 2319-96-2; **17**, 316-14-3; **18**, 2381-31-9; **19**, 2381-16-0; **20**, 2381-15-9; **21**, 6111-78-0; **22**, 2422-79-9; **23**, 2541-69-7; **24**, 4076-39-5; **25**, 2606-85-1; **26**, 2381-19-3; **27**, 4076-40-8; **28**, 652-04-0; **29**, 2381-34-2.

Acknowledgment.—The authors are grateful to Professor M. S. Newman of this department for his contribution of the isomeric methyl-1,2-benzanthracenes and methylbenzo[*c*]phenanthrenes used in this study.

The Equilibrium between N-Benzyl-N-methylpiperidinium Ion and N-Benzylpyridinium Ion. The Carbon Basicity of Nitrogen[1]

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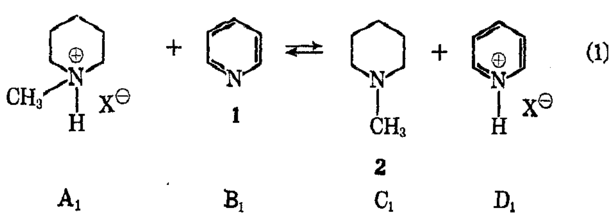
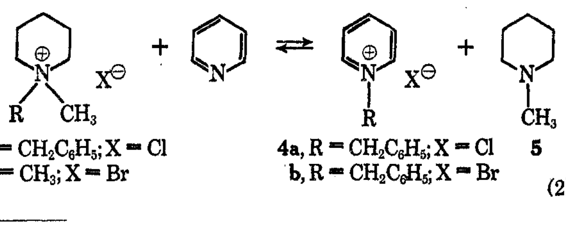
The equilibrium constants for the reaction between N-benzyl-N-methylpiperidinium halides and pyridine to form N-benzylpyridinium salts and N-methylpiperidine (eq 2) have been measured in organic solvents, principally benzyl alcohol and nitrobenzene, at temperatures from 140 to 195°. The temperature coefficient of the equilibrium has been determined from the linear plot of log K *vs.* $1/T$, and the equilibrium constant at 25° in benzyl alcohol has been obtained. Similar measurements have been made on the equilibrium between N,N-dimethylpiperidinium bromide and pyridine. Measurements of equilibrium concentrations have been made by two independent methods—electrometric titration of N-methylpiperidine in nonaqueous solution with perchloric acid in dioxane and comparisons of nmr absorptions of the product mixture. The relative pK_a values for N-methylpiperidine and pyridine in benzyl alcohol at 25° have been determined; combination of these data and the equilibrium constants shows that, under the conditions specified, N-methylpiperidine is a stronger base than pyridine toward the proton by a factor of 2.5×10^6. The ratio of carbon basicities of N-methylpiperidine compared with pyridine is much smaller, however; for the N-benzyl-N-methylpiperidinium reaction, the corresponding ratio is 1.7×10^2, and, for the N,N-dimethylpiperidinium case, the ratio is 1.4×10^3.

It is well known that pyridine (1) is a much weaker base than a saturated amine, such as N-methylpiperidine (2), the dissociation constants differing by a factor of about 10^5 in water at 25°;[2] in other words, the equilibrium constant for reaction 1 is about 10^{-5}. We wished to know whether the equilibrium constant would be of the same order of magnitude for reaction 2, in which a carbon group instead of a proton is transferred. In other terminology, we wished to determine the carbon basicity[3] of the nitrogen in the aromatic heterocycle compared to that of the nitrogen in the saturated heterocycle. This is an *equilibrium* and not a *rate* measurement.



(1)



3a, $R = CH_2C_6H_5; X = Cl$
b, $R = CH_3; X = Br$

4a, $R = CH_2C_6H_5; X = Cl$
b, $R = CH_2C_6H_5; X = Br$

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(2)

It is well known that quaternary ammonium salts are attacked by nucleophiles, with transfer of a carbon group from nitrogen to the nucleophile.[4] However, there appears to be little equilibrium data, as opposed to kinetic data, dealing with reactions like 2. Some qualitative studies of equilibrations of N-benzyl-N-methyl quaternary iodides, diastereoisomeric around nitrogen, have been reported; attempts to equilibrate N,N-dialkyl quaternary ammonium salts from saturated nitrogen heterocycles were unsuccessful.[5] With analogous compounds, House[6] found that lithium iodide in decalol required a 200° temperature to form methyl iodide from N,N-dimethyl quaternary salts.

The fundamental studies of Brown on the reactions of pyridines with protons and Lewis acids[7] do not include information about equilibria of the type of eq 2. Kosower[8] has determined equilibrium constants for the formation of charge-transfer complexes from pyridinium iodides.

The present paper reports determination of the equilibrium constants (by two independent analytical methods) for reaction 2 ($R = CH_2C_6H_5$ and $R = CH_3$) in organic solvents at 140–195°; the change of the equilibrium with temperature has been determined,

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[1] Aided by Grant 2252-C from the Petroleum Research Fund of the American Chemical Society. Grateful acknowledgment is expressed to the donors of this fund.

[2] D. D. Perrin ["Dissociation Constants of Organic Bases in Aqueous Solution," Butterworth and Co. Ltd., London, 1965, pp 138, 141] gives pK_a of pyridine as 5.2 and of N-methylpiperidine as 10.1.

[3] (a) J. F. Bunnett, C. F. Hauser, and K. V. Nahabedian, *Proc. Chem. Soc.*, 305 (1961); (b) A. J. Parker, *ibid.*, 371 (1961); (c) J. Hine and R. D. Weimar, Jr., *J. Amer. Chem. Soc.*, **87**, 3387 (1965); (d) W. P. Jencks, *Progr. Phys. Org. Chem.*, **2**, 104 (1964); (e) J. F. Bunnett, *Ann. Rev. Phys. Chem.*, **14**, 271 (1963).

[4] One of the early interesting observations was that of R. R. Williams, *et al.* [*J. Amer. Chem. Soc.*, **57**, 536, 1849 (1935)], that thiamine was deactivated by sodium sulfite through a nucleophilic attack on the thiazolium center; for related reactions and references, see H. R. Snyder, *et al.*, *ibid.*, **61**, 668, 2895 (1939); **66**, 200 (1944), and later papers; D. S. Tarbell and J. R. Vaughan, Jr., *ibid.*, **65**, 231 (1943); J. McKenna, B. G. Hutley, and J. White, *J. Chem. Soc.*, 1729 (1965).

[5] J. McKenna, J. M. McKenna, and J. White, *ibid.*, 1733 (1965).

[6] H. O. House and C. G. Pitt, *J. Org. Chem.*, **31**, 1062 (1966); H. O. House, *et al.*, *ibid.*, **28**, 2407 (1963).

[7] For leading references, see H. C. Brown and B. Kanner, *J. Amer. Chem. Soc.*, **75**, 3865 (1953); **88**, 986 (1966); H. C. Brown, D. Gintis, and L. Domash, *ibid.*, **78**, 5387 (1956); H. C. Brown, D. H. McDaniel, and O. Häfliger in "Determination of Organic Structures by Physical Methods," Vol. I, E. A. Braude and F. C. Nachod, Ed., Academic Press, New York, N. Y., 1955, pp 597 ff, 634 ff.

[8] E. M. Kosower and J. C. Burbach, *J. Amer. Chem. Soc.*, **78**, 5838 (1956), and earlier papers.

and the relative pK_a values for pyridine and N-methylpiperidine have been measured in benzyl alcohol. When the values for equilibrium constants for eq 1 and 2 are converted into comparable conditions of solvent and temperature, it is found that the difference in carbon basicity for pyridine and N-methylpiperidine is much less (by several powers of ten) than the difference in hydrogen basicity.

Experimental Section[9]

Procedure.—**N-Benzyl-N-methylpiperidinium chloride (3a)**, prepared by treatment of N-methylpiperidine with benzyl chloride, melted at 245° after crystallization from chloroform–petroleum ether (bp 30–60°). Its nmr spectrum showed 6 H at 1.50–2.07 (H on C-3, C-4, and C-5 of piperidine), 2.88 (3 H, s, $-NCH_3$), 3.30 (4 H, t, H on C-2 and C-6 of piperidine), 4.43 (2 H, s, benzylic H), and 7.50 (5 H, s, aromatic protons). N-Benzyl-N-methylpiperidinium bromide (**3a**, X = Br), prepared similarly, had mp 216°, and its nmr spectrum was identical with that of the chloride. **N-Methylpyridinium iodide**, prepared from methyl iodide and pyridine, melted at 116–116.5° [10] and its nmr spectrum showed the following features: 4.40 (3 H, s, $N-CH_3$), 8.07 (2 H, t, C-3 and C-5 H), 8.55 (1 H, t, C-4 H), 8.82 (2 H, d, C-2 and C-6 H). N-Benzylpyridinium promide[11] (**4b**) was deliquescent. It had the following nmr spectrum: 5.60 (2 H, s, benzylic H), *ca.* 7.25 (5 H, d, aromatic H), 7.87 (2 H, t, C-3 and C-5 H), 8.35 (1 H, m, C-4 H), and 8.75 (2 H, d, C-2 and C-6 H). Change of solvent from D_2O to *t*-butyl alcohol caused a marked shift particularly in the protons on the pyridinium ring, as shown by the following results for **N-benzylpyridinium chloride**[11] (**4a**) in *t*-butyl alcohol: 6.28 (2 H, s, benzylic H), 7.2–7.5 (3 H, aromatic H), 7.7–8.0 (2 H, aromatic H), 8.25 (2 H, t, C-3 and C-5 H), 8.77 (1 H, t, C-4 H), and 9.75 (2 H, d, C-2 and C-6 H).

N,N-Dimethylpiperidinium bromide, prepared from methyl bromide and N-methylpiperidine, had mp >345° [12] after crystallization from chloroform–petroleum ether; its nmr spectrum showed bands at 1.53–2.10 (6 H, on C-3, C-4, and C-5 of piperidine), 3.13 [6 H, s, $N(CH_3)_2$], and 3.37 (4 H, t, C-2 and C-6 of piperidine).

Purification of Solvents.—**Benzonitrile**, bp 85° (20 mm), n^{20}D 1.5253,[13] and **nitrobenzene**, bp 101° (20 mm), n^{26}D 1.5490,[14] were purified by distilling from phosphorus pentoxide. **Benzyl alcohol** was washed with dilute hydrochloric acid, dilute sodium bisulfite, and dilute sodium carbonate, dried over solid sodium carbonate, and distilled, bp 108° (20 mm), n^{26}D 1.5378.[15] Potentiometric titration showed negligible amounts of acid and base in the purified solvents. The same results in the equilibrations were obtained using Baker Analyzed nitrobenzene and benzyl alcohol, although the latter showed a small blank when titrated with standard acid.

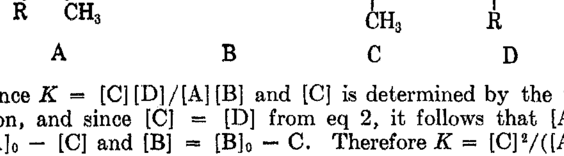
Measurement of Equilibria.—The equilibria were usually measured starting with the N-benzyl-N-methylpiperidinium salt (**3**) and pyridine because of the hygroscopic character of the pyridinium salt. The only cold solvent which would dissolve the piperidine salts was benzyl alcohol; so stock solutions could not generally be used. The tubes containing *ca.* 15 ml of reaction mixture were sealed and placed in a vapor bath at a temperature of 140° (xylene), 161° (cyclohexanol), 180° (*o*-dichlorobenzene), or 195° (decalin) for varying periods of time; concentrations were chosen such that all components remained in solution at the equilibration temperatures. The equilibrium measured using N-benzyl-N-methylpiperidinium chloride and pyridine in benzonitrile and nitrobenzene was also approached from the opposite side, using solutions made by treating redistilled benzyl chloride with excess pyridine under the equilibration conditions for 30 min, cooling the solution, and adding N-methylpiperidine.

Reaction of N-benzylpyridinium chloride with excess N-methylpiperidine yielded, on cooling, a precipitate of N-benzyl-N-methylpiperidinium chloride, which was identified and shown to be pure by its nmr spectrum, mp 245°, and mixture melting point with an authentic sample. Nmr spectra were obtained for the salt mixtures resulting from almost every run on each equilibrium. In reactions of N-benzyl-N-methylpiperidinium salts with pyridine, no nmr evidence for the formation of N-methylpyridinium salt was obtained, although the chemical shifts of the pyridinium ring protons in this compound are different from those in N-benzylpyridinium salts. An nmr spectrum of the salt mixture obtained from the reaction of N,N-dimethylpyridinium bromide with pyridine in benzyl alcohol showed the presence of phenyl protons and indicated that possibly 20% of the pyridinium bromide formed was the N-benzylpyridinium bromide. The spectrum of the N,N-dimethylpiperidinium bromide present in the mixture was unaltered. After equilibration the solutions were analyzed by two methods as follows.

1. **Titration Procedure.**—The solutions were transferred to 25-ml volumetric flasks and made up to the mark with chloroform. The quantity of N-methylpiperidine was then determined by diluting 10 ml of the stock solution with 20–30 ml of chloroform and titrating with 0.01 *N* perchloric acid in 1,4-dioxane[16] using a Radiometer G 200B glass electrode and a silver–silver chloride reference electrode dipping directly in the solution being titrated.[16,17] The latter electrode was prepared by activating the surface of the silver wire with nitric acid and then dipping the wire in dilute hydrochloric acid. The same results were obtained using a silver electrode with a saturated solution of N,N-dimethylpiperidinium bromide in benzyl alcohol as bridge; this was a more satisfactory reference electrode. The end point was determined by a sharp break in the titration curve; the break was sharper than when water was used as solvent.

The method was standardized by using weighed amounts of purified N-methylpiperidine in the presence of pyridine and of the pure quaternary salt. The volumes of a stock solution of perchloric acid in dioxane required to react with a quantity of N-methylpiperidine in chloroform containing pyridine and quaternary salt were 22.1, 22.1 and 22.1 ± 0.05 ml. The last figure was obtained about 3 weeks after the first two, almost as long as any stock solution was kept. The standardization using N-methylpiperidine was checked using as the primary standard diphenylguanidine[18] recrystallized twice from ethanol and from toluene. Agreement to within ±0.5% was obtained for standardizations with the two bases.

In eq 3, as given in Table I, it will be assumed that the equilibrium was established with A and B of initial concentration $[A]_0$ and $[B]_0$, as the initial components. (The calculations are quite similar if the equilibrium is approached from the side of C and D.)



(3)

Since $K = [C][D]/[A][B]$ and [C] is determined by the titration, and since $[C] = [D]$ from eq 2, it follows that $[A] = [A]_0 - [C]$ and $[B] = [B]_0 - C$. Therefore $K = [C]^2/([A]_0 - [C])([B]_0 - [C])$. A maximum error of ±3% in determining the extent of reaction was indicated and therefore an error of ±9% in determining the equilibrium constant. Where errors exceeded this it is likely that side reactions such as oxidation were interfering.

2. **By Nmr Measurements.**—The second and completely independent method of analysis involved measurement of the nmr spectrum after equilibration. The 15-ml sample of solution remaining after the titration was poured into ether and the salts were extracted into water which was then washed several times with ether. The water was evaporated and replaced by D_2O or

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[9] Nmr spectra were taken in D_2O, on a Varian A-60 spectrometer, and are given in δ (parts per million) units relative to TMS as internal standard; the multiplicity is indicated by s (singlet), etc.

[10] A. B. Prescott [*J. Amer. Chem. Soc.*, **18**, 91 (1896)] reported mp 117°.

[11] G. D. Sichev, *J. Russ. Phys. Chem. Soc.*, **60**, 325 (1928); *Chem. Abstr.*, **23**, 1329 (1929).

[12] R. Lukes and Z. Vesely [*Chem. Listy*, **50**, 1643 (1956); *Chem. Abstr.*, **51**, 1949 (1957)] reported mp 345–346°.

[13] Lit. $n^{25.5}$D 1.52568 [R. E. Van Dyke and T. S. Harrison, *J. Amer. Chem. Soc.*, **73**, 402 (1951)].

[14] Lit. n^{20}D 1.5526 [K. B. McAlpine and C. P. Smith, *J. Chem. Phys.*, **3**, 55 (1935)].

[15] Lit. $n^{21.5}$D 1.53987 [K. G. Falk, *J. Amer. Chem. Soc.*, **31**, 89 (1909)]

[16] J. S. Fritz, *Anal. Chem.*, **22**, 578, 1028 (1950); **25**, 407 (1953).

[17] J. S. Fritz, "Acid–Base Titrations in Nonaqueous Solvents," G. Frederick Smith Chemical Co., Columbus, Ohio, 1962.

[18] C. A. Carlton, *J. Amer. Chem. Soc.*, **44**, 1469 (1922).

D_2O-*t*-butyl alcohol. In the study of equilibration of benzyl salts, the absorption in D_2O–*t*-butyl alcohol mixtures of the 2,6-pyridinum protons, which are farthest downfield (9.75 in *t*-butyl alcohol), was compared with the total absorption of the phenyl protons of both salts, which coincide with each other but not with other protons' absorption in the mixture. Because there are two protons being measured (in the 2 and 6 positions) of D, and there are five phenyl protons each in the benzyl groups in D and A, the following ratio of areas for the proton absorptions in question holds.

$$\frac{[D]}{[A] + [D]} = \frac{\text{area of 2,6-pyridinium protons in D}}{2/5(\text{area of phenyl protons in A + D})}$$

Since $[D]_0 = 0$, $[A] + [D] = [A]_0$. Multiplication of the ratio $[D]/([A] + [D])$ by $[A]_0$ gives $[D]$, which can be compared with $[C]$ determined by titration.

If methyl equilibration was being studied, D_2O alone was used as solvent, and the absorption of the six piperidinium salt protons, on C-3, C-4 and C-5 of the piperidine ring, was compared with that of the two pyridinium protons at C-2 and C-6. In this case

$$\frac{[D]}{[A]} = \frac{\text{area of two 2,6-pyridinium protons}}{1/3(\text{area of six piperidinium protons})}$$

$[D]/([A] + [D])$ is obtained from $[D]/[A]$ and $[D]/([A] + [D]) = [D]/[A]_0$ since $[D]_0 = 0$. Multiplication by $[A]_0$ gives $[D]$. The values of $[D]$ agree reasonaly with the values of $[C]$ obtained by titration.

Measurement of Relative pK_a values of N-Methylpiperidine and Pyridine in Benzyl Alcohol.—It was necessary to determine the equilibrium constant $K_1 = [C_1][D_1]/[A_1][B_1]$ for eq 1 in benzyl alcohol in order to get the desired comparison of carbon basicity to hydrogen basicity of N-methylpiperidine and pyridine. It is interesting that the breaks in titration curves for titration of base mixtures are sharper when benzyl alcohol is the principal solvent than when water is the solvent. Presumably benzyl alcohol is not much if any more leveling than water. This is in agreement with earlier quantitative determinations of basic strength in nonaqueous solvents,[19] in which pK_a values for a large number of organic bases were shown to follow the same relative order in several organic solvents, and the same order as in H_2O. K_1 was obtained as follows.[20] If $K'' = [C_1][H^+]/[A_1]$ and $K''' = [B_1][H^+]/[D_1]$, then $pK_1 = pK'' - pK''' = pH'' - pH'''$ for the pH'' and pH''' at half-neutralization of the two bases. The emf of a glass electrode in the titration of C_1 or B_1 should be proportional to the pH of the solution, pH''' [$= \log([B_1]/[D_1]) - \log K'''$], and similarly for pH''. The slope of a plot of emf *vs.* pH''' is the same as the slope of a plot of emf *vs.* $\log([B_1]/[D_1])$. Electrometric titration of N-methylpiperidine and pyridine with HCl in benzyl alcohol was carried out, and the emf values obtained at different stages of the titration were plotted against the $\log([\text{amine}]/[\text{amine}\cdot H^+])$ value. The ratio $[\text{amine}]/[\text{amine}\cdot H^+]$ was obtained from the percentage completion of the titration for each point at which the emf was recorded.

The glass electrode was the indicator electrode, and the silver electrode and bridge described above was the reference electrode. Since only ratios of dissociation constants are significant here, absolute values of emf are not necessary, but it is important that the reference electrode remains at constant potential.

Plots of emf *vs.* $\log([\text{amine}]/[\text{amine}\cdot H^+])$ from titration at 25° of N-methylpiperidine (C_1, about 0.01 *M*) and of pyridine (B_1, about 0.014 *M*) with HCl (*ca.* 0.14 *M*), all in benzyl alcohol, were essentially straight lines of identical slope 42 mV/pH unit. The difference in emf values at half-neutralization was 280 mV, indicating a pK_1 [$= pH'' - pH'''$] of 6.6 ± 0.2. At 65°, the slopes were both 48 mV/pK unit and the difference in emf values at half-neutralization was 294 mV/pK unit, indicating $pK_1 = 6.2 \pm 0.2$.

HCl was used because perchloric acid reacted with the benzyl alcohol. The reference electrode used gave stable reproducible emf values and the constant slope of plots of emf *vs.* $\log([\text{amine}]/[\text{amine}\cdot H^+])$ indicated bridge potentials were constant during the titration. The straight plots indicate the possible interaction $\text{amine} + \text{amine}\cdot H^+ \rightleftharpoons \text{amine}_2\cdot H^+$ is not important. The results are not accurate enough for a satisfactory value of ΔH for equilibrium constants at higher temperatures to be calculated, but the temperature effect on the equilibrium constant is similar to that of the equilibria involving alkyl-group exchange.

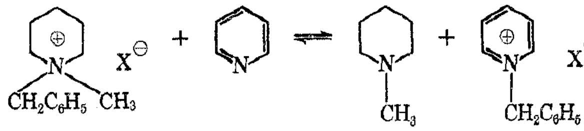
Determination of the Temperature Coefficient of the Equilibrium *K*.—A plot of values of log *K vs.* $1/T$ for reaction 2, $R = CH_2C_6H_5$, $X = Br$, in benzyl alcohol, gave a good straight line, where $T = 140$, 161, and 180°. A similar plot with similar slope was obtained for *K* in nitrobenzene solution where $R = CH_3$ and $T = 161$, 180, and 195°.

Discussion

No reaction was observed on prolonged heating of N-benzyl-N-methylpiperidinium chloride and pyridine in water at 140°, and it was concluded that hydroxylic solvents retard the reaction. Later tests showed that equilibrium could be obtained using benzyl alcohol as solvent at 180° and that the bromides exchanged faster than the chlorides (Table I). Benzyl alcohol was probably a fortunate choice as it has been observed that the reaction of ethyl iodide with triethylamine is particularly fast in this solvent.[21] Equilibrium was established most rapidly in nonhydroxylic solvents. The results (Table II) show that eq 2 proceeds in both directions. The agreement of equilibrium constants obtained from solutions in which the equilibrium had been approached from opposite sides and the agreement of the nmr (salt determining) and titration (N-methylpiperidine determining) analyses indicate that benzyl group exchange was the principal reaction occurring. The equilibrium constants measured did not alter when the benzyl-exchange equilibration time was altered by factors of 6–16. This with the lack of nmr evidence for methylpyridinium salt formation suggests that methyl exchange was negligibly slow.

Table I

Equilibration of N-Benzyl-N-methylpiperidinium Chloride and Bromide with Pyridine in Benzyl Alcohol at 180° [a]



A B C D

X^-	Components, mol/l. $[A]_0$	$[B]_0$	Time, hr	$[C]$	$[D]$	K_t
Cl	0.1525	0.5504	1.0	0.0493	0.046	0.047
Cl	0.1883	0.5245	2.0	0.0588	0.056	0.057
Cl	0.1957	0.5341	3.0	0.0611	0.066	0.058
Cl	0.1489	0.3674	4.0	0.0446	0.047	0.059
Br	0.1502	0.5593	0.5	0.0534	0.049	0.058
Br	0.1522	0.7659	1.0	0.0615	0.047	0.059
Br	0.1278	0.5251	4.0	0.0475	0.046	0.058

[a] $[A]_0$ and $[B]_0$ are the initial concentrations (moles per liter) of A and B. $[C]$ and $[D]$ are the equilibrium concentrations (moles per liter) of C and D determined by titration and nmr, respectively.

The exchange of a methyl group as carried out in the latter experiments involves more accessible exchanging groups in the N,N-dimethylpiperidinium salts; the methyl groups in the latter are more accessible than the methyl group in the N-benzyl-N-methylpiperidinium salts. The methyl group exchanges more than six

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[19] (a) H. K. Hall, Jr., *J. Phys. Chem.*, **60**, 63 (1956); (b) J. S. Fritz, *Anal. Chem.*, **25**, 407 (1953).

[20] *Cf.* W. Huber, "Titrations in Nonaqueous Solvents," Academic Press, New York, 1967, p 18 ff and references therein, particularly papers of Hall and Fritz, quoted in preceding references.

[21] N. Menschutkin, *Z. Physik. Chem.*, **6**, 41 (1890).

TABLE II

SUMMARY OF EQUILIBRIUM MEASUREMENTS

Initial components		Solvent	Temp, °C	Time, hr	K_t
N-Benzyl-N-methylpiperidinium bromide	Pyridine	$C_6H_5CH_2OH$	161	7	0.043
				7	0.046
Same	Same	Same	140	30	0.028
					0.031
Same	Same	Same	140[a]	30	0.036
				50	0.033
N-Benzyl-N-methylpiperidinium chloride	Same	C_6H_5CN	140	2.0	0.046
				4.0	0.044
N-Methylpiperidine	Benzylpyridinium chloride	Same	140	2.5	0.036
				3.8	0.045
N-Benzyl-N-methylpiperidinium chloride	Pyridine	$C_6H_5NO_2$	140	3.0	0.032
				4.0	0.041
				6.5	0.031
N-Methylpiperidine	Benzylpyridinium chloride	Same	140	3.3	0.037
				3.8	0.040
N-Benzyl-N-methylpiperidinium bromide	2-Picoline	$C_6H_5CH_2OH$	180	2.0	0.015[b]
				4.0	0.013
N-Benzyl-N-methylpiperidinium bromide	4-Picoline	Same	180	1.3	0.24[b]
				2.3	0.22
N,N-Dimethylpiperidinium bromide	Pyridine	$C_6H_5NO_2$	195	0.3	0.0088
Same	Same	Same	180	1.3	0.0074
				3.8	0.0068
Same	Same	Same	161	14	0.0054
				14	0.0056
N-Benzyl-N-methylpiperidinium bromide	Same	Same	140	4	0.028
				0.5	0.027

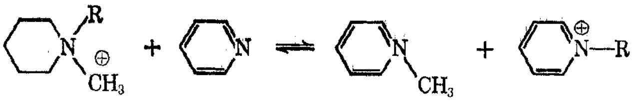
[a] Preheated to 180° for 0.75 hr, then kept at 140° for indicated time. [b] Decomposition as observed for the reactions in nitrobenzene and benzonitrile may make these results a little inaccurate.

times as fast as the N-propyl group in the exchange reaction.[22]

$$[(CH_3)_3N\overset{+}{—}R]\ X^- + \text{ethanolamine} \longrightarrow (CH_3)_3N + R\overset{+}{N}H_2CH_2CH_2OH$$

This factor and the entropy effect stabilizing the six-membered ring make it unlikely that considerable ring cleavage occurs, and, since the measured equilibrium constant did not alter with a threefold increase in reaction time, ring cleavage should be negligible. The nmr spectrum of the salt mixture from the methyl exchange reaction run in nitrobenzene showed only N,N-dimethylpiperidinium and N-methylpyridinium bromides. The reaction in nitrobenzene appears uncomplicated.

The equilibrium constants for benzyl exchange for reaction in benzonitrile, nitrobenzene, and benzyl alcohol at 140° agree closely. It is reasonable to extrapolate the accurate equilibrium constants obtained for methyl group exchange in nitrobenzene at 161, 180, and 195°, and benzyl group exchange in benzyl alcohol at 140, 161, and 180° to 25°, and to compare the results with those for exchange of a proton, because of the small differences in solvent effect. Straight line plots of log K *vs.* $1/T$ taken from the average values of K at each temperature indicate the ΔH values for reaction from left to right and equilibrium constants at 25° given below. The temperature dependence of the proton-exchange reaction is not established accurately but appears similar to that for alkyl exchange, indicating a similar heat of reaction. In comparing the equilibrium constants, the constant for methyl exchange must be halved to allow for the two exchangeable methyl groups. There is a decrease in K with decrease in size of the exchanging group from benzyl to methyl to the proton.



(a) R = H for reaction in benzyl alcohol, $K = 4.0 \times 10^{-7}$
(b) R = CH_3 for reaction in nitrobenzene, $K = 6.9 \times 10^{-4}$ and $\Delta H = 5.4$ kcal
(c) R = $CH_2C_6H_5$ for reaction in benzyl alcohol, $K = 5.8 \times 10^{-3}$ and $\Delta H = 5.4$ kcal

Registry No.—**3a**, X = Cl, 13127-28-1; **3a**, X = Br, 18266-96-1; **3b**, X = Br, 18266-97-2; **4a**, X = Cl, 2876-13-3; **4a**, X = Br, 2589-31-3.

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[22] S. Hünig and W. Baron, *Chem. Ber.*, **90**, 395 (1957).