Ethyl, *n*-propyl and *n*-butyl bromides were all prepared from the corresponding alcohols by treatment with a mixture of sodium bromide and sulfuric acid, and the bromides obtained were washed with concentrated sulfuric acid, water, 10% sodium carbonate solution, again with water, then dried over calcium chloride and finally fractionally distilled just before use.

Eastman Kodak C.P. β-bromoethyl ethyl ether was washed, dried and distilled and the fraction boiling at 125° (760 mm.) was collected.

Both γ-bromopropyl ethyl ether and α-bromobutyl ethyl ether were prepared and purified by the methods described elsewhere.[8b]

β-Chloroethyl bromide and γ-chloropropyl bromide were both Eastman Kodak white label products. Both were purified as in the case of alkyl bromides.

γ-Chlorobutyl bromide or 1-bromo-4-chlorobutane was prepared by the method used by the previous workers[19] and the fraction boiling at 103–104° (110 mm.) was collected.

Both β-bromoethylbenzene and γ-bromopropylbenzene were Eastman Kodak Co. white label products. δ-Bromobutylbenzene was prepared by the method described elsewhere.[8a] All these bromides were purified as in the previous work.[8a]

β-Bromoethyl ethyl sulfone was prepared by oxidizing β-bromoethyl ethyl sulfide with 30% hydrogen peroxide in acetic acid solution. The fraction boiling at 126–128° (3.5 mm.) was collected and used.

(19) J. Cason, L. Wallcave and C. N. Whiteside, *J. Org. Chem.*, **14**, 37 (1949).

γ-Bromopropyl ethyl sulfone was also obtained by the same treatment starting from γ-bromopropyl ethyl sulfide ($n^{20}D$ 1.5113, b.p. 54–56° (5 mm.)), which was made by the reaction between a little excess trimethylene bromide and sodium ethylmercaptide in rather poor yield. The fraction of the oxidized compound boiling at 140° (4 mm.) was collected and used; yield 66%. This compound solidified at room temperature (around 15°).

Allyl chloride was Eastman Kodak Co. white label product, while the preparation of chlorovinyl ethyl sulfone is described elsewhere.[16b]

The Rate Determination.—The rate measurements were made according to those of Hammett and his co-workers.[11f] However, in our case, accurately measured initial concentrations were used for the calculations; in other words, the equation was used

$$k = \frac{2.03}{t(a-b)} \log \frac{b(a-x)}{a(b-x)}$$

The concentrations of sodium thiosulfate and organic halide were 0.1 *N*, while that of sodium acetate was maintained as 0.01 *N*, except in two series, *i.e.*, ω-phenylalkyl bromides and allylic chlorides. In both cases the concentrations of both sodium thiosulfate and organic halide were just half of those of the other experiments, while maintaining the concentration of sodium acetate as the same, since allylic chlorides were too reactive with the ordinary concentrations while ω-phenyl bromides were found not to be soluble in the ordinary concentration.

OSAKA, JAPAN

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, PURDUE UNIVERSITY]

The Interaction of Alkyl Halides with Dimethylformamide[1]

BY NATHAN KORNBLUM AND ROBERT K. BLACKWOOD[2]

RECEIVED OCTOBER 21, 1955

Solutions of alkyl halides in dimethylformamide undergo dehydrohalogenation and salt formation on standing at room temperature.

Alkyl halides react with dimethylformamide (DMF) at room temperature. This rather unexpected reaction, while not rapid, does occur at a significant rate (*cf.* Table I).[3,4]

These reactions were followed by titration of the acid formed or by titration of halide ion produced. Only in one case was an organic product isolated and characterized; from a DMF solution of *t*-butyl bromide, isobutylene was obtained in 46% yield.[5]

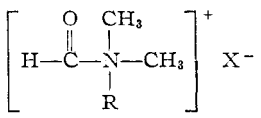
The kinetics of the reaction of three of the compounds listed in Table I were studied. The first-order rate constants ($k_1 \times 10^7$ sec.$^{-1}$) are: 1-iodobutane 3.39, 2-iodobutane 7.22, *t*-butyl bromide 24. These relative rates are in the order primary < secondary < tertiary and this, plus the fact that isobutylene is isolated, strongly suggests that dehydrohalogenation is an important factor. However, since DMF solutions of methyl iodide and benzyl bromide liberate halide ion, it is apparent that a second process, nucleophilic displacement, occurs, presumably to form the salt I.

TABLE I

INTERACTION OF ALKYL HALIDES WITH DMF

Halide	Concn., mole/liter	Temp., °C.	Reaction, (% complete)[a]
Methyl iodide	0.2	25–30	10%, 12 days
1-Iodobutane	.100	25	41%, 17 days
2-Iodobutane	.100	25	69%, 19 days
Benzyl bromide	.2	25–30	10%, 19 days
1-Bromoöctane	.200	25–30	64%, 324 days
2-Methyl-1-bromopropane	.200	25–30	25%, 280 days
2-Bromoöctane	.200	25–30	79%, 304 days
t-Butyl bromide	.100	25	75%, 7 days

[a] The reaction was followed only to the percentage completion given.



I

(1) This research was supported by the United States Air Force under Contract No. AF 18 (600)-310 monitored by the Office of Scientific Research, Air Research and Development Command.

(2) E. I. du Pont de Nemours and Co. Fellow 1954–1955.

(3) It was first noted when the conductivity of a DMF solution of *n*-heptyl iodide was measured. A large increase in conductivity with time suggested the formation of ions [D. D. Mooberry, Ph.D. Thesis, Purdue University, 1954].

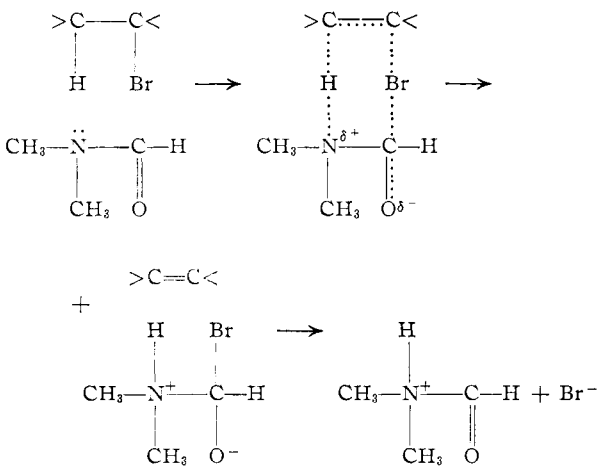
(4) A referee has kindly called our attention to a paper by G. M. Coppinger [THIS JOURNAL, **76**, 1372 (1954)] in which benzyl chloride is shown to react with DMF when heated at 150° for 6 hr. The two products isolated were dimethylbenzylamine and methyldibenzylamine. It should also be noted that E. Rochow and K. Gingold [*ibid.*, **76**, 4852 (1954)] have examined the reaction of chlorosilanes with DMF at elevated temperatures. These workers also found that carbon tetrachloride reacts violently with DMF at reflux temperature in the presence of iron powder to give a mixture of chlorinated hydrocarbons.

(5) *t*-Butyl bromide is also dehydrohalogenated in DMF containing $NaNO_2$ but at a much faster rate [N. Kornblum, H. O. Larsen, R. K. Blackwood, D. D. Mooberry, E. P. Oliveto and G. E. Graham, THIS JOURNAL, **78**, 1497 (1956).

The view that both dehydrohalogenation and salt formation occur in DMF solutions receives support from potentiometric titration studies of the acidity developed by DMF solutions of 1-bromoöctane (after 324 days) and of 2-bromoöctane (after 304 days). In each instance three inflection points, indicative of three acids of different strengths, are found. Furthermore, when a solution of hydrogen chloride, formic acid and triethylamine hydrochloride is titrated potentiometrically, one obtains three inflection points which correspond very closely to those obtained with aged bromoöctane–DMF solutions. It is probable, therefore, that the three inflection points found with the aged 1- (and 2)-bromoöctane solutions are indicative of the neutralization of a strong acid (HBr), an acid of intermediate strength (HCOOH) and a weak acid (an ammonium salt). The hydrogen bromide results from dehydrohalogenation, whereas formic acid and the "weak" acid arise *via* the salt I, which hydrolyzes (during the titration if not earlier) according to eq. 1.[6]

$$\mathrm{I} + \mathrm{H_2O} \longrightarrow \mathrm{HCOOH} + [\mathrm{RNH(CH_3)_2}]^+\mathrm{Br}^- \quad (1)$$

Finally, attention should be called to the possibility that the dehydrohalogenation reaction, which occurs under unusually mild conditions, may be a *cis*-elimination passing through a cyclic transition state



Experimental

The DMF (du Pont) was dried over calcium hydride before use. The alkyl halides were carefully purified samples.

Kinetics.—Rate constants for 1-iodobutane and 2-iodobutane in DMF at 25° were determined by titration of the iodide ion using a modified Volhard procedure.[7] Sample data for 2-iodobutane are given in Table II.

(6) Another "weak" acid which may be present is $[\mathrm{H_2N(CH_3)_2}]^+$; this could form by the reaction: $\mathrm{HC(=O)—NH(CH_3)_2} \rightarrow \mathrm{CO} + \mathrm{H_2N(CH_3)_2}$. The analogous process occurs when hydrogen chloride solutions in DMF are heated to 90° ["DMF Product Information," Grasselli Chemicals Dept., E. I. du Pont de Nemours and Co., Inc., Wilmington, Del.]. The lower reaction temperature employed here may be compensated for by the longer reaction period. Still another route to the formation of $[\mathrm{RNH(CH_3)_2}]^+$ is readily envisioned: $\mathrm{I} \rightarrow \mathrm{CO} + [\mathrm{RNH(CH_3)_2}]^+$. Apropos of this, and also the reaction of eq. 1, the work of Gold and Jefferson [*J. Chem. Soc.*, 1409, 1416 (1953)] is of considerable interest.

(7) See R. K. Blackwood, Ph.D. Thesis, Purdue University, June, 1955, p. 77, for details.

TABLE II

RATE OF REACTION OF A DMF SOLUTION OF 2-IODOBUTANE (0.100 *N*) AT 25°

t, hr.	x, ml.[a]	$\log \frac{a}{a-x}$	t, hr.	x, ml.[a]	$\log \frac{a}{a-x}$
17.0	0.524	0.0209	164.2	3.755	0.1778
41.9	1.105	.0452	213.2	4.750	.2404
89.2	2.326	.1013	257.2	5.380	.2851
115.9	2.927	.1318	449.1	7.750	.5133

[a] Ml. of 0.08967 *N* $AgNO_3$; a = 11.178 ml. of this $AgNO_3$; slope (by method of least squares) = 1.134×10^{-3} hr.$^{-1}$; $k_1 = 7.26 \times 10^{-7}$ sec.$^{-1}$. A duplicate run gave $k_1 = 7.18 \times 10^{-7}$ sec.$^{-1}$.

The rate constant for *t*-butyl bromide was determined by titration of the acid formed. Aliquots were added to absolute ethyl alcohol and titrated with aqueous standard sodium hydroxide, using methyl red as the indicator[8]; *cf.* Table III.

TABLE III

RATE OF REACTION OF A DMF SOLUTION OF *t*-BUTYL BROMIDE (0.100 *N*) AT 25°

t, hr.	x, ml.[a]	$\log \frac{a}{a-x}$	t, hr.	x, ml.[a]	$\log \frac{a}{a-x}$
1.7	0.175	0.0076	66.1	4.190	0.2314
18.3	1.212	.0552	90.0	5.302	.3210
24.3	1.692	.0792	124.3	6.539	.4489
42.1	2.810	.1408	162.1	7.588	.5980
48.6	3.240	.1670			

[a] Ml. of 0.0989 *N* NaOH; a = 10.150 ml. of this NaOH; $k_1 = 23.8 \times 10^{-7}$ sec.$^{-1}$. A duplicate run gave $k_1 = 23.8 \times 10^{-7}$ sec.$^{-1}$.

With the remaining halides listed in Table I standard DMF solutions were allowed to stand at room temperature and aliquots were removed periodically and titrated for halide ion.

Dehydrohalogenation of *t*-Butyl Bromide in DMF.—A solution of *t*-butyl bromide (0.44 mole) in DMF (450 ml.), which had stood at room temperature for 15 days, was placed in a bath at 25° and the pressure was gradually reduced; the isobutylene was trapped in Dry Ice traps. Some DMF was carried over into the first trap, but it was easily removed by distillation of the isobutylene from an ice–water-bath into the second trap; this left the DMF behind. The molecular weight of this isobutylene was found to be 56.7 by the Dumas method, using air as a standard (calcd. 56); b.p. −7°. The yield, 18 ml. (46%), is unquestionably low for considerable losses were incurred in isolation.

The isobutylene was characterized as the 2,4-dinitrobenzenesulfenyl chloride adduct according to the method of Kharasch[9]; m.p. and mixed m.p. with an authentic sample, 87°.

Potentiometric Titrations.—Five-ml. aliquots of the DMF solution to be titrated were added to 95 ml. of abs. ethanol and titrated with aqueous sodium hydroxide (0.0972 *N*) using a Beckman *p*H meter. "Synthetic" mixtures were

TABLE IV

PRODUCTS FROM DMF SOLUTIONS OF 1(AND 2)-BROMOOCTANE[a]

Products[b]	1-Bromoöctane	2-Bromoöctane
Br^-	129	158
HBr	6	20
HCOOH	34	16
$^+NR_3H$	140	195
Total acid	180	231

[a] Temp. 25–30°, reaction time 324 days for 1-bromooctane, 304 days for 2-bromoöctane; initial concn. of the bromoöctanes 200 meq./liter. [b] Concn. of all products in meq./liter.

(8) H. C. Brown and R. S. Fletcher, THIS JOURNAL, **71**, 1845 (1949).

(9) N. Kharasch, H. L. Wehrmeister and H. Tigerman, *ibid.*, **69**, 1612 (1947).

prepared by making up stock solutions (*ca.* 0.1 *N*) in abs. ethanol of hydrogen chloride, formic acid and triethylamine. Aliquots of these three solutions were combined, 5 to 10 ml. of DMF was added and the solution was made up to *ca.* 100 ml. with abs. ethanol before titrating.

Titration of a solution containing hydrogen chloride, formic acid and triethylammonium chloride gave inflection points at *p*H 6.0, 8.7 and 12.2. Titration of a 1-bromooctane solution in DMF which had stood 324 days gave inflection points at *p*H 6.0, 8.8 and 12.1 while with the 2-bromoöctane–DMF solution (aged 304 days) the inflection points were at *p*H 5.8, 8.8 and 12.0. (The individual *p*H determinations are probably not in error by more than ±0.1 unit.)

Table IV gives the products formed in DMF solutions of 1- (and 2-)bromoöctanes.

LAFAYETTE, INDIANA

[CONTRIBUTION FROM THE ROHM & HAAS COMPANY]

t-Carbinamines, $RR'R''CNH_2$. I. Reaction with Alkyl Halides and Alkylene Oxides[1]

BY NEWMAN BORTNICK, LEO S. LUSKIN, M. D. HURWITZ, W E CRAIG, L. J. EXNER AND J. MIRZA

RECEIVED NOVEMBER 18, 1955

The reactions of a variety of alkyl halides and alkylene oxides with *t*-butylamine and *t*-octylamine have been investigated. Pure secondary amines were obtained in satisfactory yield. Tertiary amine derivatives were also obtained by the action of methylating agents or of ethylene oxide upon both amines and in low yield by the alkylation of *t*-butylamine with benzyl chloride.

A study has been made of the reactions of *t*-butylamine (I) and of *t*-octylamine (1,1,3,3-tetramethylbutylamine) (II) which are commercially available examples of highly branched primary aliphatic amines, $R(R')(R'')CNH_2$. The results of alkylations by means of alkyl halides and alkylene oxides are reported in this communication.

Pure secondary amines were obtained by the reaction of most alkyl halides with both amines in molar ratios of at least 1 to 2 (Table I). High yields were obtained with reactive halides, such as benzyl chloride and its derivatives, or *n*-alkyl bromides. Substituted alkyl chlorides, such as β-chloroalkyl ethers and 1,2-dichloroethane, reacted very slowly. 2-Bromopropane or 2-bromobutane and *t*-butylamine gave products which were difficult to purify; the corresponding derivatives of *t*-octylamine were obtained in low yield.

The catalytic influence of water was noted in the reactions of II with 1,2-dichloroethane and with 1,2-dibromoethane, for its omission led to complete failure in the former and decreased yield in the latter instance. The effect of water[2] may be due to its behavior as an electrophilic agent in this concerted displacement process.[3]

The action of methyl iodide or dimethyl sulfate on these amines led to a mixture of primary, secondary and tertiary amines (separable by careful fractionation) and quaternary ammonium salts. The use of excess methyl iodide gave the quaternary ammonium derivative of II in good yield.[4]

Both secondary and tertiary amines were also obtained by the reaction of II with ethylene chlorohydrin. In other reactions, the absence (or occasional small yield) of tertiary amines was the result of steric effects which decrease the reactivity of the secondary amines. Under similar conditions, substantial amounts of both secondary and tertiary amines were obtained from the reaction of *n*-butylamine and benzyl chloride. Earlier studies[5] have also indicated the importance of steric factors in the reactions of these amines, although their basicity is comparable to similar, less branched amines.[6]

Efforts were made to force the formation of tertiary amine derivatives of I. The use of excess benzyl chloride followed by slow addition of alkali gave low yields of the desired *t*-butyldibenzylamine. However, similar treatment of II was accompanied by cleavage, and considerable amounts of diisobutylene and tribenzylamine were isolated.

Normal quaternizations giving *t*-octyltrimethylammonium chloride and benzyl-*t*-butyldimethylammonium chloride were carried out. There is some evidence, which is being investigated, that quaternizations of N,N-dialkyl-*t*-octylamines do not always proceed to the expected product.

From the reaction of dichlorodiphenylmethane with *t*-octylamine, N-*t*-octylbenzophenoneimine was prepared in low yield.[7]

No examples of the reaction of *t*-carbinamines with epoxides were found in the literature.[8] Interaction of I or II with ethylene oxide led to secondary and tertiary amines (Table II). Either could be obtained as the principal product by adjustment of the molar ratios of the reactants. Under anhydrous conditions, these reactions proceeded very slowly. Addition of water promoted vigorous and rapid reactions. The water is considered to act as an electrophilic agent which facilitates the opening of the oxirane ring.[9]

Secondary amines were obtained exclusively

(1) Presented in part before the Division of Organic Chemistry at the 119th Meeting of the American Chemical Society, Cleveland, Ohio, April 10, 1951.

(2) W. R. Boon, *J. Chem. Soc.*, 307 (1947).

(3) C. G. Swain and W. P. Langsdorf, Jr., THIS JOURNAL, **73**, 2813 (1951).

(4) N. Kornblum and D. L. Kendall, private communication.

(5) (a) G. Vavon and L. Bourgeois, *Compt. rend.*, **202**, 1593 (1936); (b) O. L. Brady and F. R. Cropper, *J. Chem. Soc.*, 507 (1950); (c) M. Brander, *Rec. trav. chim.*, **37**, 67 (1917).

(6) G. Vexlearschi, *Compt. rend.*, **228**, 1655 (1949).

(7) L. M. Long, C. A. Miller and H. D. Troutman, THIS JOURNAL, **70**, 900 (1948).

(8) That such reactions are not new, however, may be inferred from the description of di-2-chloroethyl-*t*-butylamine, C. E. Redemann, S. W. Chaikin and R. B. Fearing, *ibid.*, **70**, 1648 (1948); *cf.* also E. L. Carpenter, U. S. Patent 2,453,062 (to American Cyanamid Co.).

(9) C. G. Swain, THIS JOURNAL, **72**, 4578 (1950); S. Winstein and R. B. Henderson in R. C. Elderfield, "Heterocyclic Compounds," Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1950, p. 27; L. Schechter, J. Wynstra and R. P. Kurkjy, *Ind. Eng. Chem.*, **48**, 94 (1956).