The Reaction of Chlorodimethyl Ether with Ethanol and with Ethoxide Ions.

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The reaction of chlorodimethyl ether has been studied in ethanol, and in mixtures of ethanol and diethyl ether, with and without added lithium chloride, lithium ethoxide, and other electrolytes. Evidence is presented that the solvolyses are unimolecular, and at least about 10^{14} times faster than the corresponding reaction of methyl chloride; and that the reactions in the presence of ethoxide ions are substantially bimolecular, and some 10^5 times faster than the corresponding reaction of methyl chloride.

Chlorodimethyl ether and its analogues very readily undergo reactions in which the halogen is displaced by a nucleophilic reagent. It is commonly supposed that such reactions are unimolecular (S_N1), since the methoxyl group would be expected to facilitate reaction by this mechanism, through its power of mesomeric release towards the developing carbonium ionic centre. It is not clear, however, whether such an effect might also facilitate bimolecular nucleophilic substitution. Leimu and Salomaa (*Acta Chem. Scand.*, 1947, **1**, 353) have examined the alcoholysis of chlorodimethyl ether and related compounds. In ethanol as solvent, they recorded that the rate, though fast, is measurable, and that the reaction is accelerated by added sodium ethoxide. They concluded that the solvolysis is unimolecular, but that reaction in the presence of added base contains a bimolecular (S_N2) component.

These authors also examined the reactions of α-chloro-ethers with small quantities of ethanol in dioxan. They found that hydrogen chloride catalyses the reaction, and supported a mechanism due to Bohme (*Ber.*, 1941, **74**, 248), whereby catalysis was determined by addition of a proton to the oxygen atom of the chloro-ether :

$$RO{\cdot}CH_2Cl + H^+ \longrightarrow RHO^+{\cdot}CH_2{\cdot}Cl \xrightarrow[ROH]{} RO{\cdot}CH_2{\cdot}OR + H^+ + H^+ + Cl^-$$

In media of such low ionising capacity, however, the formal order of the reaction with respect to added catalysts of this sort is not necessarily a measure of the molecularity of the reaction (cf. Gelles, Hughes, and Ingold, *J.*, 1954, 2918). Salomaa (*Annales Universitatis Turkuensis*, 1953, A, XIV[*]) recently has adopted the view that catalysis by added hydrogen chloride in the alcoholysis of chloro-ethers is in fact the result of a primary salt effect.

The present experiments have been carried out largely with solvents of low ionising

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[*] We are indebted to Dr. Salomaa for drawing our attention to this publication, and for interesting discussions.

capacity, so that the rates should be conveniently measurable. The effects of added ethoxides have been examined in solvents of widely differing ionising power, and have been compared with the effects of other added salts; for further comparison, the reactions of acetyl chloride and of triphenylchloromethane have been studied in outline under the least ionising of the conditions employed.

EXPERIMENTAL

Materials.—Chlorodimethyl ether, prepared from methanol, formaldehyde, and hydrogen chloride, and purified by careful fractional distillation, had b. p. 58·8—59·0°/761 mm., and was almost completely free from dissolved hydrogen chloride. Triphenylchloromethane, recrystallised from benzene, had m. p. 111—112°. Acetyl chloride, purified by fractional distillation, had b. p. 50·8—51·0°/760 mm. 2-Chloroethyl methyl ether, b. p. 93°/758 mm., was prepared as described by Jones and Power (*J. Amer. Chem. Soc.*, 1924, **46**, 2531), and 1-chloroethyl methyl ether, b. p. 70—72°/710 mm., as described by Henze and Murchison (*ibid.*, 1931, **53**, 4077). Ethanol was dried by Manske's method (*ibid.*, p. 1106). Diethyl ether was dried over sodium wire, and distilled, with precautions to avoid the entry of water. A solvent described as " x% " ether refers to a mixture of x ml. of ether and $(100 - x)$ ml. of ethanol, measured at room temperature. Lithium chloride was dried by heating it in a current of dry air. Solutions of the various ethoxides were obtained by dissolving the appropriate metal in the solvent. The radioactive materials and methods have been described elsewhere (de la Mare and Vernon, *J.*, 1954, 2504).

Kinetics.—Conventional methods were used for the kinetic measurements. The following details exemplify the general features. The solvent (*ca.* 60 ml. of 50% ether containing 0·064N-lithium chloride) was brought to thermostat temperature (0·0°) in a volumetric flask. Chlorodimethyl ether was added and, at intervals, samples (5·0 ml.) were pipetted into neutralised acetone which had been cooled to below −50°, and were titrated with 0·0303N-sodium ethoxide in ethanol (lacmoid as indicator). Results were :

Time (min.)	0·38	1·15	2·33	3·80	5·80	9·13	16·07	∞
Titre (ml.)	1·08	2·12	3·68	5·40	7·19	9·86	13·23	17·18
k_1 (min.$^{-1}$)	—	0·093	0·093	0·093	0·089	0·091	0·090	—

Stable end-points were obtained by this technique, and the constancy of the first-order rate-coefficients, illustrated above, was typical of all the solvolytic measurements. Reactions with added ethoxide were followed by pipetting the samples into acetone, cooled to below −50°, to which had been added a small proportion (usually not more than 5% by volume) of standard aqueous hydrochloric acid, in measured amount, in excess of that required to neutralise the ethoxide in the sample, which was then back-titrated with ethanolic sodium ethoxide in the usual way. The results shown in the Tables are, for mutual comparison, given as first-order rate-coefficients, calculated (by the usual formula) on the disappearance of organic chloride. For runs with added ethoxide ion, therefore, since these were of second-order form, the first-order coefficients refer to initial values, obtained by extrapolation to zero time. Rate-coefficients obtained by the above methods are as follows.

In 90% *ether.* (*a*) Chlorodimethyl ether; (i) at 25·0°; 10^4k_1 (sec.$^{-1}$) = 0·69; +0·018M-LiCl, 3·3; +0·25M-LiCl, 19·3; +0·015M-LiOEt, 3·6; +0·022M-LiOEt, 4·8; +0·018M-$LiClO_4$, 2·6; +0·008M-NaOEt, *ca.* 40 (falling); (ii) at 0·0° : 10^4k_1 = 0·089; +0·0066M-$NaClO_4$, 0·25; +0·034M-LiCl, 0·57; +0·020M-NaOEt, 12 (falling); +0·010M-KOEt, 9·5 (falling). (*b*) Acetyl chloride, at 25·0° : (i) 10^4k_1 = 8·8; +0·018M-LiCl, 11·5; (ii) at 0·0°, +0·022M-LiOEt, >150. (*c*) Triphenylchloromethane at 25° : 10^4k_1 = 1·04; +0·25M-LiCl, 1·24; +0·02M-NaOEt, *ca.* 4 (falling). (*d*) 1-Chloroethyl methyl ether : reaction too fast to be measured at 0°.

In 50% *ether.* Chlorodimethyl ether, at 0·0° : 10^4k_1 = 12·3; +0·062M-LiCl, 15·3; +0·106M-LiCl, 16·8; +0·073M-LiOEt, 62 (falling); +0·139M-LiOEt, 127 (falling); +0·068M-NaOEt, 88 (falling).

In ethanol. (*a*) Chlorodimethyl ether, at 0·0° : 10^4k_1 = 142; +0·124M-LiCl, 147; +0·151M-LiOEt, 570 (falling); +0·066M-NaOEt, 450 (falling). (*b*) 2-Chloroethyl methyl ether underwent solvolysis negligibly slowly in this solvent even at 90° : a very slow solvolysis ($k_1 \ngtr 3 \times 10^{-8}$ sec.$^{-1}$) could be detected in 50% aqueous ethanol at the latter temperature.

Subsidiary experiments showed that the product of reaction between chlorodimethyl ether and ethanol in mixtures of diethyl ether and ethanol was that of nucleophilic displacement of chloride; none of the product of the possible reaction $\overset{\curvearrowright}{X^{-}}\ \mathrm{Me{-}\overset{\curvearrowright}{O}{-}CH_2\overset{\curvearrowright}{-}Cl}$ was detected in either the presence or the absence of chloride ions.

The exchange reaction between chlorodimethyl ether and lithium chloride labelled with ^{36}Cl was studied in outline in the following way. Samples were pipetted into cold acetone and brought to neutrality (lacmoid) with standard alkali. The acetone and the chlorodimethyl ether were then evaporated at low temperature; negligible further acidity developed. The specific radioactivity of the lithium chloride residue was then determined in the usual way. The velocity coefficients were determined by the formulæ:

$$k_1 = bk_2 = \frac{2{\cdot}303b}{t(a+b)}\log_{10}\left\{\frac{1}{1 - x(1 + b/a)/c}\right\}$$

Here the symbols have the usual significance (cf. de la Mare, Hughes, Ingold, and Pocker, *J.*, 1954, 2930). The results are in Table 1.

TABLE 1. *Exchange reactions between chlorodimethyl ether and* ^{36}Cl^{-}.

Solvent	Temp.	a	b	t (min.)	Acidity of sample (M)	c	$c - x$	10^4k_1 (sec.$^{-1}$)
90% Ether	0·0°	0·0275	0·0336	3·59	0·00045	176·1	122·8	26
Acetone	−4·5	0·0834	0·0204	3·60	0·00095	93·9	19·3	*ca.* 60,000

Conductance Measurements.—The conductances of some of the electrolytes used in the kinetic measurements were measured at 25° using audio-frequency alternating current and conventional apparatus. The cell-constant was 0·264 cm.$^{-1}$. Measurements were made by successive dilutions of a stock sample of known concentration. Results obtained in ethanol for sodium ethoxide, lithium ethoxide, and lithium chloride were in reasonable accordance with those of the more detailed investigations made by White (*J.*, 1928, 1413), Jones and Hughes (*J.*, 1934, 1197), and Copley, Murray-Rust, and Hartley (*J.*, 1930, 2492). The conductances in 50% ether were measured similarly. Values for the most dilute solutions were obtained in the following way. To the solvent (25 ml., contained in the cell) were added, by means of a carefully calibrated 0·1-ml. graduated pipette, successive portions of *ca.* 0·025N-solutions of the salts in the solvent, and the resistances were measured after each addition. The quoted equivalent conductances of ethoxides are not corrected for the conductance of the solvent, since the self-ionisation of ethanol is repressed in the presence of ethoxide ions. The results are not considered to be sufficiently precise to justify attempted correction for the presence of dissolved impurities; such corrections, discussed by Jones and Hughes (*loc. cit.*), are small except at the highest dilutions.

Conductances at 25° in 50% ether. c *in mole l.*$^{-1}$.

NaOEt. *Solvent,* R = 422,000 *ohms.*

10^4c	811	325	65·0	32·5	12·2	7·68	6·50	3·76	2·78	1·47	0·98
R (Ω)	817	1733	4376	6520	11590	15850	19000	27260	34930	47300	92000
Λ_c	4·0	4·7	9·2	12·2	18·7	21·7	21·4	25·8	27·2	28·3	29·2

LiOEt. *Solvent,* R = 411,000 *ohms.*

10^4c	948	379	75·8	37·9	16·8	11·3	7·60	3·79	2·57	1·30
R (Ω)	1124	2208	5844	8790	13600	17210	21990	34530	44600	72100
Λ_c	2·5	3·1	5·9	7·9	11·6	13·6	15·8	20·2	23·0	28·3

LiCl. *Solvent,* R = 410,000 *ohms.*

10^4c	743	149	37·1
R (Ω)	469	1387	3314
Λ_c	7·6	12·8	21·5

The following are the results for the resistances of a 0·005N-solution of sodium ethoxide in ether containing different proportions of ethanol at 25°:

Ethanol (%)	10	13·5	19·6	25·0	30	43·5
Resistance (ohms) ...	3,260,000	1,000,000	210,000	76,200	28,530	7880

The very rapid decrease in conductance with decreasing proportion of ethanol probably results largely from a decrease in the energy of solvation, and consequent increase in ion-pair formation, combined with a decrease in the equivalent conductance at infinite dilution. Ionisation of the electrolytes is very small when the solvent contains less than 30% of ethanol, though these values are likely to be inaccurate because alternating-current methods are not suitable for the precise measurement of such high resistances.

In estimating the limiting slope expected on the Onsager theory for 50% ether, the dielectric constant is assumed to be 13·6 (cf. King and Patrick, *J. Amer. Chem. Soc.*, 1921, **43**, 1835), and the viscosity is taken as 0·00472 c.g.s. unit. The latter was determined by using a conventional Ostwald viscometer, with ethanol (viscosity assumed to be 0·108 c.g.s. unit) as a standard of reference. The value obtained similarly for ether (0·00263 c.g.s. unit) is in good agreement with accepted values.

DISCUSSION

The Effect of the Methoxyl Group on Reactivity by the S_N1 Mechanism.—Although the solvolysis of chlorodimethyl ether in pure ethanol is very rapid, it is not too fast to be measured. The rate-coefficient, obtained in the present investigation ($10^4k_1 = 142$ sec.$^{-1}$ at 0·0°) by following the production of acid, is in good agreement with that ($10^4k_1 = 152$ sec.$^{-1}$) derived by a short extrapolation of Leimu and Salomaa's data (*loc. cit.*); the latter value was obtained by following the unchanged chlorodimethyl ether, titrated as formaldehyde after alkaline hydrolysis. The increased rate observed in the presence of added base is small when compared with the magnitude of the increase expected when reaction with the solvent is bimolecular (cf. Hughes, Ingold, Masterman, and McNulty, *J.*, 1940, 899), so it can be concluded with confidence that the sovolysis is essentially unimolecular.

The rate of ethanolysis of chlorodimethyl ether is considerably reduced when the solvent is changed to 50% ether ($10^4k_1 = 12·3$ sec.$^{-1}$ at 0·0°) and to 90% ether ($10^4k_1 = 0·089$ sec.$^{-1}$ at 0·0°). Application of the same type of criterion as was used for the work in ethanol as solvent determines that in the less ionising solvents the solvolyses are unimolecular also. For the solvent containing 90% of ether, conductance measurements indicate that added electrolytes exist almost entirely as ion-pairs; as a check, therefore, the effect of added base on the rate of solvolysis of acetyl chloride was measured also, since this compound would be expected to react by a second-order (presumably bimolecular) process (cf. Brown and Hudson, *J.*, 1953, 3352) in the presence of an effective nucleophilic reagent. Added lithium ethoxide very powerfully accelerated the sovolysis of acetyl chloride; it accelerated the solvolysis of chlorodimethyl ether only by a relatively small factor, and hardly had any effect on the rate of solvolysis of triphenylchloromethane. Hence it is considered that the solvolyses of the last two compounds are unimolecular even in 90% ether. On this basis, comparison of the reactivity of chlorodimethyl ether and triphenylchloromethane shows that the methoxyl substituent, in its power of facilitating heterolysis of the C–Cl system, is roughly equivalent to three phenyl groups. It is, of course, very much more effective than three methyl groups; *tert.*-butyl chloride undergoes solvolysis in ethanol at 44·6° with a velocity coefficient of $1·33 \times 10^{-6}$ sec.$^{-1}$ (de la Mare and Vernon, unpublished measurements), some 5×10^6 times less rapidly than chlorodimethyl ether ($k_1 = 0·7$ sec.$^{-1}$ at 44·6°, by extrapolation of Leimu and Salomaa's data).

Further structural comparisons of some interest can be made indirectly. The rates of S_N1 solvolyses of other compounds (cf. de la Mare and Vernon, *J.*, 1954, 2504) are usually increased by a factor of about 5×10^3 by change from ethanol to 50% aqueous ethanol. The rate of solvolysis of chlorodimethyl ether in 50% aqueous ethanol would on this basis be about 71 sec.$^{-1}$ at 0°, and about $0·5 \times 10^7$ sec.$^{-1}$ at 90°. The rate of solvolysis of 2-chloroethyl methyl ether at 90° is certainly not greater than about 10^{-7} sec.$^{-1}$ (cf. Experimental section), and hence the α-, as compared with the β-methoxyl substituent, has increased the rate of solvolysis by a factor of between 10^{13} and 10^{14} or thereabouts.* Similarly, since chlorodimethyl ether is about 7×10^4 times more reactive in ethanol than 3 : 3-dimethylallyl chloride, which itself is some 4×10^8 times more reactive than *n*-propyl chloride (de la Mare and Vernon, *loc. cit.*; Vernon, *J.*, 1954, 423), it may be concluded that

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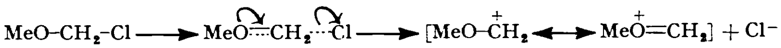
* "Neighbouring-group" participation of the β-hydroxyl substituent is regarded by Winstein (*Bull. Soc. chim., France*, 1951, **18**, 55) as providing only about 1 kcal./mole of "driving force" for the solvolyes of such compounds.

chlorodimethyl ether is probably at least 10^{13} times more reactive than *n*-propyl chloride, and hence (cf. Bateman and Hughes, *J.*, 1940, 945) probably 10^{14} times more reactive, by the S_N1 mechanism, than methyl chloride.

The extremely large effect of the α-methoxyl substituent must be attributed to conjugation of the group with the developing carbonium ionic centre, and may be represented :



$$\mathrm{MeO{-}CH_2{-}Cl} \longrightarrow \mathrm{MeO{\cdots}CH_2{\cdots}Cl} \longrightarrow [\mathrm{MeO{-}\overset{+}{C}H_2} \longleftrightarrow \mathrm{Me\overset{+}{O}{=}CH_2}] + \mathrm{Cl^-}$$

The following structural comparisons concerning the unimolecular reactions of chloro-ethers can now be made, using results of the present investigation in conjunction with those obtained by Leimu and Salomaa (*loc. cit.*) and by Salomaa (*loc. cit.*) :

Compound	$\mathrm{MeO{\cdot}CHMeCl}$	$\mathrm{Me{\cdot}CH_2{\cdot}O{\cdot}CH_2Cl}$	$\mathrm{MeO{\cdot}CH_2Cl}$	$\mathrm{EtO{\cdot}CH_2{\cdot}O{\cdot}CH_2Cl}$	$\mathrm{(CH_2Cl)_2O}$
Rel. rate of solv....	>100	3	1	0·003 *	0·0001

Introduction of a second electron-donating group (the methyl group) directly on the reacting carbon atom increases reactivity so much that the rate of solvolysis cannot be measured at 0°, even in 90% ether. When introduced into the methoxyl substituent, the methyl group increases, whereas ethoxyl or chlorine considerably reduces, the rate of unimolecular solvolysis. Presumably these groups act by altering inductively the availability of the lone pair of electrons on the oxygen atom of the activating substituent. Similar effects, though rather smaller, have been recorded by Bradfield, Brynmor Jones, and their co-workers (cf. Bradfield, *Trans. Faraday Soc.*, 1941, **37**, 726) for the activating influences in aromatic halogenation of substituted methoxyl groups.

Salt Effects in the Unimolecular Solvolysis of Chlorodimethyl Ether.—Unimolecular solvolyses are facilitated by increase in the ionising power of the environment, so increase in the ionic strength of the solution should increase the rate of the reaction : this is in accordance with the observations. The magnitude of the influence of added salts would be expected to increase as the dielectric constant and ionising power of the solvent diminished, and the following results illustrate this point :

Solvent	Ethanol	50% Ether	90% Ether
Dielectric constant	23·0	13·6 †	6·0 †
Equivalent conductance ($\Lambda_{0\cdot016}$)	24·5	6·0	~0·01
Rate of solvolysis of chlorodimethyl ether, in the presence of 0·02N-lithium chloride, relative to rate in the absence of added salt	1·01	1·08	5·1

The effect of added lithium or sodium perchlorate on the rate in 90% ether is of the same order of magnitude as that found for lithium chloride.

Although the rate of solvolysis of chlorodimethyl ether in 90% ether increases linearly and rapidly with the lithium chloride concentration, it would be incorrect to conclude that, in the lithium chloride-catalysed solvolysis, either the chloride or the lithium ion participated covalently in the rate-determining process. The influence of these ions is, in our view, essentially a matter of ion-atmosphere stabilisation of the transition state, and is particularly large in the present instance, because of the low ionising power of the solvent.‡ A similar consideration applies to the effect of added hydrogen chloride, investigated by Leimu and Salomaa and by Böhme (*locc. cit.*) in similar solvents. In these cases also, the influence of hydrogen chloride may be the result of a primary salt-effect, or could be the result of electrophilic catalysis of the heterolysis of the C–Cl bond (cf. Gelles, Hughes, and Ingold, *loc. cit.*). The special interpretation, proposed by Böhme (*loc. cit.*), which makes catalysis depend on attachment of the proton to the oxygen atom of the methoxyl group,

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* Estimated by Salomaa (*loc. cit.*) from the rate of release of the second chlorine atom in the ethanolysis of bischloromethyl ether.

† Estimated from the dielectric constant of ether (4·2 ; International Critical Tables).

‡ The structure of the cationic intermediate is also of importance. The solvolysis of triphenylchloromethane is accelerated much less powerfully than that of chlorodimethyl ether, as may be explained by the relatively large size of the triphenylmethyl cation, since dispersion of charge over such a large volume must considerably reduce the forces of solvation.

is unnecessary.* It is, of course, theoretically likely that attachment of a proton would inhibit, rather than catalyse, the heterolysis of the C–Cl bond.

Bimolecular Reactions of Chlorodimethyl Ether.—Leimu and Salomaa (*loc. cit.*) concluded that, in ethanol, added sodium ethoxide increases the rate of reaction of chlorodimethyl ether through the incursion of a bimolecular (S_N2) reaction. The experiments recorded above are in agreement with this view. Although the rates are rather too fast for accurate measurement, it is clear that lithium chloride, which from its conductance appears to be more dissociated than lithium ethoxide, has very little influence on the rate of the solvolysis, whereas both lithium and sodium ethoxide increase the rate of the reaction considerably.

Similar conclusions can be reached from consideration of the results obtained by using 50% ether as solvent. Rates therein were more conveniently measurable, and variation in the concentration of lithium ethoxide proved the second-order character of the reaction.

The annexed Table gives second-order rate-coefficients, obtained by calculating as first-order coefficients the rate of disappearance of chlorodimethyl ether, extrapolating these rates to zero reaction, subtracting the rate of the concomitant solvolysis, and dividing by the initial concentration of ethoxide :

Second-order rate-coefficients for reactions of chlorodimethyl ether with ethoxides.

Solvent	Ethanol	50% Ether	90% Ether
k_2 (NaOEt, 0·0°; l. mole^{-1} sec.$^{-1}$)	0·47	0·11	0·06
k_2 (LiOEt, 0·0°; l. mole^{-1} sec.$^{-1}$)	0·30	0·07	Very small

Bimolecular reactions between ions and neutral molecules are usually faster in a less ionising solvent. Vernon (*loc. cit.*), however, showed that for allylic chlorides, the change in rate with solvent is often in the opposite direction. He associates this behaviour with an abnormally high polarity of the transition state, resulting essentially from mesomeric release of electrons from the vinyl substituent. The methoxyl group is electronically similar, and releases electrons very much more powerfully. An abnormal solvent effect might, therefore, be expected also in the case of chlorodimethyl ether.

There is another factor which deserves consideration in this connection, namely, the effect that could be attributed following such treatments as that of Evans and Sugden (*J.*, 1949, 270) to incomplete dissociation of the electrolytes. The results of Copley *et al.* (*loc. cit.*) for the conductances of very dilute solutions of sodium ethoxide in ethanol show small negative deviations from the slope required by the Onsager theory. Such deviations have been interpreted (cf. Ogston, *Trans. Faraday Soc.*, **1936**, **32**, 1679) as resulting from ion-pair formation; for this electrolyte in this solvent the effect seems to be rather small. Lithium ethoxide, however, gives consistently greater deviations from the Onsager theory (cf. Jones and Hughes, *loc. cit.*), and this, taken in conjunction with the consistently lower second-order rate-coefficients observed with this salt, suggests that at least a part of these differences may be attributed to incomplete dissociation of lithium ethoxide.

Our results suggest that the situation is very similar in 50% ether. The results for sodium ethoxide suggest that the initial slope of the plot of Λ_c against $c^{\frac{1}{2}}$ is not considerably greater than that required by the Onsager theory ($\Lambda_c = \Lambda_0 - 383c^{\frac{1}{2}}$, on the assumptions given above). Hence sodium ethoxide is probably not much more associated in this solvent than in ethanol.

It is concluded, therefore, that the results in the Table may exaggerate the effect of the solvent on the observed second-order rate coefficients, but that correction for incomplete

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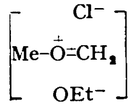
* It should be noted also that changes in the rate of reaction which depend on changes in the proportion of a reactive and relatively ionising species (*e.g.*, ethanol) added to a relatively non-ionising solvent cannot be treated satisfactorily by calculating the apparent order of the reaction with respect to the ionising component from the change in rate with concentration of the latter. Such changes in rate are properly to be considered as effects resulting from changes in the medium, and are not necessarily a reflection of the number of molecules of the reactive component participating through covalency changes in the transition state.

dissociation would probably not alter the direction of change, namely, decrease in rate with decreasing ionising power.

The measurements of conductance in 90% ether suggest that the electrolytes under these conditions must exist very largely as uncharged species. Indeed, it is questionable whether in this solvent the solutes are behaving as electrolytes at all; their observed influences on the rates of reaction may arise essentially from dipolar interactions between the reactants and ion-pairs or neutral molecules. The specific influences of different ethoxides could also result from bimolecular reactions involving these formally uncharged species, or from electrophilic catalysis of the heterolysis.

The Effect of the Methoxyl Group on Reactivity by the S_N2 Mechanism.—Vernon (*loc. cit.*) measured the rate and activation energy for the reaction of *n*-propyl chloride with ethoxide ions in ethanol. Extrapolation to 0° gives a rate coefficient of $k_2 = 2{\cdot}4 \times 10^{-8}$ l. mole^{-1} sec.$^{-1}$. Methyl chloride would be expected to react about a hundred times faster than *n*-propyl chloride under these conditions (cf. Dostrovsky and Hughes, *J.*, 1946, 157). Hence chlorodimethyl ether must be rather more than 10^5 times more reactive than methyl chloride by the S_N2 mechanism.

Although the effect of the methoxyl group is in this case much smaller than that of the same group in the S_N1 mechanism, it is still very considerable and requires discussion. The effects of substituents on the rates of bimolecular substitution are difficult to predict in any specific case, since electron-release facilitates breaking of the C–Cl bond but inhibits attack by a nucleophilic reagent. There is some evidence, however, that groups which have their influence on the rate mainly through conjugative, rather than inductive, processes, generally facilitate bimolecular reactions of this type. Hughes, Ingold, and Shapiro (*J.*, 1936, 225) discussed this matter in relation to the effect of the phenyl substituent, and more recently Vernon (*loc. cit.*) has discussed the effect of the α-vinyl group in accelerating the rate of bimolecular nucleophilic substitution. The conjugative power of the methoxyl group is, as has been observed above, much greater than that of the vinyl substituent, and hence the former group has a considerable influence on the rate of bimolecular substitution. In the valence-bond representation, the annexed structure contributes to the transition state for the bimolecular reaction of chlorodimethyl ether; no similar structure of corresponding importance can be written for methyl chloride.



$$\left[\begin{array}{c}\text{Cl}^-\\ \text{Me}-\overset{+}{\text{O}}=\text{CH}_2\\ \text{OEt}^-\end{array}\right]$$

The exchange reactions between chlorodimethyl ether and chloride ion have been investigated only in outline. Reaction in acetone was almost, but not quite, complete in 3·6 min., and an estimate of the rate-coefficient indicates that chlorodimethyl ether is more reactive than methyl chloride (de la Mare, *J.*, 1955, 3169) in this solvent by a factor of 10^5. As this estimate accords with the value indicated above for reaction with ethoxide ion, the presumption is that the exchange reaction is bimolecular in this solvent, and it seems likely that this could be tested by kinetic measurements at lower temperatures. The exchange in 90% ether is much faster than the accompanying solvolysis, and therefore also may be bimolecular, but in this solvent a kinetic test would probably be difficult to interpret, since the salt is scarcely dissociated under these conditions if measurements of conductance can be taken as a guide.

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