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NOVEL OXYGEN EXCHANGE REACTION OF SULFOXIDES IN ALKALINE MEDIA (1)

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During the course of our study on the mechanism of the formation of o-methylmercaptophenol and o-methylmercaptophenyl phenyl ether in the reaction of bromobenzene with potassium t-butoxide in dimethyl sulfoxide (2), we have found that these methylmercapto compounds were incorporated with an excess of ^{18}O when potassium t-butoxide ^{18}O-labeled was used. This observation can be explained if one assumes that a novel oxygen exchange reaction takes place between dimethyl sulfoxide and potassium t-butoxide before dimethyl sulfoxide is added to benzyne. In fact, when dimethyl sulfoxide was refluxed with potassium t-butoxide-^{18}O for ten minutes under nitrogen stream, and purified through fractional distillation, it was found to be incorporated with an excess of ^{18}O and its ^{18}O concentration was shown to be nearly identical to that expected from the complete scrambling of ^{18}O between dimethyl sulfoxide and t-butoxide. The results are shown in Table I.

Other sulfoxides such as di-(n-butyl), p-tolyl methyl and diphenyl sulfoxides were also found to undergo oxygen exchange reaction in the presence of potassium tert-butoxide, as shown in Table II. But in a large excess of tert-butanol no oxygen exchange reaction was found between sulfoxides and tert-butoxide.

TABLE I*

Oxygen Exchange Reaction of Dimethyl Sulfoxide with Potassium tert-Butoxide

Compounds	Excess ^{18}O-concentration (atom%) starting compounds	 recovered compounds
t-BuOK (as t-BuOH)	1.24	
DMSO	0.00	0.21
(calcd)**	0.00	0.21

* Dimethyl sulfoxide, 0.09 mole was reacted with 0.018 mole of potassium tert-butoxide, namely, the mole ratio was 5 : 1.

** The calculated value is given by the equation $1.24/6 = 0.21$.

However, the oxygen exchange reaction was usually not as facile as that with dimethyl sulfoxide and sometimes other side reactions prevailed, especially with diphenyl and di-(n-butyl) sulfoxides. Namely, the major reaction with diphenyl sulfoxide was the aromatic nuclophilic substitution, while E_2 reaction was the main path for the reaction with di-(n-butyl) sulfoxide. However, the fact that this novel oxygen exchange was not confined to the sulfoxides bearing methylene groups is important, since it indicates that the reaction involves a nucleophilic replacement on the sulfur atom of the sulfoxide group.

Sodium hydroxide was also found to undergo oxygen exchange with dimethyl sulfoxide, when 0.025 mole of dimethyl sulfoxide was refluxed in 4 gr. of methanol containing 0.025 mole of $Na^{18}OH$ for five hours in a sealed tube at 150°C. The results are shown in Table III.

TABLE II*

Oxygen Exchange Reaction of some Sulfoxides with Potassium tert-Butoxide

Sulfoxides	Sulfoxides/t-BuOK (mole ratio)	Conditions °C	hr	Excess ^{18}O-concentration (atom%) starting compounds	recovered compounds
$C_6H_5SOC_6H_5$	2.5	130	1	0.00	0.05
$C_6H_5SOC_6H_5$	2.5	160	1	0.00	0.08
n-BuSOBu-n	2	100	1	0.00	0.08
t-Bu^{18}OK				0.81	
p-$CH_3C_6H_4SO^{18}CH_3$**	5 (in DMSO)	150	25	1.05	0.87***
p-$CH_3C_6H_4SO^{18}CH_3$	- (in DMSO)	150	25	1.05	1.03

* The amounts of ^{18}O exchange of both diphenyl and dibutyl sulfoxides were estimated by measuring the incorporation of heavy oxygen from potassium tert-butoxide-^{18}O, while that of p-tolylmethylsulfoxide was determined by the loss of heavy oxygen from the ^{18}O labeled starting compound.

** p-Tolyl methyl sulfoxide-^{18}O was synthesized following the procedure described in the literature (3).

*** In this case, a large excess of dimethyl sulfoxide was used as the solvent, which was found in a separate experiment not to undergo oxygen exchange reaction with this particular sulfoxide in the same condition. Dibenzyl sulfoxide, however, was found to undergo oxygen exchange reaction with dimethyl sulfoxide. The nature of this and similar oxygen exchange will be dealt separately.

TABLE III*

Oxygen Exchange between Sulfoxides and Sodium or Potassium Hydroxide in Methanol or Water

Compounds	Excess ^{18}O-concentration (atom%) starting compounds	recovered compounds
CH_3SOCH_3**	0.00	0.10
CH_3SOCH_3***	0.00	0.32
p-$CH_3C_6H_4$-SO^{18}-CH_3****	1.16	1.16

* This reaction was carried out at 150°C for 5 hrs in sealed tube.

** Sulfoxide, 0.025 mole was dissolved in 4 gr. of methanol containing 0.025 mole of sodium hydroxide -^{18}O (1.40 atom%).

*** Sulfoxide, 0.025 mole was dissolved in 0.2 mole of heavy oxygen water (1.93 atom%) containing 0.03 mole of potassium hydroxide.

**** Sulfoxide, 0.002 mole was dissolved in 3 gr. of methanol solution containing 0.002 mole of potassium hydroxide and 0.2 mole of water.

Diphenyl and dibenzyl sulfoxides were found to undergo oxygen exchange reaction very little under the same condition, as we have previously observed (4b). Apparently the oxygen exchange reaction of dimethyl sulfoxide is more facile with potassium t-butoxide than with sodium hydroxide. Since potassium t-butoxide is a stronger base than sodium hydroxide, the nucleophilic attack of t-butoxide ion on the sulfur atom of sulfoxide group would be more facile than that of hydroxide ion.

Although the detailed mechanistic interpretation of the oxygen exchange reaction has to await further extensive investigation that is now underway in these laboratories, the possibility of the nucleophilic attack of alkoxide is quite significant in the mechanistic interpretation of a few well-known reactions between alcohols and dimethyl sulfoxide. Both the formation of benzaldehyde in the oxidation of benzyl alcohol with boiling dimethyl sulfoxide (5) and the dehydration of 1-alkylcyclohexanol in refluxing dimethyl sulfoxide (6), may be explained on the basis of the nucleophilic attack of alkoxy group on the sulfur atom of dimethyl sulfoxide .

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