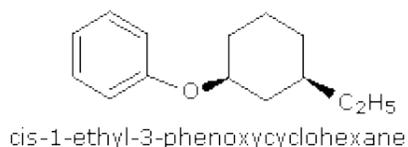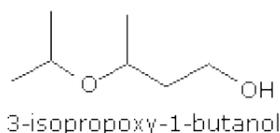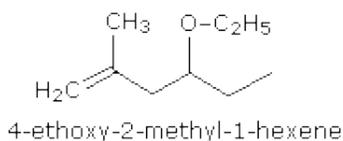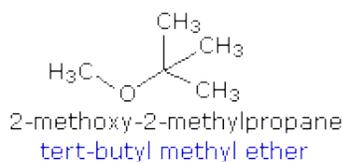# The Chemistry of Ethers

1. Nomenclature

Ethers are compounds having two alkyl or aryl groups bonded to an oxygen atom, as in the formula R^1–O–R^2. The ether functional group does not have a characteristic IUPAC nomenclature suffix, so it is necessary to designate it as a substituent. To do so the common alkoxy substituents are given names derived from their alkyl component, as shown in the table on the right below. Examples of ether nomenclature are provided on the left. Simple ethers are given common names in which the alkyl groups bonded to the oxygen are named in alphabetical order followed by the word "ether". The top left example shows the common name in blue under the IUPAC name. Many simple ethers are symmetrical, in that the two alkyl substituents are the same. These are named as "dialkyl ethers". Examples are: $CH_3CH_2OCH_2CH_3$, diethyl ether (sometimes referred to as ether), and $CH_3OCH_2CH_2OCH_3$, ethylene glycol dimethyl ether (glyme).

CH3
CH3
H3C
O
CH3
2-methoxy-2-methylpropane
tert-butyl methyl ether

CH3 O–C2H5
H2C
4-ethoxy-2-methyl-1-hexene

O
OH
3-isopropoxy-1-butanol

O
C2H5
cis-1-ethyl-3-phenoxycyclohexane

Alkyl Group	Name	Alkoxy Group	Name
CH_3–	Methyl	CH_3O–	Methoxy
CH_3CH_2–	Ethyl	CH_3CH_2O–	Ethoxy
$(CH_3)_2CH$–	Isopropyl	$(CH_3)_2CHO$–	Isopropoxy
$(CH_3)_3C$–	tert-Butyl	$(CH_3)_3CO$–	tert-Butoxy
C_6H_5–	Phenyl	C_6H_5O–	Phenoxy

Sulfur analogs of ethers (R–S–R') are called **sulfides**. For example, $(CH_3)_3C$–S–CH_3 is tert-butyl methyl sulfide. Sulfides are chemically more reactive than ethers, reflecting the greater nucleophilicity of sulfur relative to oxygen.
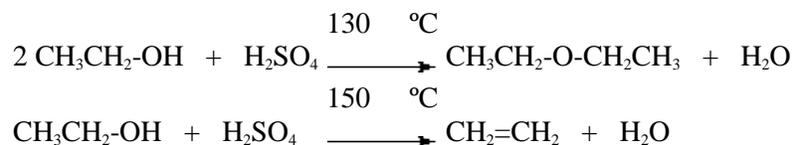
2. Preparation of Ethers

Ethers are usually prepared from alcohols or their conjugate bases. One important procedure, known as the **Williamson Ether Synthesis**, proceeds by an S_N2 reaction of an alkoxide nucleophile with an alkyl halide. Reactions #1 and #2 below are two examples of this procedure. When applied to an unsymmetrical ether, as in this case, there are two different combinations of reactants are possible. Of these one is usually better than the other. Since alkoxide anions are strong bases, the possibility of a competing E2 elimination must always be considered. Bearing in mind the factors that favor substitution over elimination, a 1º-alkyl halide should be selected as a preferred reactant whenever possible. Thus, reaction #1 gives a better and cleaner yield of benzyl isopropyl ether than does reaction #2, which generates considerable elimination product.
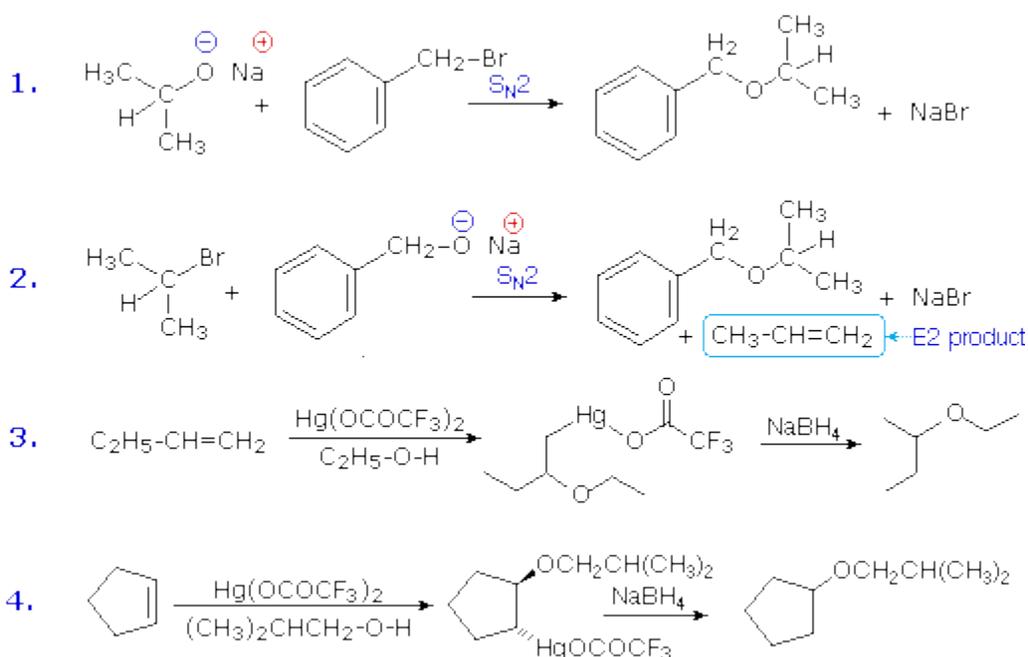

A second general ether synthesis, **alkoxymercuration**, is patterned after the oxymercuration reaction. Reactions #3 and #4 are examples of this two-step procedure. Note that the alcohol reactant is used as the solvent, and a trifluoroacetate mercury (II) salt is used in preference to the acetate (trifluoroacetate anion is a poorer nucleophile than acetate). The mechanism of alkoxymercuration is similar to that of oxymercuration, with an initial anti-addition of the mercuric species and alcohol being followed by reductive demercuration.

Acid-catalyzed dehydration of small 1º-alcohols constitutes a specialized method of preparing symmetrical ethers. As shown in the following two equations, the success of this procedure depends on the temperature. At 110º to 130 ºC an S_N2 reaction of the alcohol conjugate acid leads to an ether product. At higher temperatures (over 150 ºC) an E2 elimination takes place.

$$2\ CH_3CH_2\text{-}OH\ +\ H_2SO_4\ \xrightarrow[\ ]{130\quad °C}\ CH_3CH_2\text{-}O\text{-}CH_2CH_3\ +\ H_2O$$

$$CH_3CH_2\text{-}OH\ +\ H_2SO_4\ \xrightarrow[\ ]{150\quad °C}\ CH_2=CH_2\ +\ H_2O$$
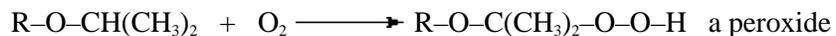
3. Reactions of Ethers

Ethers are widely used as solvents for a variety of organic compounds and reactions, suggesting that they are relatively unreactive themselves. Indeed, with the exception of the alkanes, cycloalkanes and fluorocarbons, ethers are probably the least reactive, common class of organic compounds. The inert nature of the ethers relative to the alcohols is undoubtedly due to the absence of the reactive O–H bond. The most common reaction of ethers is cleavage of the C–O bond by strong acids. This may occur by S_N1 or E1 mechanisms for 3^0-alkyl groups or by an S_N2 mechanism for 1^0-alkyl groups. Some examples are shown in the following diagram. The conjugate acid of the ether is an intermediate in all these reactions, just as conjugate acids were intermediates in certain alcohol reactions.
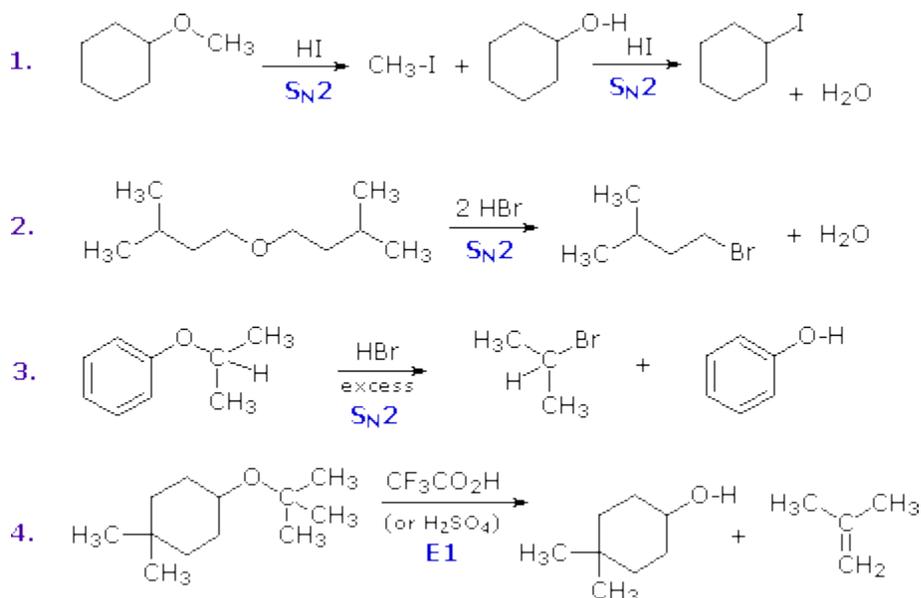
The first two reactions proceed by a sequence of S_N2 steps in which the iodide or bromide anion displaces an alcohol in the first step, and then converts the conjugate acid of that alcohol to an alkyl halide in the second. Since S_N2 reactions are favored at least hindered sites, the methyl group in example #1 is cleaved first. The 2^0-alkyl group in example #3 is probably cleaved by an S_N2 mechanism, but the S_N1 alternative cannot be ruled out. The phenol formed in this reaction does not react further, since S_N2, S_N1 and E1 reactions do not take place on aromatic rings. The last example shows the cleavage of a 3^0-alkyl group by a strong acid. Acids having poorly nucleophilic conjugate bases are often chosen for this

purpose so that E1 products are favored. The reaction shown here (#4) is the reverse of the tert-butyl ether preparation described earlier.

Ethers in which oxygen is bonded to 1º- and 2º-alkyl groups are subject to peroxide formation in the presence of air (gaseous oxygen). This reaction presents an additional hazard to the use of these flammable solvents, since peroxides decompose explosively when heated or struck. The mechanism of peroxide formation is believed to be free radical in nature (note that molecular oxygen has two unpaired electrons).

$$R–O–CH(CH_3)_2 \ + \ O_2 \longrightarrow R–O–C(CH_3)_2–O–O–H \quad \text{a peroxide}$$