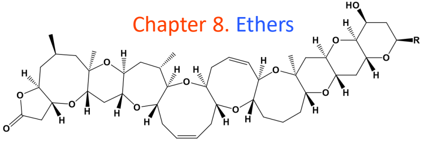
Organic chemistry for nonmajor students Chem 233

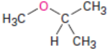
Chapter 8. Ethers



Brevatoxin A

8.1 Nomenclature of Ethers

Names of simple of Ethers



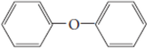
Isopropyl methyl ether

$CH_3CH_2{-}O{-}CH_3$

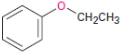
ethyl methyl ether

$CH_3CH_2{-}O{-}CH_2CH_3$

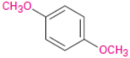
diethyl ether (the prefix *di-* is sometimes omitted)



diphenyl ether



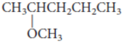
Ethyl phenyl ether



p-Dimethoxybenzene

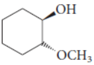
Ethers with more complex structures

For ethers with more complex structures, it may be necessary to name the OR group as an alkoxy group. In the IUPAC system, the smaller alkoxy group is named as a substituent.

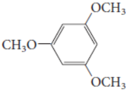


$$\underset{\displaystyle OCH_3}{CH_3\underset{|}{C}HCH_2CH_2CH_3}$$

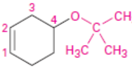
2-methoxypentane



trans-2-methoxycyclohexanol

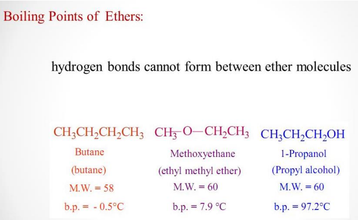


1,3,5-trimethoxybenzene



4-*tert*-Butoxy-1-cyclohexene

8.2 Physical Properties of Ethers



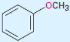
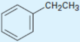
Boiling Points of Ethers:

hydrogen bonds cannot form between ether molecules

$CH_3CH_2CH_2CH_3$	$CH_3{-}O{-}CH_2CH_3$	$CH_3CH_2CH_2OH$
Butane	Methoxyethane	1-Propanol
(butane)	(ethyl methyl ether)	(Propyl alcohol)
M.W. = 58	M.W. = 60	M.W. = 60
b.p. = - 0.5°C	b.p. = 7.9 °C	b.p. = 97.2°C

The boiling points of ethers

The electronegative oxygen atom gives ethers a slight dipole moment, and the boiling points of ethers are often slightly higher than the boiling points of comparable alkanes.

Ether	**Boiling point °C**	**Hydrocarbon**	**Boiling point °C**
CH_3OCH_3	−25	$CH_3CH_2CH_3$	−45
$CH_3CH_2OCH_2CH_3$	34.6	$CH_3CH_2CH_2CH_2CH_3$	36
	65		49
	158		136

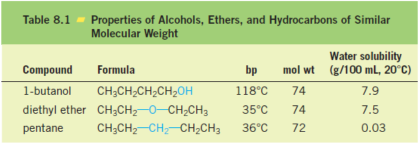
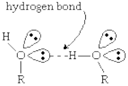
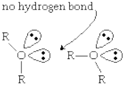


Table 8.1 ▰ **Properties of Alcohols, Ethers, and Hydrocarbons of Similar Molecular Weight**

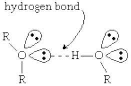
Compound	**Formula**	**bp**	**mol wt**	**Water solubility (g/100 mL, 20°C)**
1-butanol	$CH_3CH_2CH_2CH_2OH$	118°C	74	7.9
diethyl ether	$CH_3CH_2—O—CH_2CH_3$	35°C	74	7.5
pentane	$CH_3CH_2—CH_2—CH_2CH_3$	36°C	72	0.03



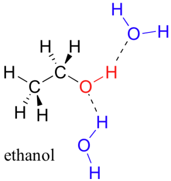
an alcohol



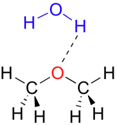
an ether



ether + alcohol



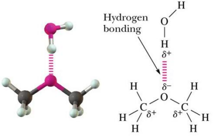
ethanol



dimethylether

Solubility of Ethers:

Ethers are soluble in water, due to their hydrogen bond formation with water molecules.



The solubility decreases with increase in the number of carbon atoms.

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Chem 233

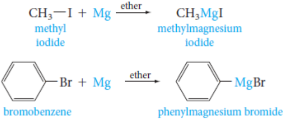
8.4 The Grignard Reagent; an Organometallic Compound

$$\underset{(X = \mathrm{Cl, Br, or\ I})}{R{-}X} + \mathrm{Mg} \xrightarrow{CH_3CH_2OCH_2CH_3} \overset{\delta-}{R}{-}\overset{\delta+}{\mathrm{Mg}}{-}X \quad \text{reacts like } R{:}^{-}\ \overset{+}{\mathrm{Mg}}X$$

organomagnesium halide
(Grignard reagent)

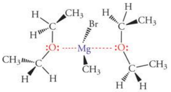
- Formula R—Mg—X (reacts like $R{:}^{-}$ ^{+}MgX).
- Ethers are used as solvents to stabilize the complex.
- Iodides are most reactive.
- May be formed from <u>any</u> halide.

Grignard Reagent



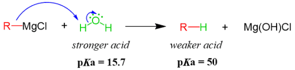
$$CH_3{-}I + Mg \xrightarrow{\text{ether}} CH_3MgI$$

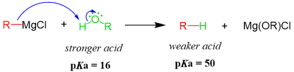
Why the ether used as a solvent for the Grignard



Ethers are used as solvents to stabilize the complex.

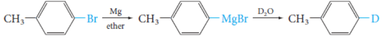
Grignard reagents are strong bases and are 'killed' by protic molecules



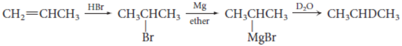


This is why the ether used as a solvent for the Grignard reagent must be scrupulously free of water or alcohol.

Deuteration of Grignard reagent

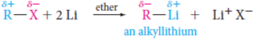


p-bromotoluene *p*-tolylmagnesium bromide *p*-deuteriotoluene



$$CH_2{=}CHCH_3 \xrightarrow{HBr} \underset{\displaystyle Br}{CH_3CHCH_3} \xrightarrow[ether]{Mg} \underset{\displaystyle MgBr}{CH_3CHCH_3} \xrightarrow{D_2O} CH_3CHDCH_3$$

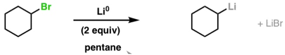
Alkyllithium reagents



$$\overset{\delta+}{R}-\overset{\delta-}{X} + 2\,Li \xrightarrow{\text{ether}} \overset{\delta-}{R}-\overset{\delta+}{Li} + Li^{+}X^{-}$$

an alkyllithium

Example #2



8.5 Preparation of Ethers

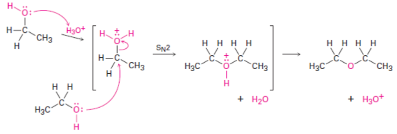
Commercial preparation of diethyl ether

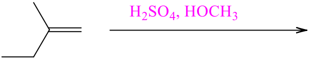
The most important commercial ether is diethyl ether. It is prepared from ethanol and sulfuric acid.

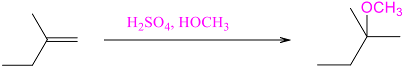
$$\underset{\text{ethanol}}{CH_3CH_2OH + HOCH_2CH_3} \xrightarrow[140^\circ C]{H_2SO_4} \underset{\text{diethyl ether}}{CH_3CH_2OCH_2CH_3} + H_2O$$

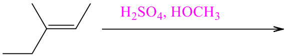
The mechanism of acid–catalyzed diethyl ether

The reaction occurs by S_N2 displacement of water from a protonated ethanol molecule by the oxygen atom of a second ethanol.

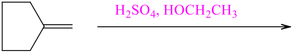


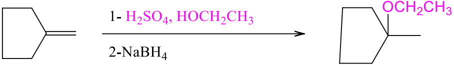

H_2SO_4, $HOCH_3$

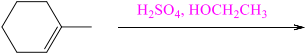

H_2SO_4, $HOCH_3$
OCH_3

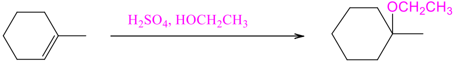

H_2SO_4, $HOCH_3$


H_2SO_4, $HOCH_3$
OCH_3

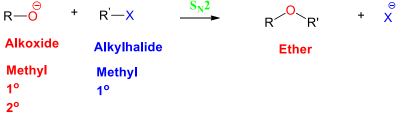

H_2SO_4, $HOCH_2CH_3$


1- H_2SO_4, $HOCH_2CH_3$
2-$NaBH_4$
OCH_2CH_3


H_2SO_4, $HOCH_2CH_3$


H_2SO_4, $HOCH_2CH_3$
OCH_2CH_3

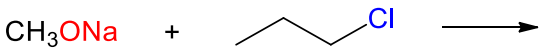
The Williamson Ether Synthesis

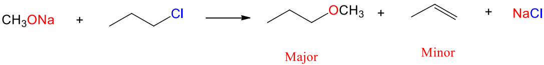


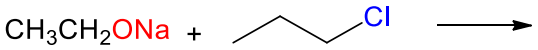
Alkoxide	Alkylhalide	Ether
Methyl	Methyl	
1°	1°	
2°		

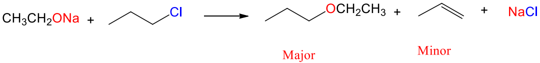
Alkylhalide

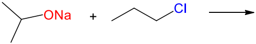
Ether

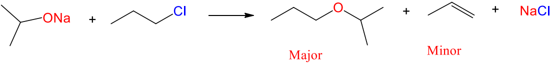

CH3ONa
+
Cl

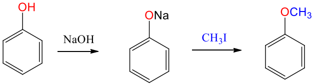

CH_3ONa
+
Cl
OCH_3
+
+
NaCl
Major
Minor

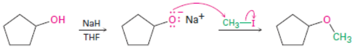

CH_3CH_2ONa
+
Cl


CH3CH2ONa
+
Cl
OCH2CH3
+
+
NaCl
Major
Minor


ONa
+
Cl

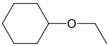
ONa
+
Cl
O
Major
+
Minor
+
NaCl


OH
NaOH
ONa
CH3I
OCH3

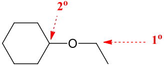


Cyclopentanol **Alkoxide ion** **Cyclopentyl methyl ether (74%)**

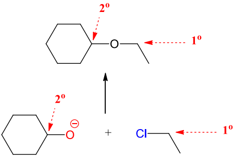
Prepare the following ether by using Williamson synthesis from the coresspoding alcohols



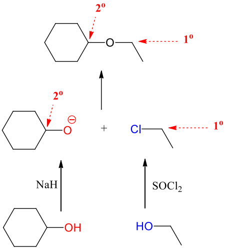
Prepare the following ether by using Williamson synthesis from the coresspoding alcohols

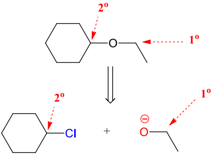


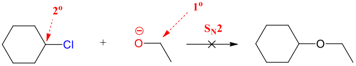
Prepare the following ether by using Williamson synthesis from the coresspoding alcohols

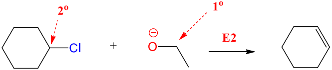


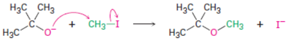
Prepare the following ether by using Williamson synthesis
from the coresspoding alcohols



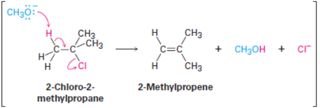

2º
O
1º
2º
1º
Cl
+
O


2º
Cl
+
1º
O
SN2


2º
Cl
+
O
1º
E2



tert-Butoxide Iodomethane *tert*-Butyl methyl ether

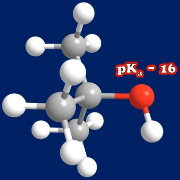


2-Chloro-2-methylpropane

2-Methylpropene

The Williamson Ether Synthesis

Generating an alkoxide nucleophile



t-butanol

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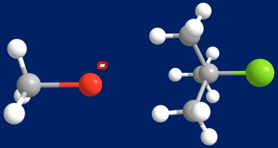
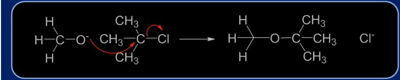
The Williamson Ether Synthesis





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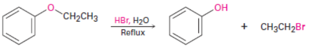
Thanks Professor Davis from ChemSurvival youtube channel the valued movie that I used in this presentation

Organic chemistry for nonmajor students
Chem 233

8.6 Cleavage of Ethers

Aromatic Ethers cleavage by using Hydrogen halides

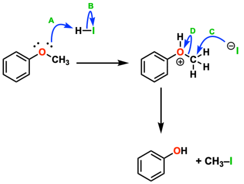
Ethers are cleaved by strong acids *via* S_N1 and S_N2 reaction mechanisms. Aqueous HBr and HI both work well, but HCl does not cleave ethers. In aromatic ethers, the products are phenol and alkyl halide.



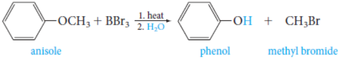
Ethyl phenyl ether **Phenol** **Bromoethane**

Step 1: protonation

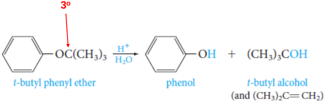
Step 2: S_N2 reaction



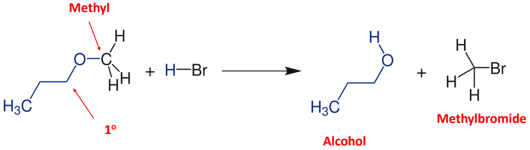
Aromatic Ethers cleavage by using Borontribromide



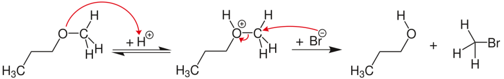
With tertiary alkyl side, a strong nucleophile is not required since reaction will occur by an
S_N1 (or E1) mechanism.



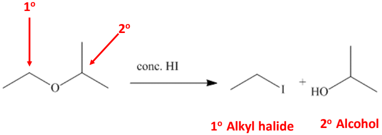
Aliphatic Ethers cleavage by using Hydrogen halides



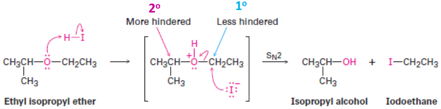
Aliphatic Ethers cleavage *via* S_N2 mechanism in Acidic halide

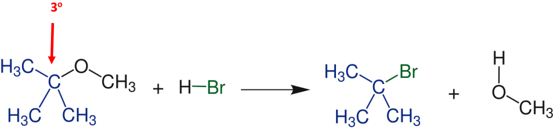


Aliphatic Ethers cleavage by using Hydrogen halides



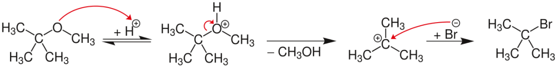
Aliphatic Ethers cleavage *via* S_N2 mechanism in Acidic halide



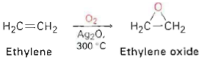


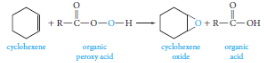
3º Alkyl halide

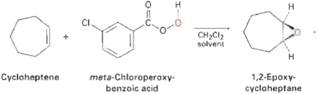
Aliphatic Ethers cleavage *via* S_N1 mechanism in Acidic halide



8.7 Epoxides (Oxiranes)

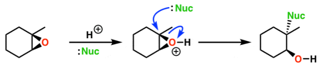






Opening of epoxides under acidic conditions occurs in two key steps

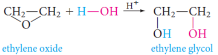
- First, the epoxide is protonated
- Second, the nucleophile attacks at the most substituted position



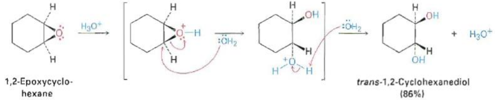
Nuc ***= nucleophile***

backside attack at most substituted carbon

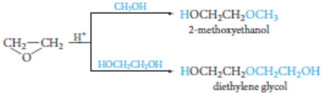
- The result is that the two groups (nucleophile and OH) are oriented *trans* to one another

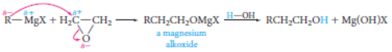


$$\underset{\text{O}}{\mathrm{CH_2{-}CH_2}} + \mathrm{H{-}OH} \xrightarrow{H^+} \underset{\mathrm{OH}}{\mathrm{CH_2}}{-}\underset{\mathrm{OH}}{\mathrm{CH_2}}$$

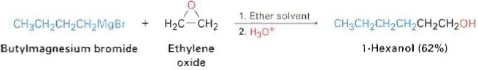


Other nucleophiles add to epoxides in a similar way.

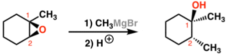




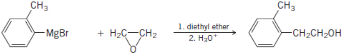
(8.21)



With more basic nucleophiles, protonation is done in a separate "quench" step - otherwise the nucleophile would be destroyed



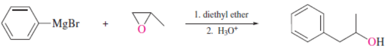
Note that the strong base CH_3MgBr is incompatible with H+, which is why H+ is added at the end of the reaction



o-Methylphenylmagnesium bromide

Ethylene oxide

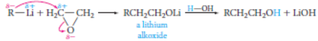
2-(*o*-Methylphenyl)ethanol (66%)



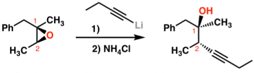
Phenylmagnesium bromide

1,2-Epoxypropane

1-Phenyl-2-propanol (60%)



$$\overset{\delta-}{R}{-}\overset{\delta+}{Li} + H_2\overset{\delta+}{C}{-}CH_2 \longrightarrow RCH_2CH_2OLi \xrightarrow{H{-}OH} RCH_2CH_2OH + LiOH \qquad (8.22)$$



note inversion of configuration at least substituted carbon (C-2)