台灣大學開放式課程

有機化學乙

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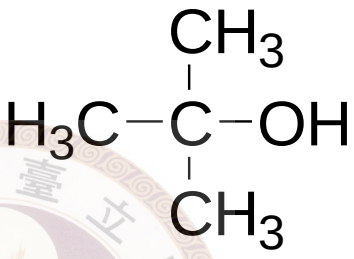
Chapter 11
Alcohols (醇類) and ethers (醚類)

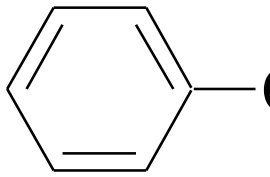
R-OH R-O-R'

CH_3OH
methanol
(methyl alcohol)



2-methyl-2-propanol
(*t*-butyl alcohol)
a 3^o alcohol

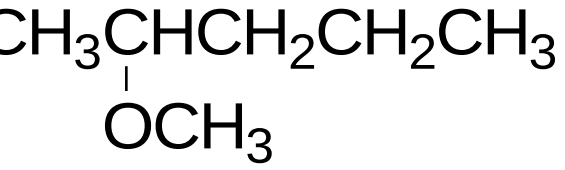
-OH hydroxyl group
When attached to 1^o carbon → 1^o alcohol, etc.



phenol (酚)

Ethers: IUPAC → alkoxyalkanes

$CH_3OCH_2CH_3$
methoxyethane
(ethyl methyl ether)

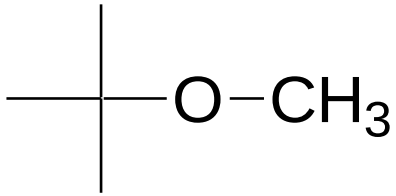


2-methoxypentane

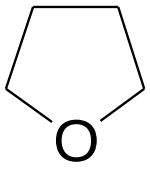
$CH_3CH_2OCH_2CH_3$

diethyl ether (or simply ether)
very common solvent
(bp 35 ^oC)

Other common ethereal solvent:



methyl *t*-butyl ether (MTBE)
another common solvent (bp 55 ^{o}C)
and anti-knocking agent

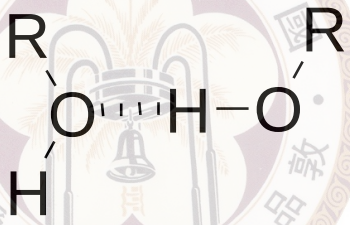


tetrahydrofuran (THF)
IUPAC: oxacyclopentane
氧代

*These are polar aprotic solvents

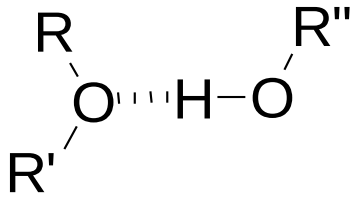
※ Structures and properties

Alcohols: intermolecular hydrogen bonding
分子間



water soluble when small

Ethers: no intermolecular H-bonding between itself

but 

例 solubility of diethyl ether in water : 8 g/100 mL

※ Some important alcohol and ethers

Methanol 甲醇，木精

Industrial synthesis: $CO + 2\,H_2 \xrightarrow[200\text{-}300\ atm]{300\text{-}400\ ^oC,\ ZnO\text{-}Cr_2O_3} CH_3OH$

Ethanol (bp 78.4 °C)

Fermentation: $C_6H_{12}O_6 \xrightarrow{yeast} 2\,CH_3CH_2OH + 2\,CO_2$

conc. at most 12~15%

distillation → 95% ethanol

forms binary azeotrope (共沸物), bp 78.2 °C:

95% EtOH, 5% H_2O

ternary azeotrope, bp 64.9 °C:

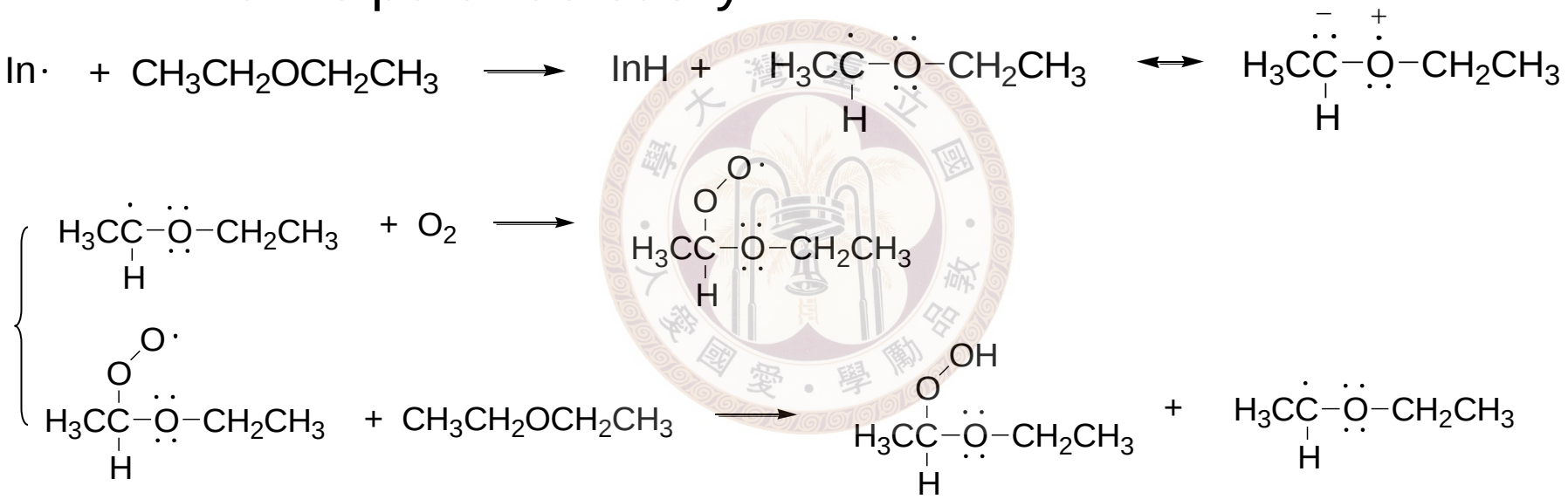
18.5% EtOH, 7.5 % H_2O, 74% benzene

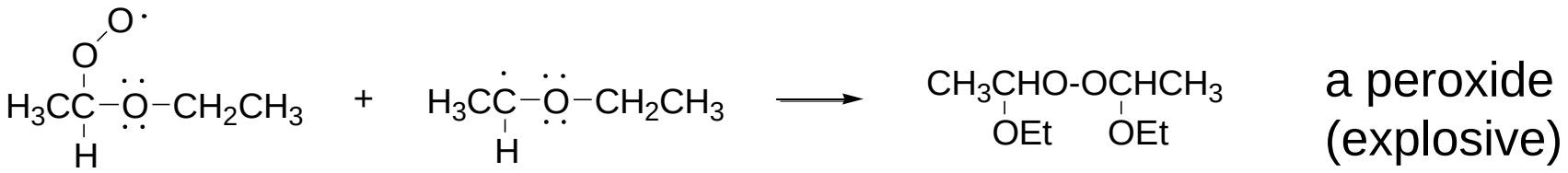
市售濃度單位: proof 100 proof = 50%

Ethylene glycol: common anti-freeze

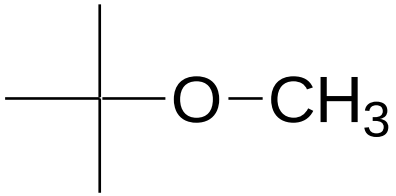
Diethyl ether: low bp
common flammable solvent

forms peroxide easily:



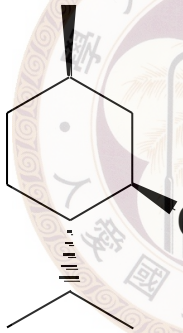


a peroxide
(explosive)



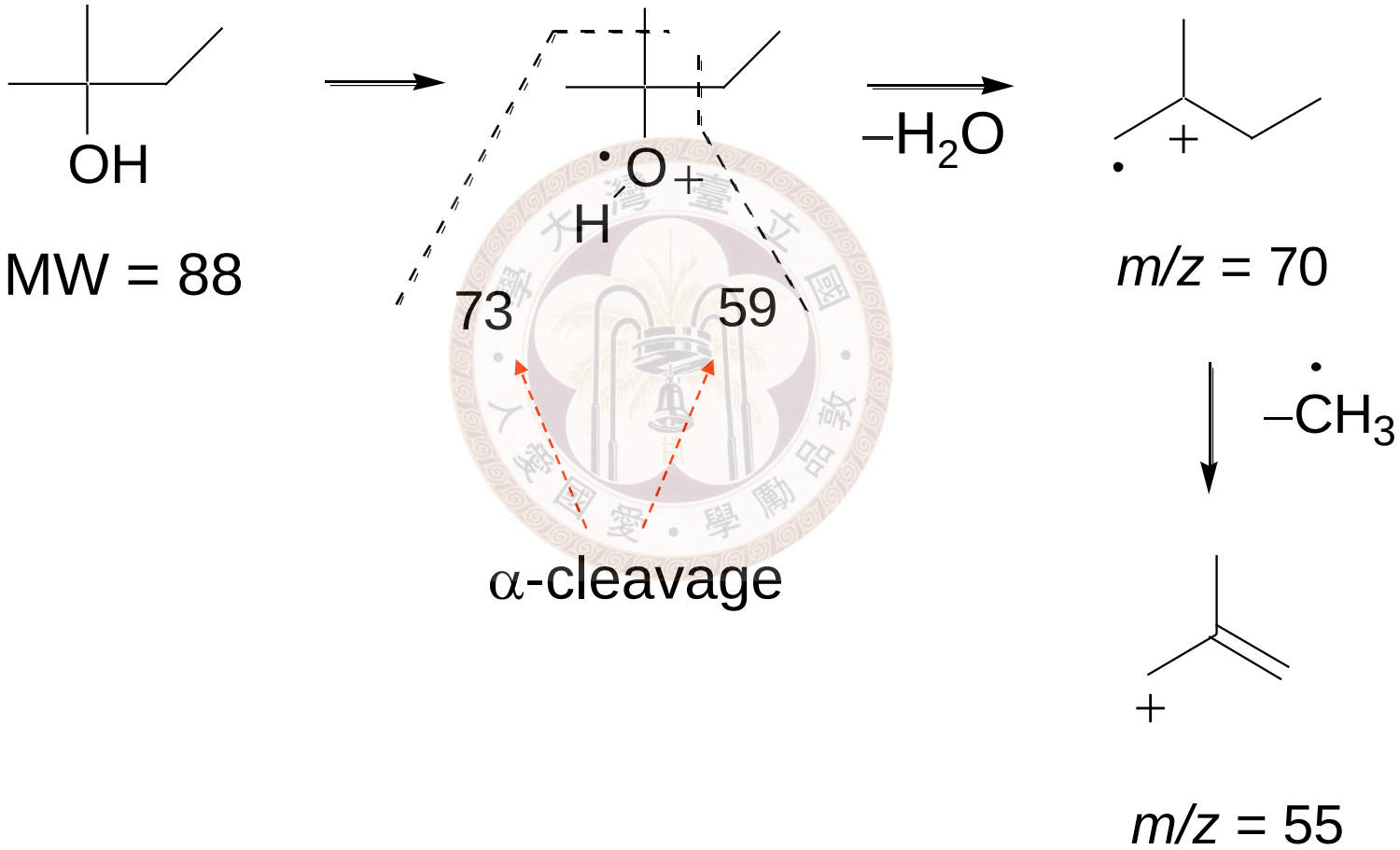
Methyl *t*-butyl ether (MTBE)
is very stable
Does not form peroxides (why?)

Many naturally occurring alcohols:



Menthol (薄荷醇)

※ Mass spectroscopy



※ Preparation of alcohols

- ✓ Hydration of alkenes
- ✓ Oxymercuration-demercuration of alkenes
- ✓ Hydroboration-oxidation of alkenes

※ Reactions of alcohols

◎ As an acid

weaker acid than H_2O

relative acidity:

$$H_2O > ROH > R\text{-}C{\equiv}C\text{-}H > H_2 > NH_3 > RH$$

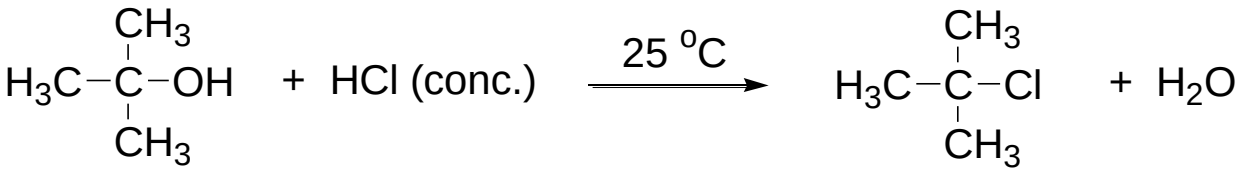
pK_a	16	17~19	25	35	38	50

relative basicity:

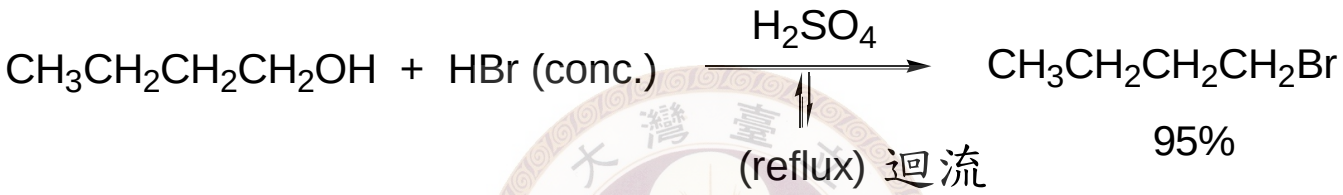
$$R^- > {}^-NH_2 > H^- > R\text{-}C{\equiv}C^- > RO^- > HO^-$$

例 $ROH + NaH \rightarrow RONa + H_2\uparrow$

◎ ROH → RX

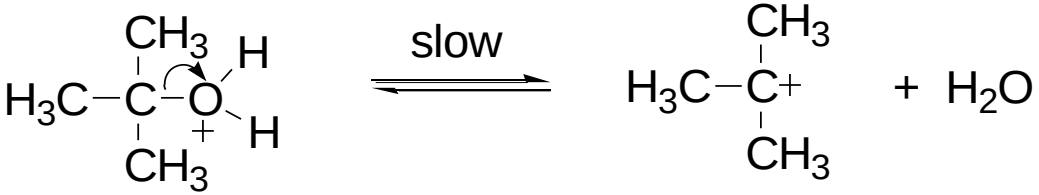


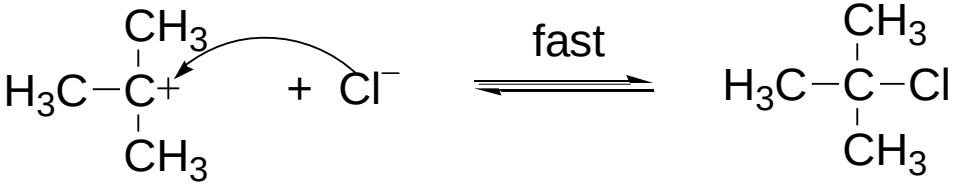
94%



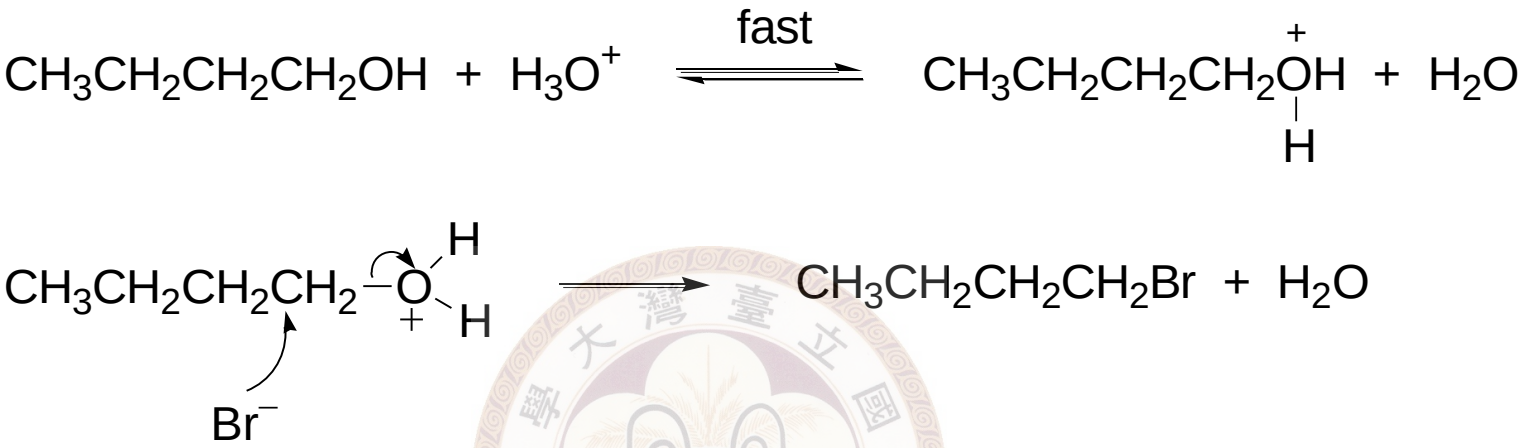
95%

Mechanism: ✓ S_N1 type for 3^o and 2^o halides





✓ S_N2 type for 1^o and methyl halides



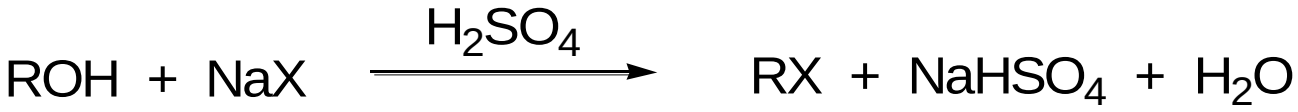
✓ Order of reactivity

$3^o > 2^o > 1^o <$ methyl

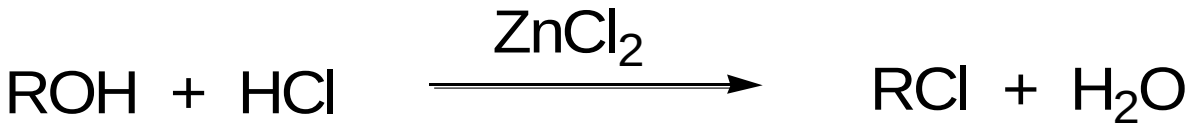
HI > HBr > HCl (HF unreactive)

Stronger acid and stronger nucleophile (I^-)

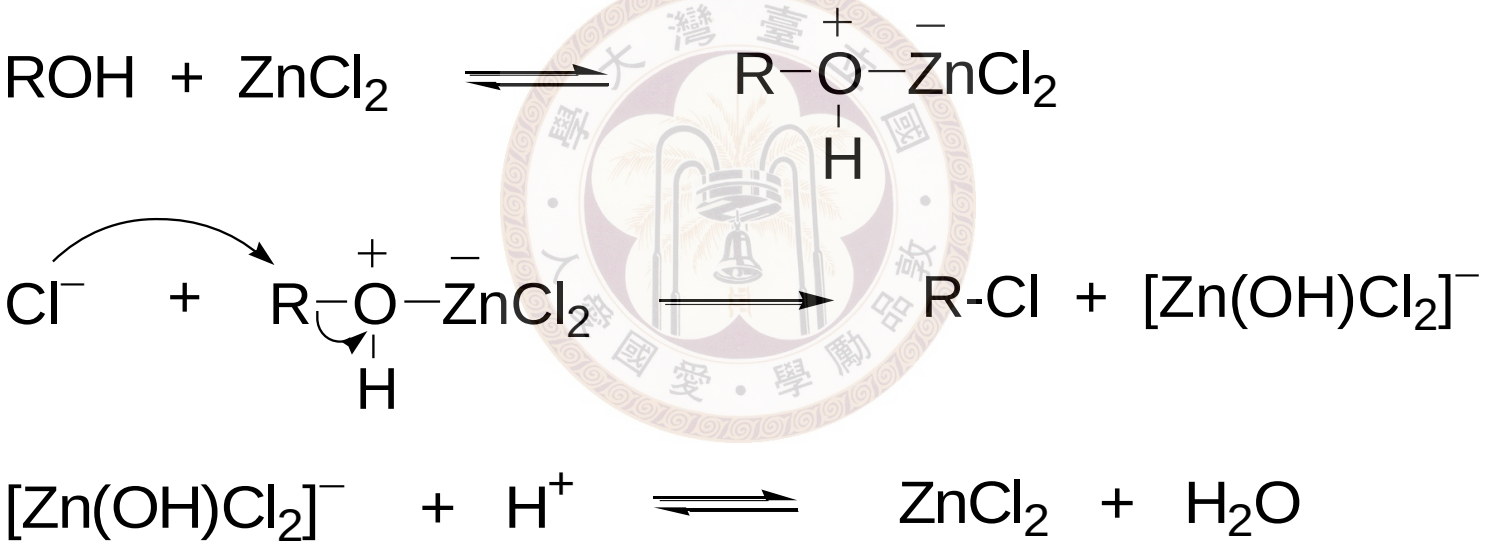
例



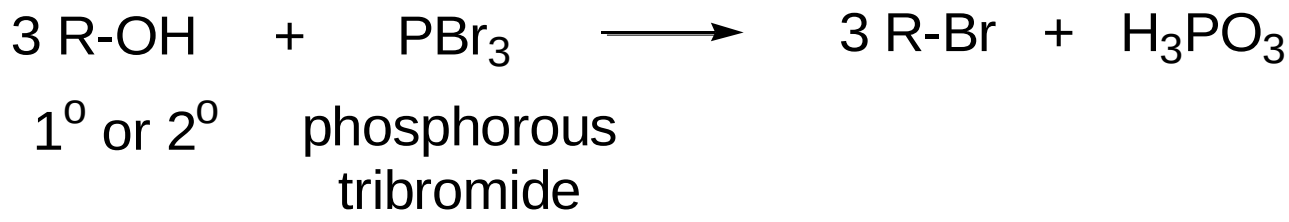
✓ Catalyzed by Lewis acids



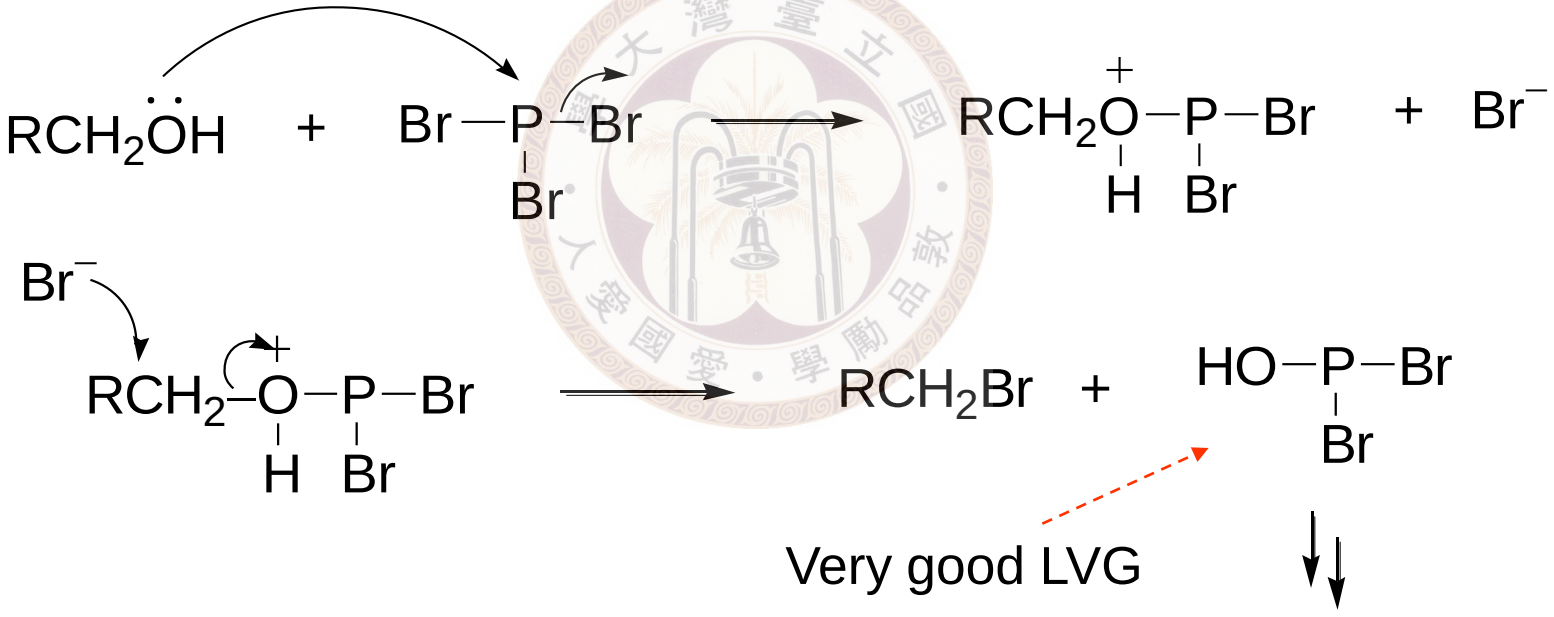
Mechanism:



✓ The use of PBr_3



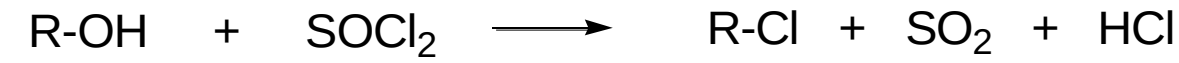
Mechanism:



No carbocation formation

→ No rearrangement

✓ The use of $SOCl_2$

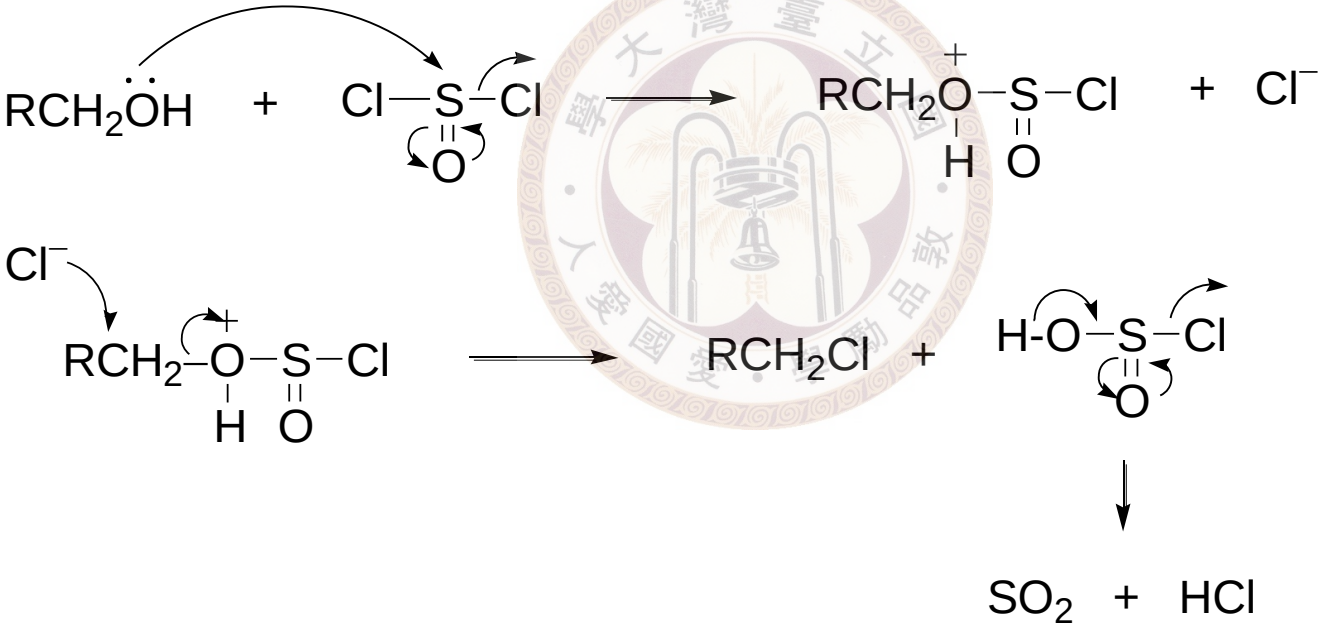


1^o or 2^o

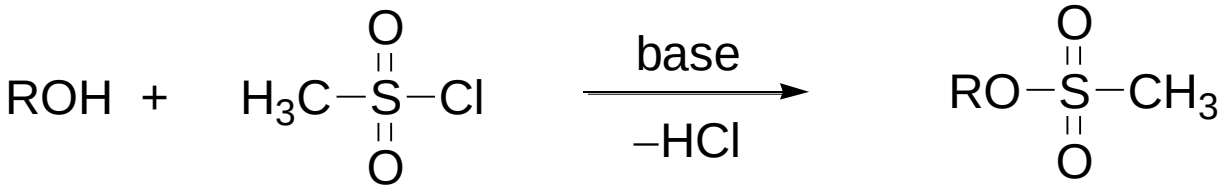
thionyl chloride

Tertiary amine can be added to remove HCl (such as Et_3N)

Mechanism:



◎ Formation of mesylate and tosylate

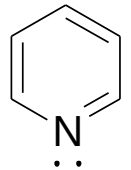


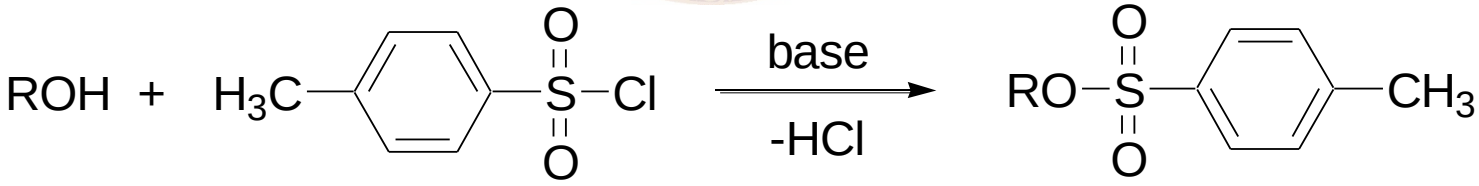
methanesulfonyl chloride

an alkyl mesylate

*Base: to remove HCl

often use amine base: Et_3N or pyridine

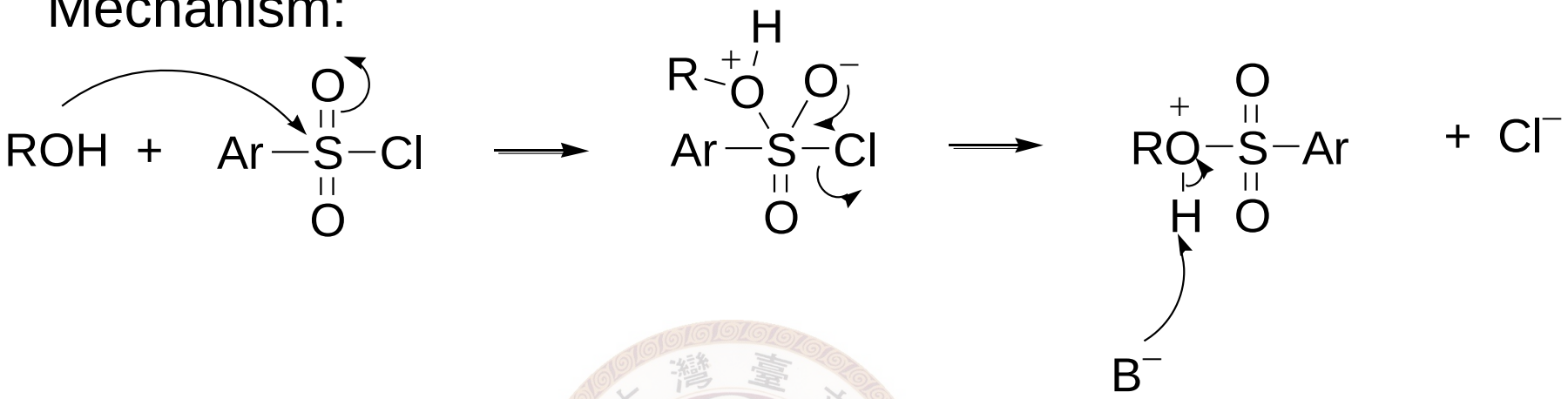




p-toluenesulfonyl chloride

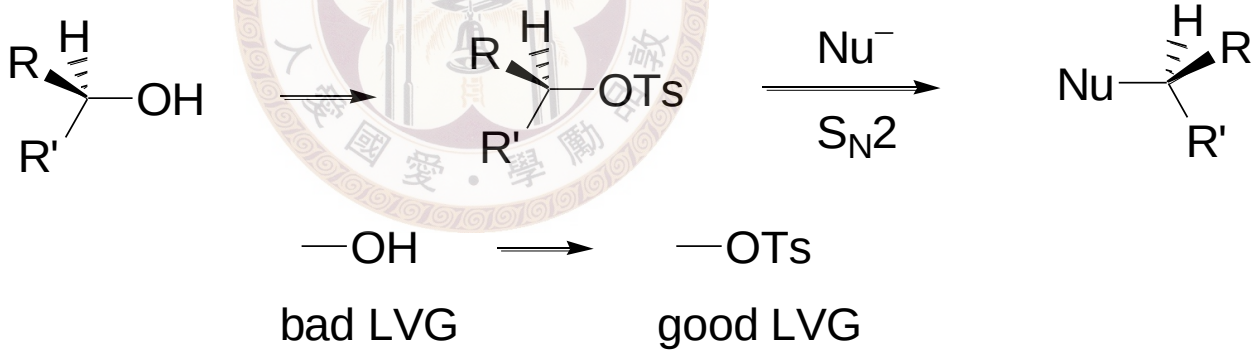
an alkyl tosylate

Mechanism:



✓ Mesylate and tosylate are good LVGs

✓ Overall:

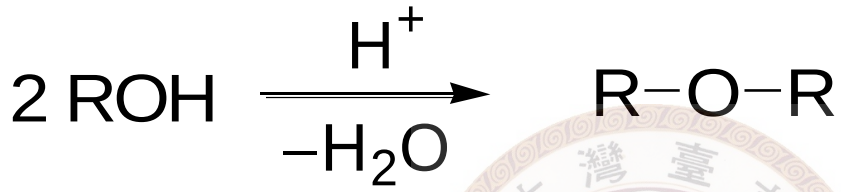


✓ Biological system

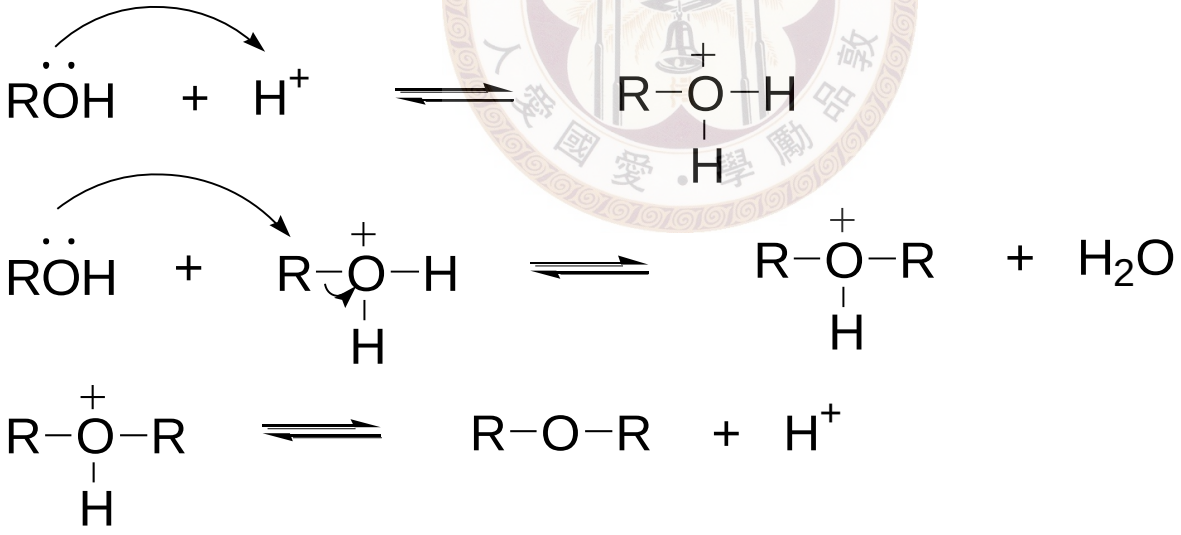
Triphosphate is often used as LVG

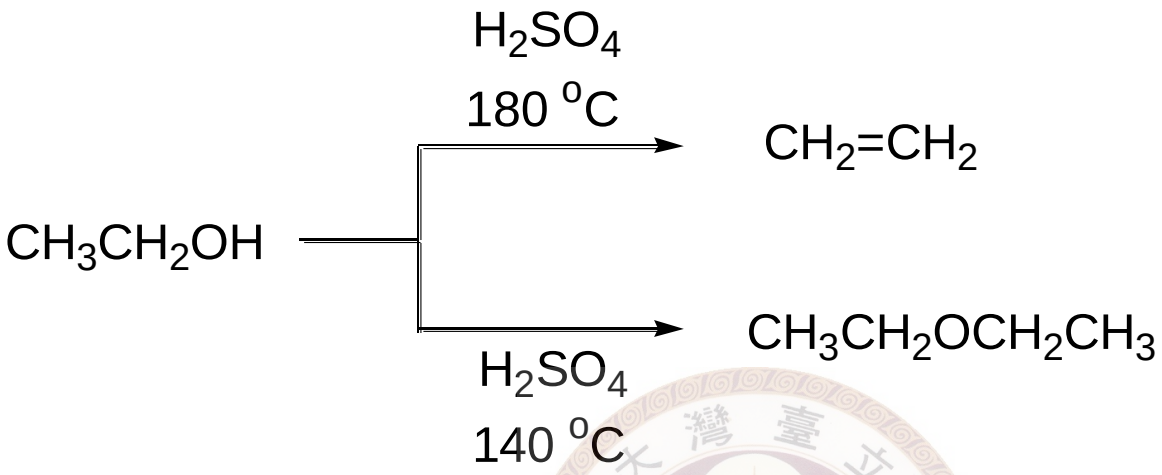
※ Synthesis of ethers

◎ Dehydration of alcohols



Mechanism:

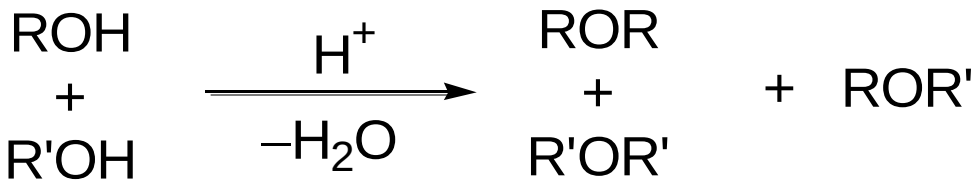




Problems:

✓ For 2° and 3° alcohols → elimination dominates

✓ Not useful for unsymmetrical ethers



◎ Williamson synthesis of ethers

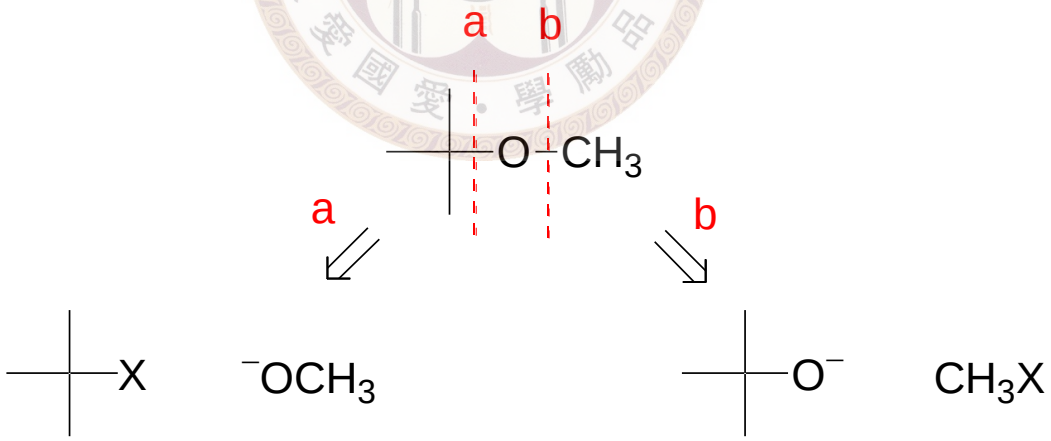
$CH_3CH_2CH_2OH + Na \rightarrow CH_3CH_2CH_2ONa + \frac{1}{2} H_2$

$\downarrow CH_3CH_2I$

$CH_3CH_2CH_2OCH_2CH_3 + NaI$

70%

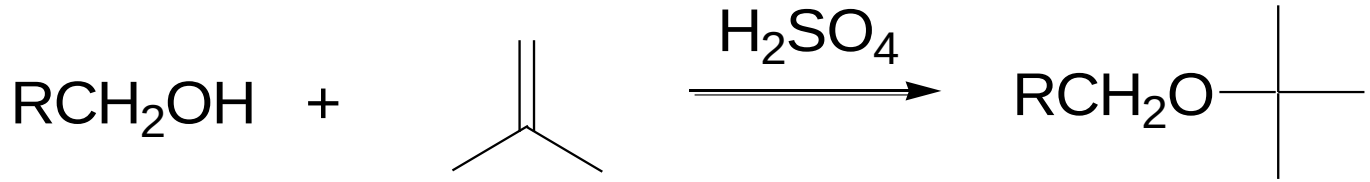
Q: synthesis of MTBE?



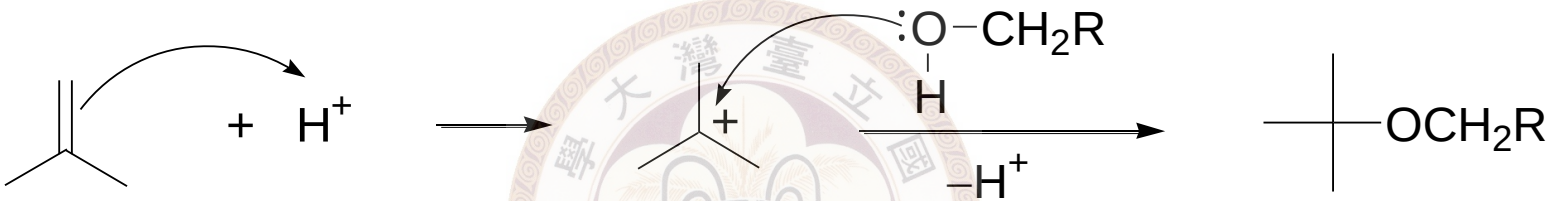
elimination will be a problem

better

◎ *t*-Butyl ethers from alkenes



Mechanism:

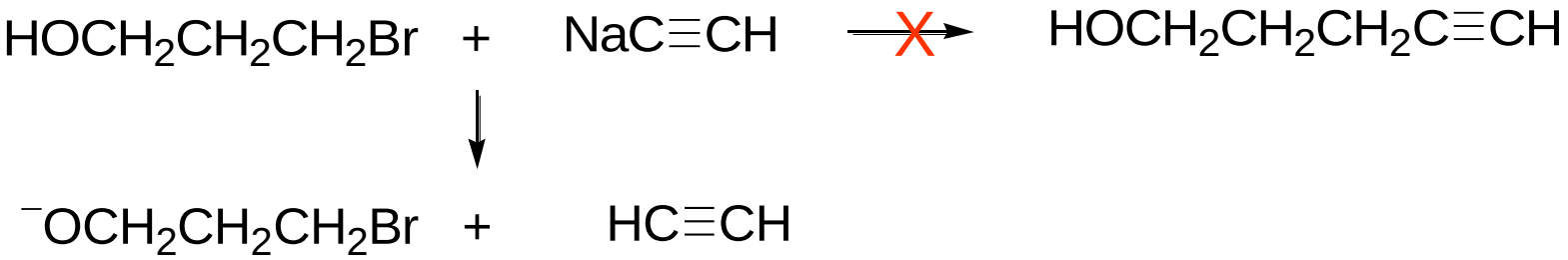


Application:

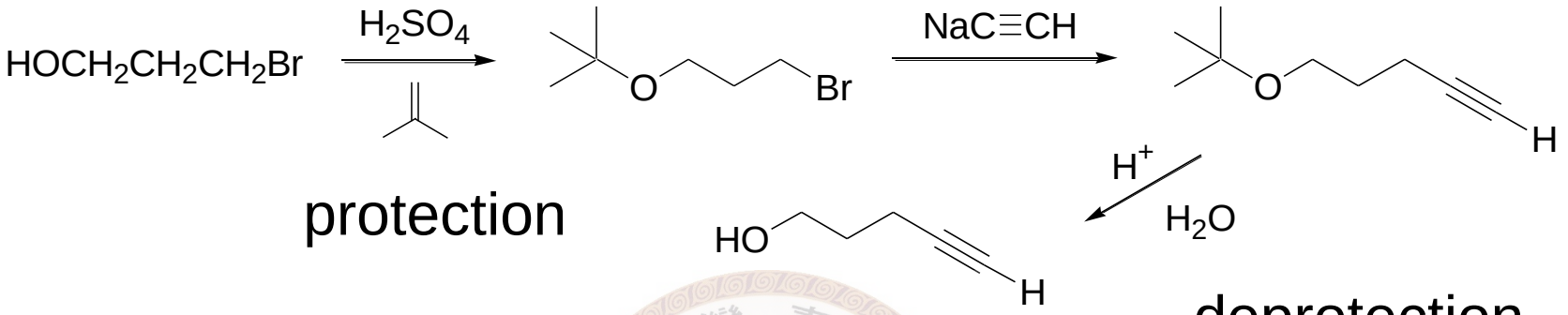
used as a protecting group (保護基)

例

problem:



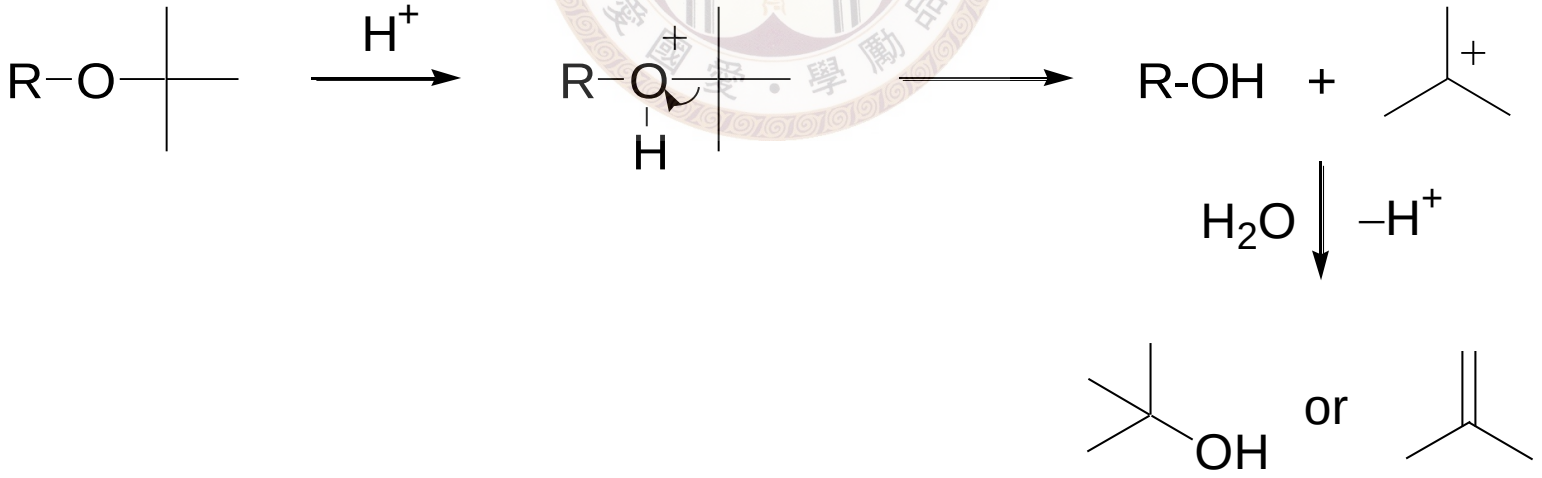
solution:



protection

deprotection
(a hydrolysis rxn)

Mechanism for deprotection:



※ Reactions of ethers

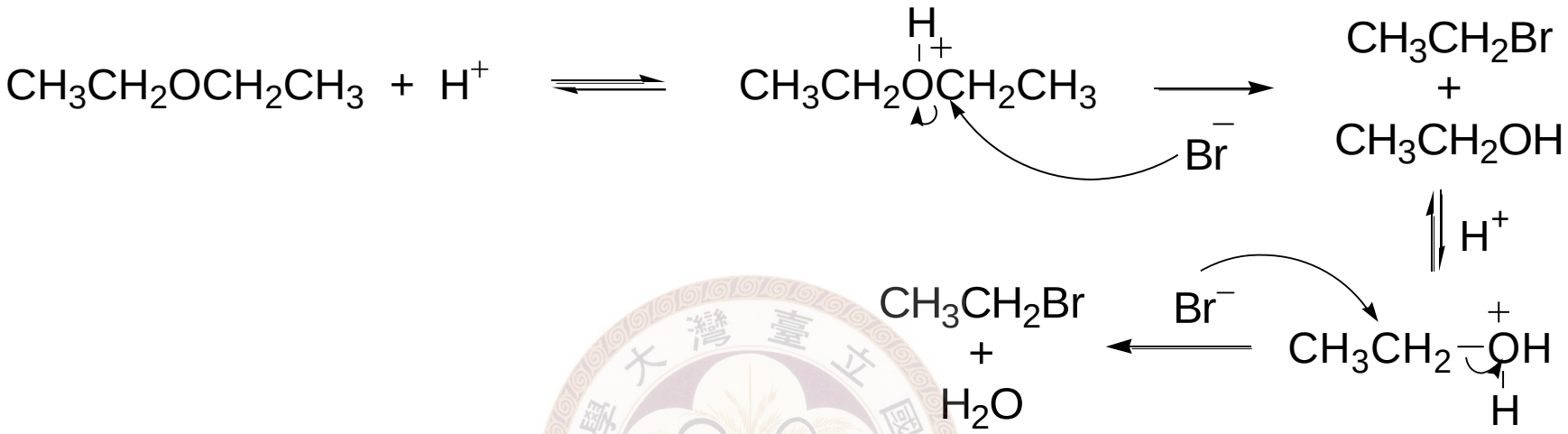
In general: quite inert
(a good quality as solvent)

Stable in basic condition

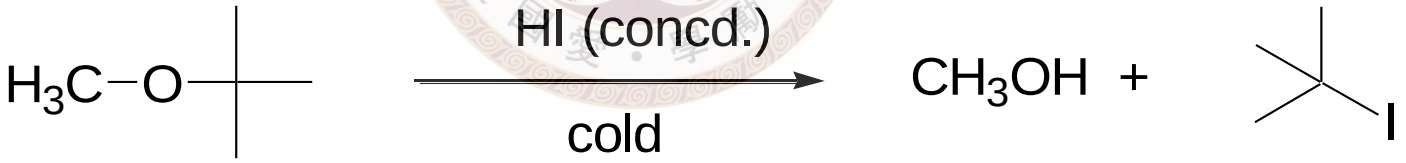
Reacts in concentrated acidic condition:

$$CH_3CH_2OCH_2CH_3 + 2\ HBr \xrightarrow[\text{(concd.)}]{\Delta} 2\ CH_3CH_2Br + H_2O$$

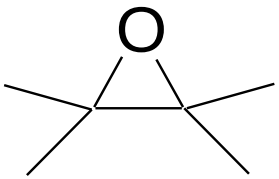
Mechanism:


CH3CH2OCH2CH3 + H+
H
CH3CH2OCH2CH3
Br−
CH3CH2Br
+
CH3CH2OH
H+
Br−
CH3CH2−OH
H
CH3CH2Br
+
H2O

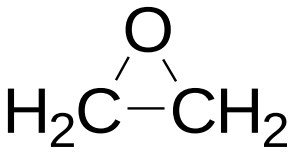
例


H3C−O
HI (concd.)
cold
CH3OH +
I

※ Epoxides (環氧乙烷)

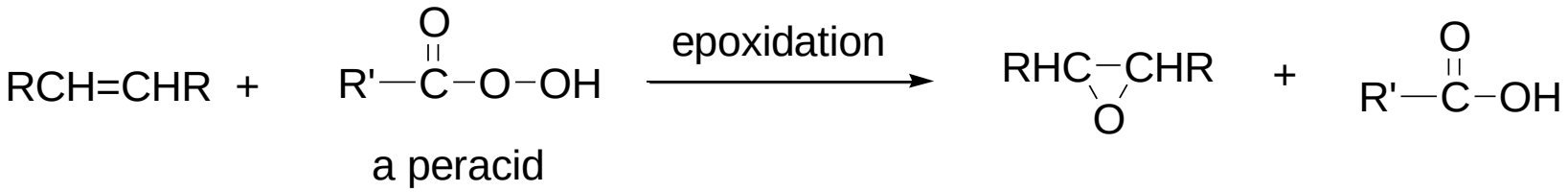


IUPAC: oxiranes
a cyclic ether



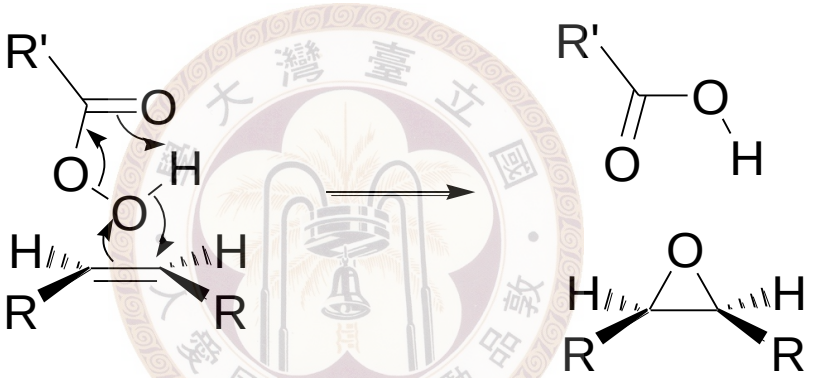
Common name: ethylene oxide

◎ Preparation

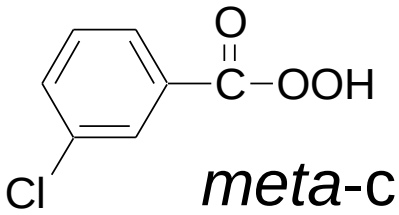


a peracid

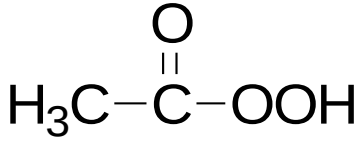
Mechanism:



- syn addition of oxygen
- common peracids for this purpose:

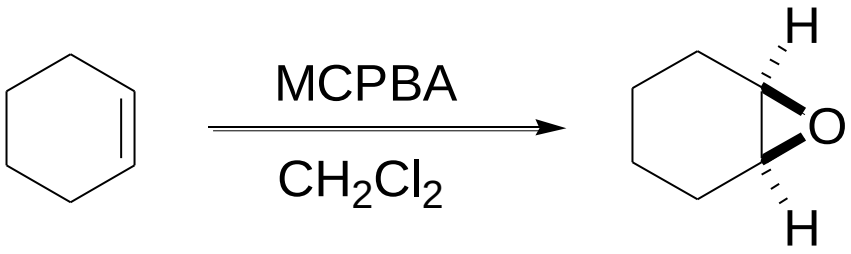


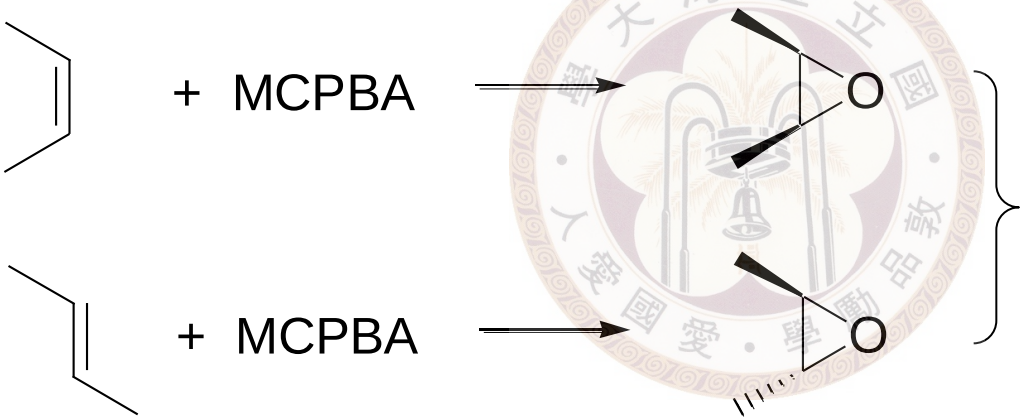
meta-chloroperbenzoic acid (MCPBA)



peracetic acid

例



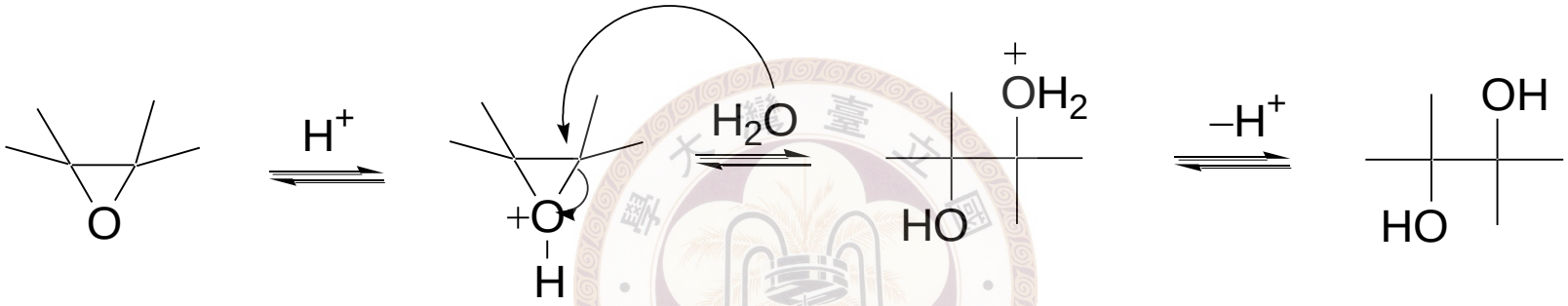


a stereospecific rxn

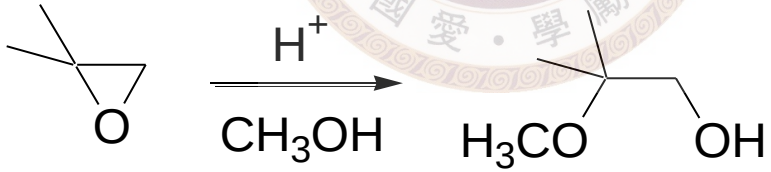
◎ Reactions of epoxides

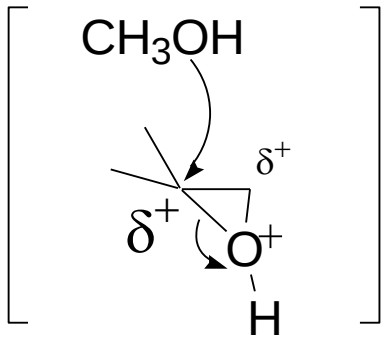
Ring opening → to relieve ring strain

✓ Acid catalyzed ring opening



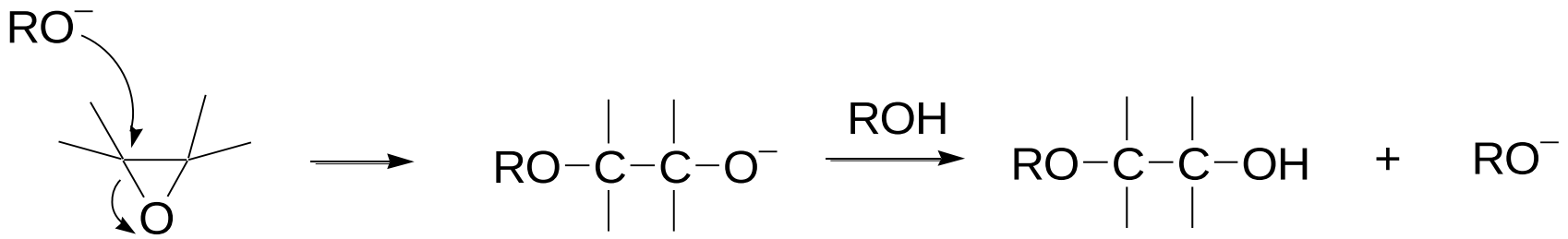
Regiochemistry:





More substituted carbon has more positive character

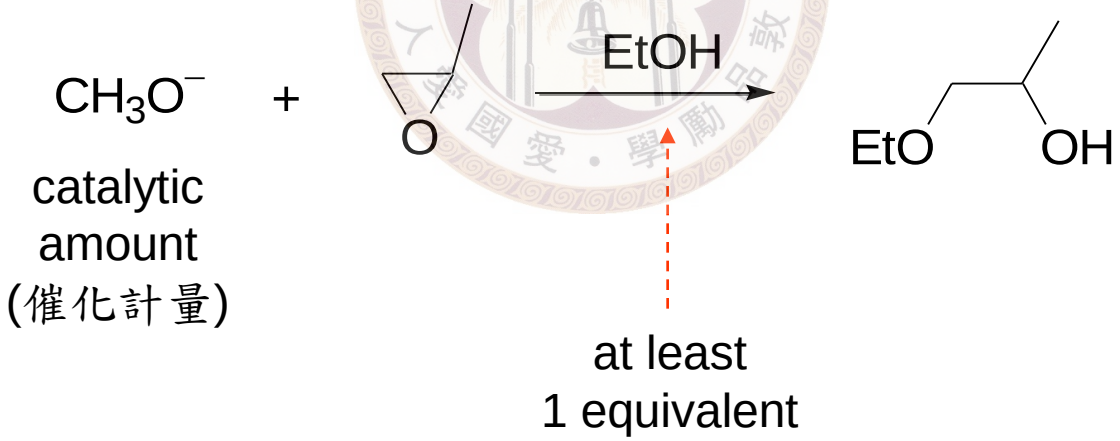
✓ Base catalyzed ring opening



Regiochemistry: steric control

nucleophile attacks less substituted carbon

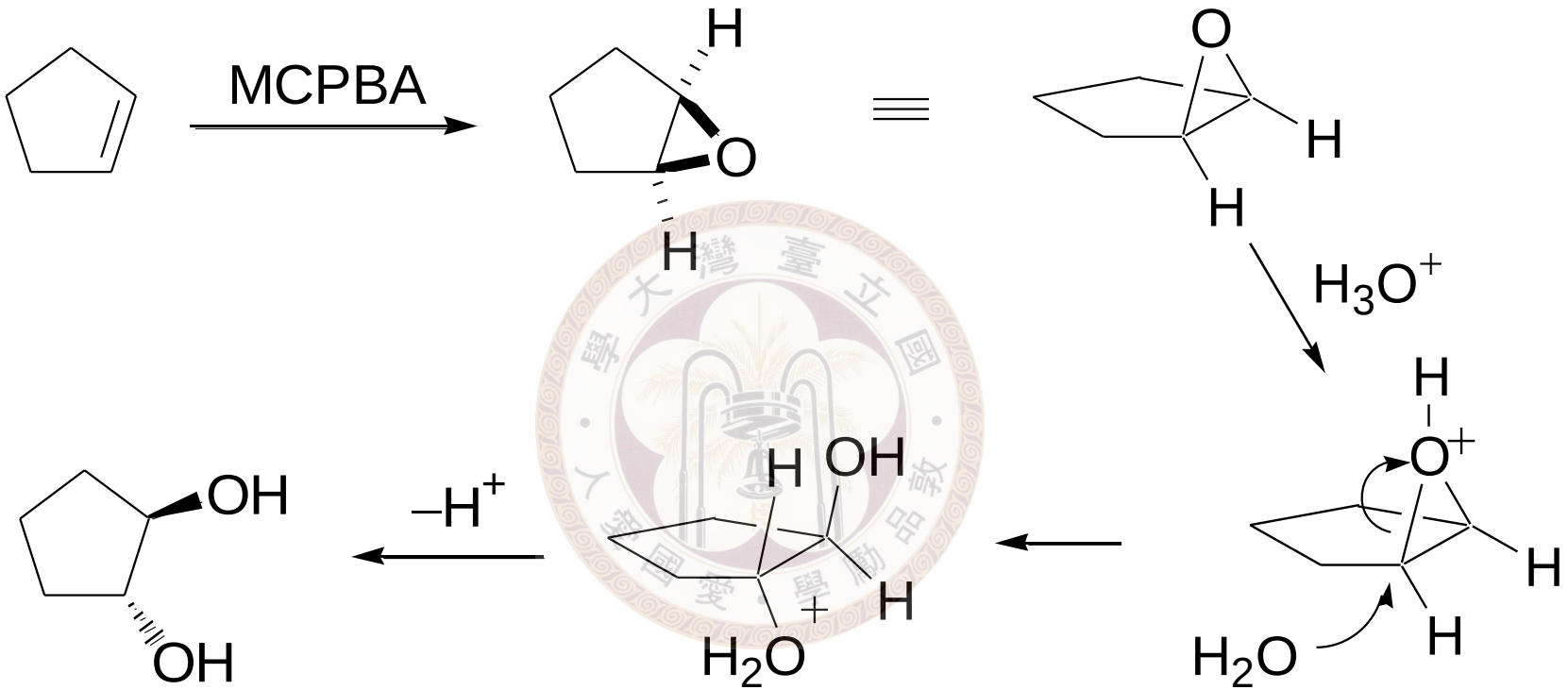
例

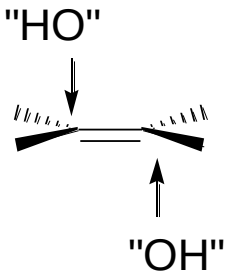


$$\left(CH_3ONa + EtOH \rightleftharpoons CH_3OH + EtONa \right)$$

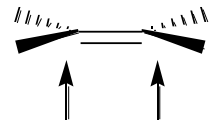
✓Stereochemistry

overall anti dihydroxylation of alkene





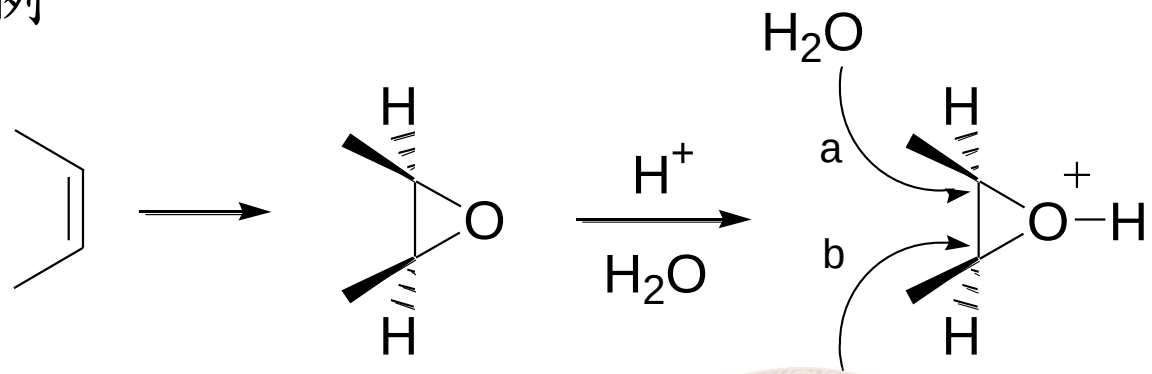
anti

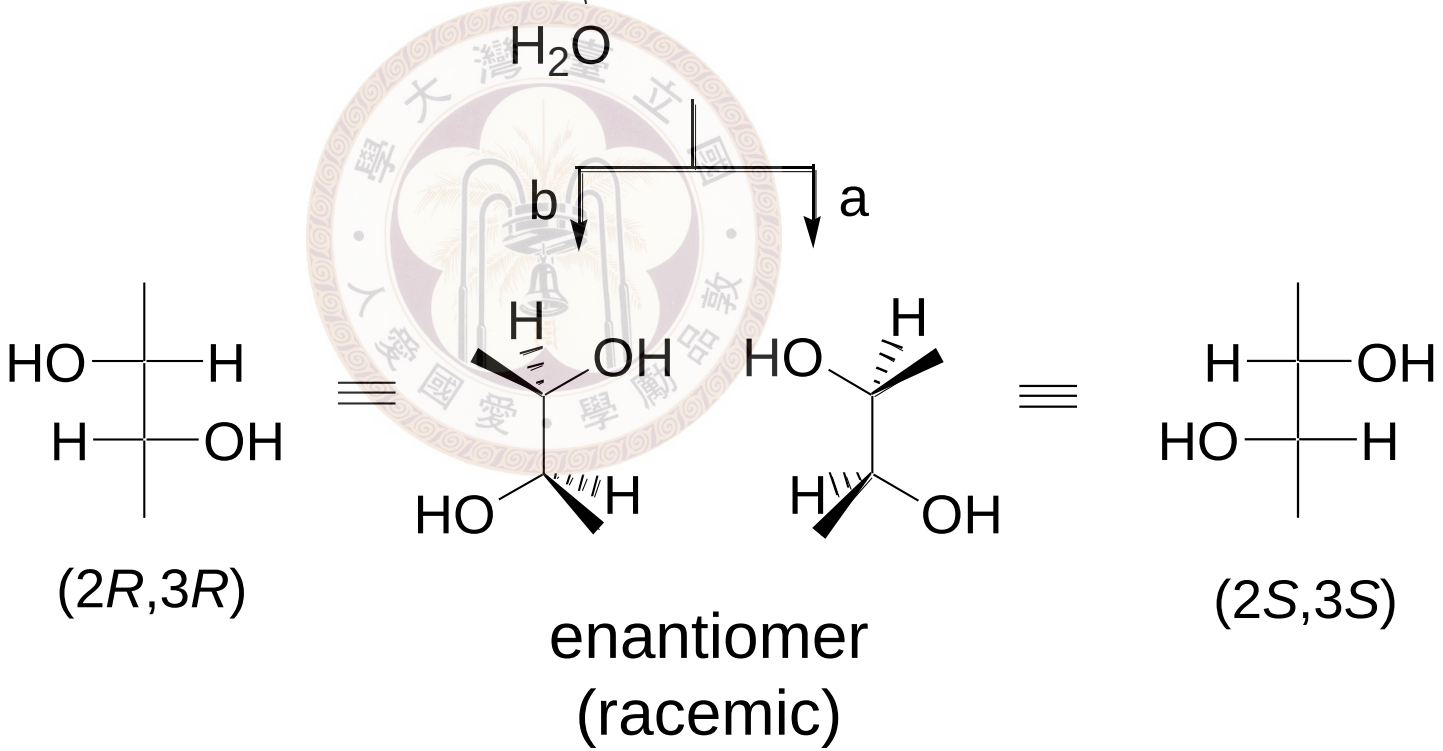


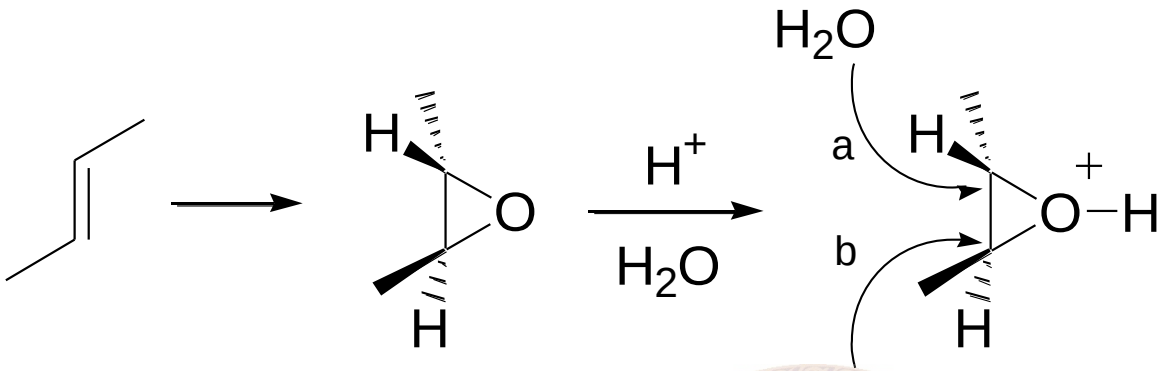
syn

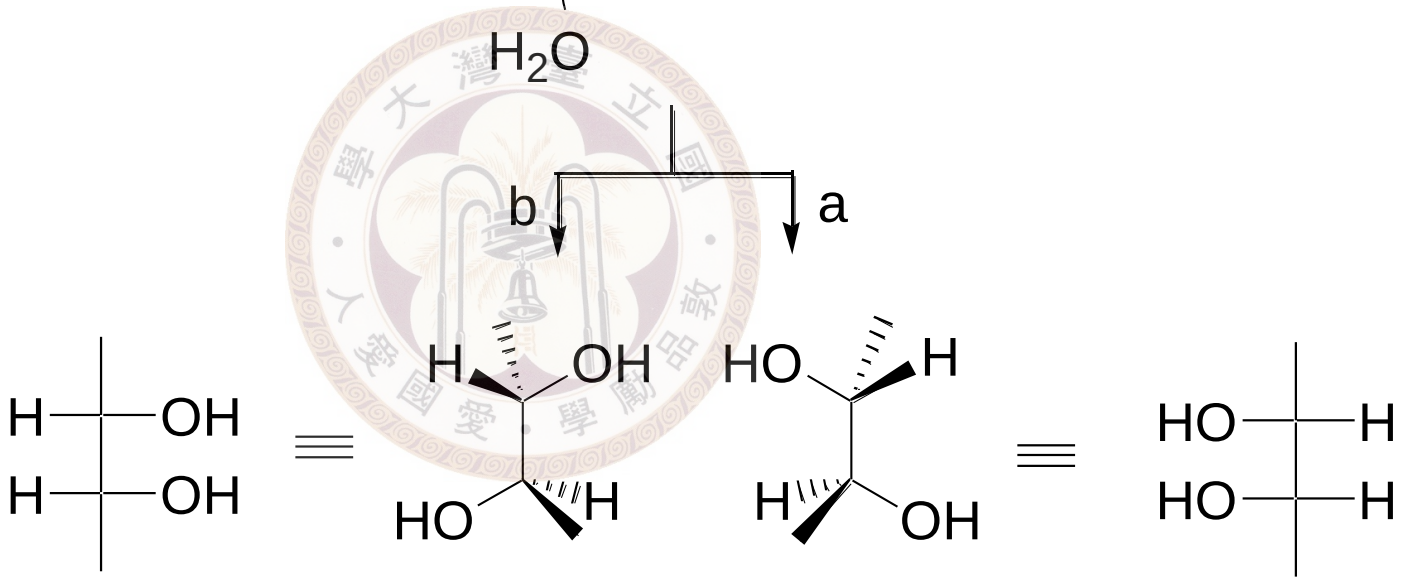
($KMnO_4$ or OsO_4)

例


H
O
H
H+
H2O
H2O
a
b
H
O
H
+
H
H

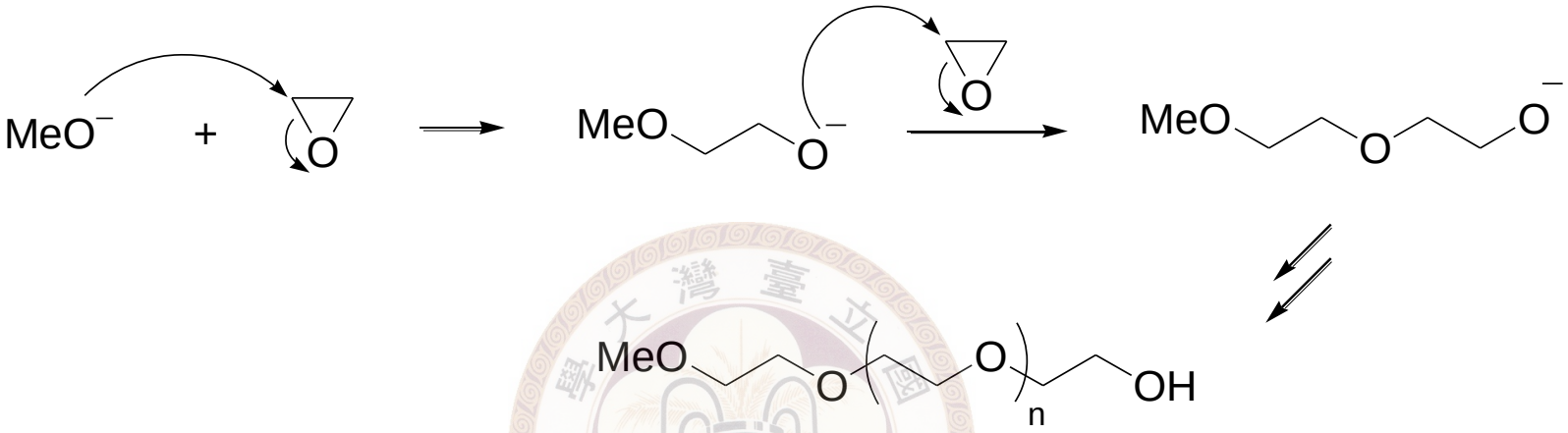

H2O
b
a
HO
H
H
OH
(2R,3R)
H
OH
HO
H
HO
H
H
OH
enantiomer
(racemic)
H
OH
HO
H
(2S,3S)





same
(meso)

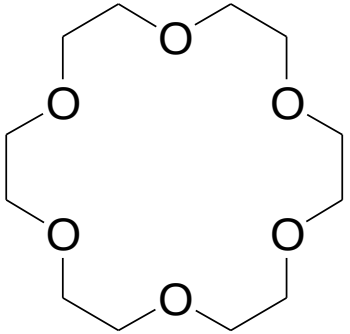
◎ Polyethers from epoxides



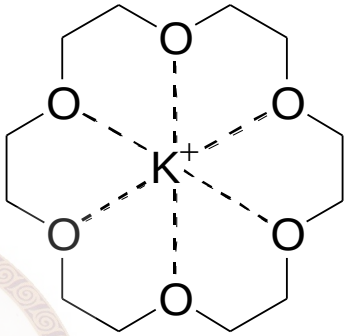
poly(ethylene glycol)
(PEG)

A polyether with good water solubility

※ Crown ethers and phase transfer catalysis



18-Crown-6 $\xrightarrow{K^+}$ chelates potassium ion

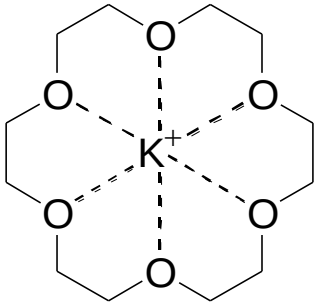


ring atoms　　oxygen atoms

The host-guest relationship:
host: Crown ether, guest: K^+

✓Application: can enhance the solubility of salt in org. solv. (as phase transfer catalyst)

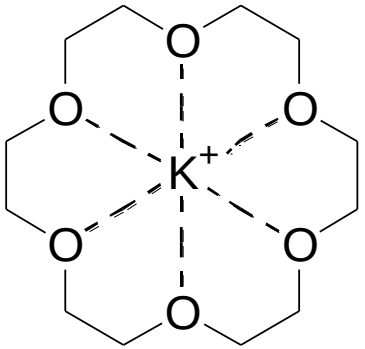
$KMnO_4$ $\xrightarrow{18\text{-Crown-6}}$



MnO_4^-

insoluble in benzene

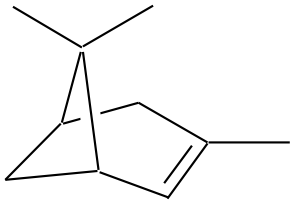
Soluble in benzene



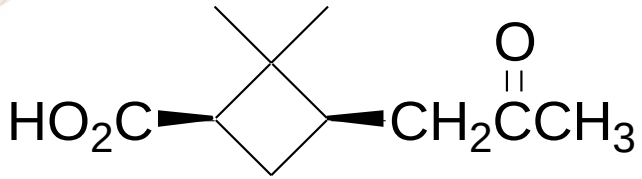
CN^-

in nonpolar solvent
→ not solvated
→ very reactive

$$RCH_2X + KCN \xrightarrow[\text{benzene}]{\text{18-Crown-6 (cat.)}} RCH_2CN + KX$$



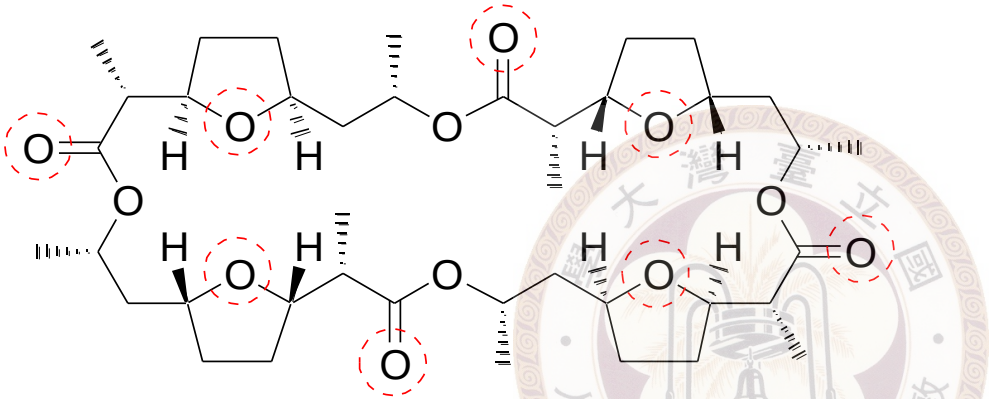
$$\xrightarrow[\text{18-Crown-6}\\ \text{benzene}]{KMnO_4}$$



90%

◎ Some naturally occurring Crown ethers

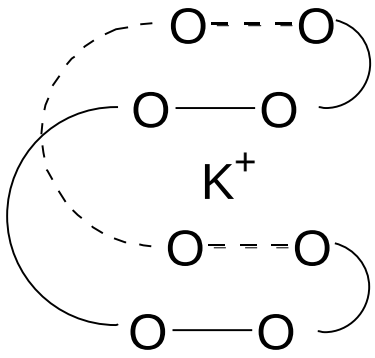
transport antibiotic:

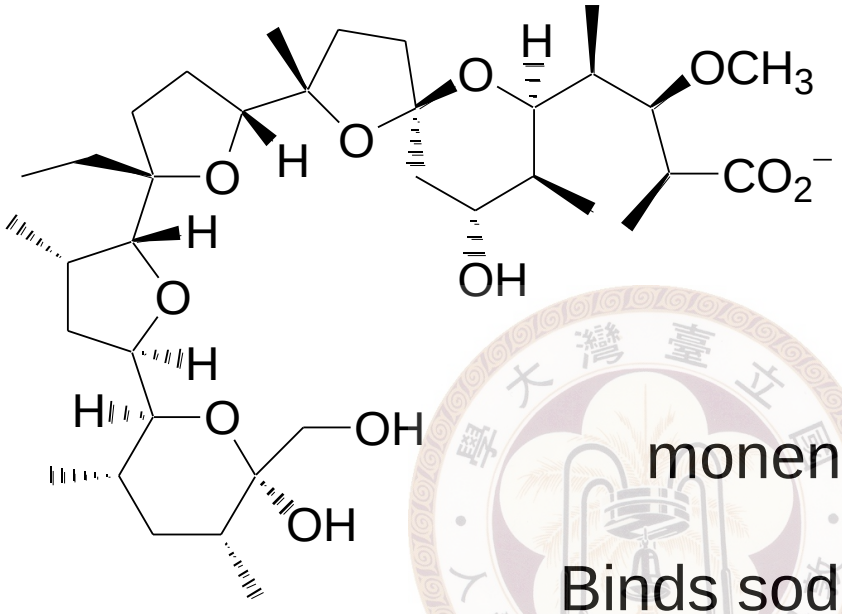


nonactin

K^+

An ionophore (ion loving): compounds that bind metal ions tightly





monensin

Binds sodium ion