Lecture 7

Alcohols, Phenols, Ethers

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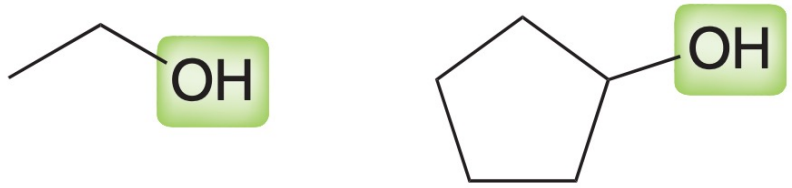
Alcohols and Phenols

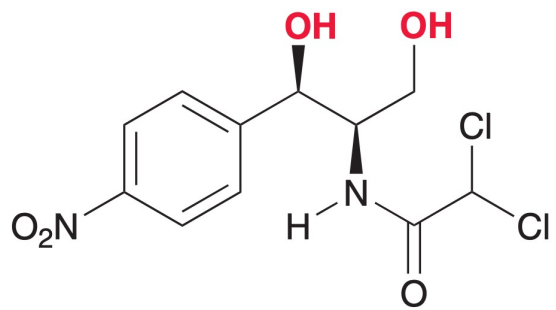
Basic Physical & Chemical Properties, Preparations, Reactions

Alcohols are compounds that possess a **hydroxyl group** (OH) connected to an sp^3-hybridized carbon atom, and are characterized by names ending in "ol":

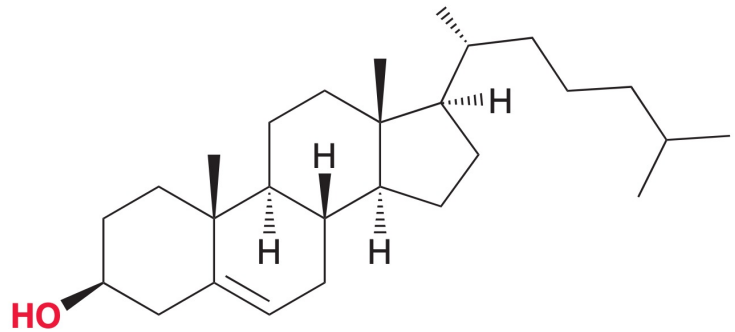


Ethanol **Cyclopentanol**

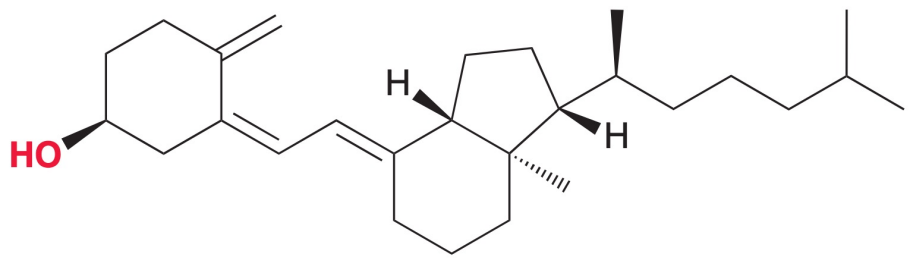
Alcohols in Nature



Chloramphenicol
An antibiotic isolated from the
Streptomyces venezuelae bacterium.
Potent against typhoid fever

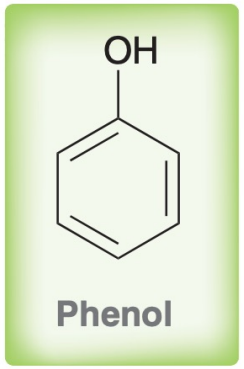


Cholesterol
Plays a vital role in the
biosynthesis of many steroids

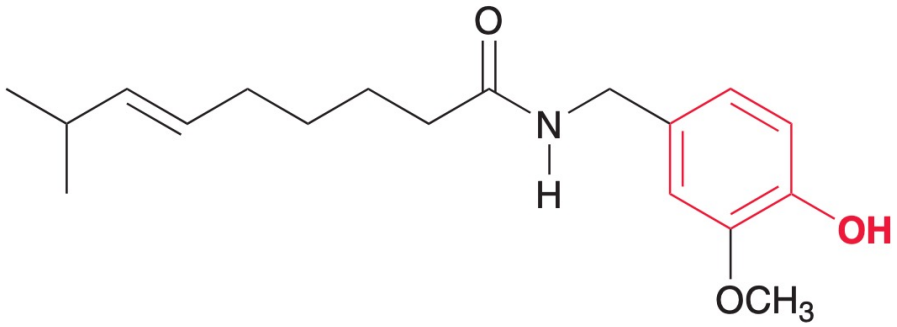


Cholecalciferol (vitamin D_3)
Regulates calcium levels and helps
to form and maintain strong bones

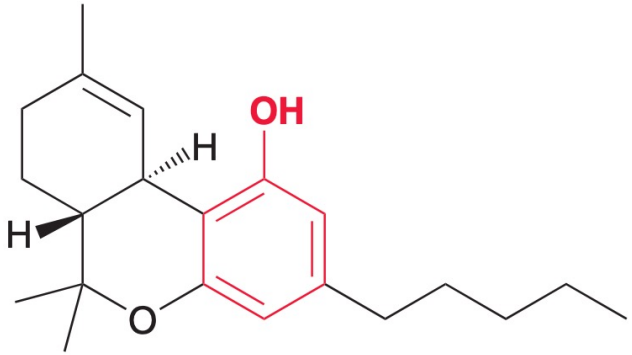
Phenol is a compound that exhibits an OH group connected directly to a phenyl ring.



Phenol



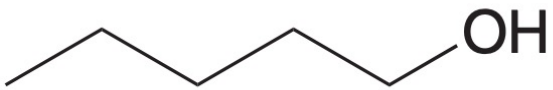
Capsaicin
The compound responsible for the spicy hot flavor of chili peppers



Tetrahydrocannabinol (THC)
The psychoactive drug found in marijuana (cannabis)

- Nomenclature of alcohols
  - follow the rules of alkane nomenclature
  - replace the suffix “e” with “ol”

Pentane



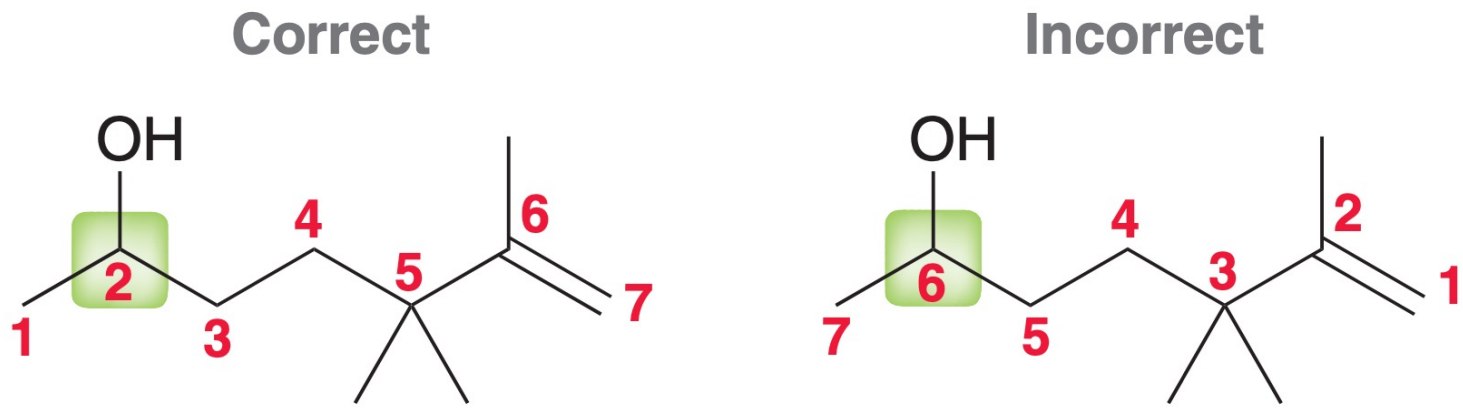
Pentanol

- Identify the longest chain with -OH

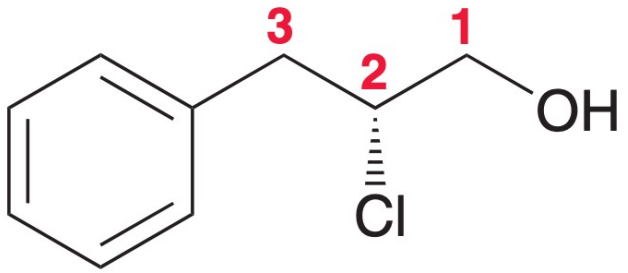
Parent = octane

Parent = hexanol

- -OH should receive the lowest number possible

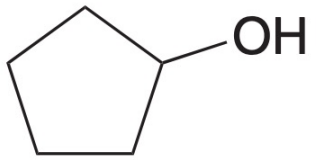


- The chiral center must be indicated

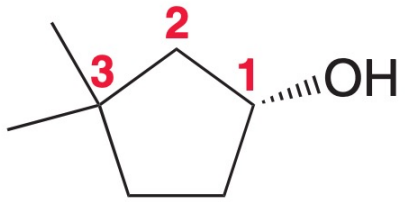


(*R*)-2-Chloro-3-phenyl-1-propanol

- Cyclic alcohol nomenclature



Cyclopentanol

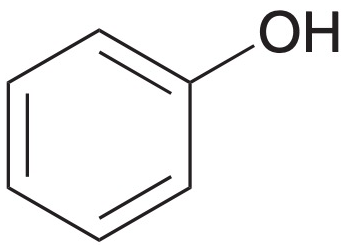


(*R*)-3,3-Dimethylcyclopentanol

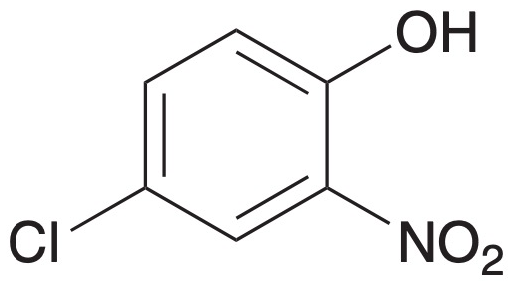
starting with the carbon bearing the hydroxyl group

no need for indicating the number of -OH (for monohydric alcohol)

- Phenols can be treated as parents

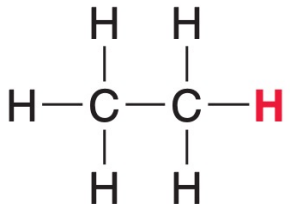


Phenol

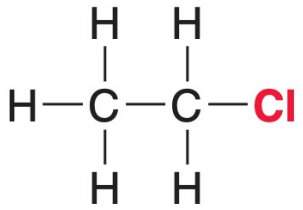


4-Chloro-2-nitrophenol

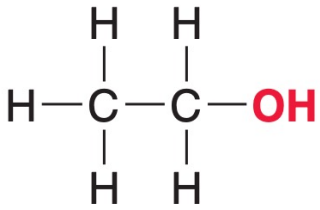
- B.P. of alcohols – IMF contributed



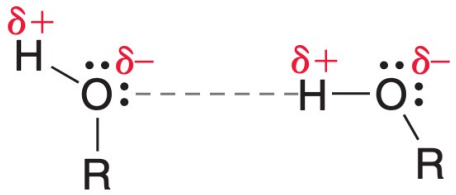
Ethane
bp = –89°C



Chloroethane
bp = 12°C

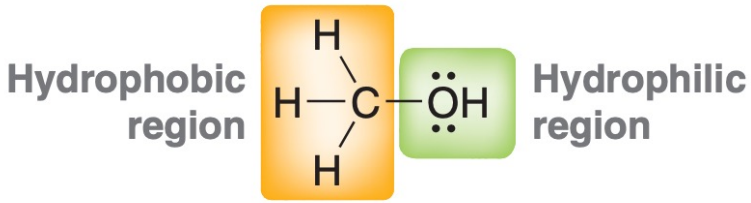


Ethanol
bp = 78°C

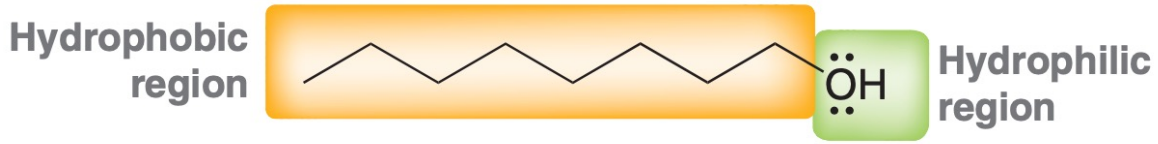


hydrogen bonding

- Solubility and carbon chain length

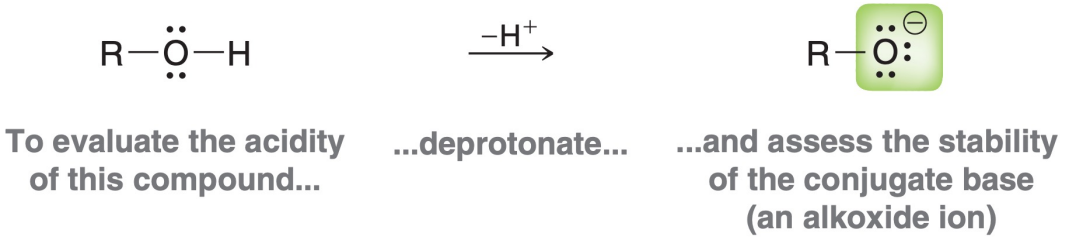


miscible

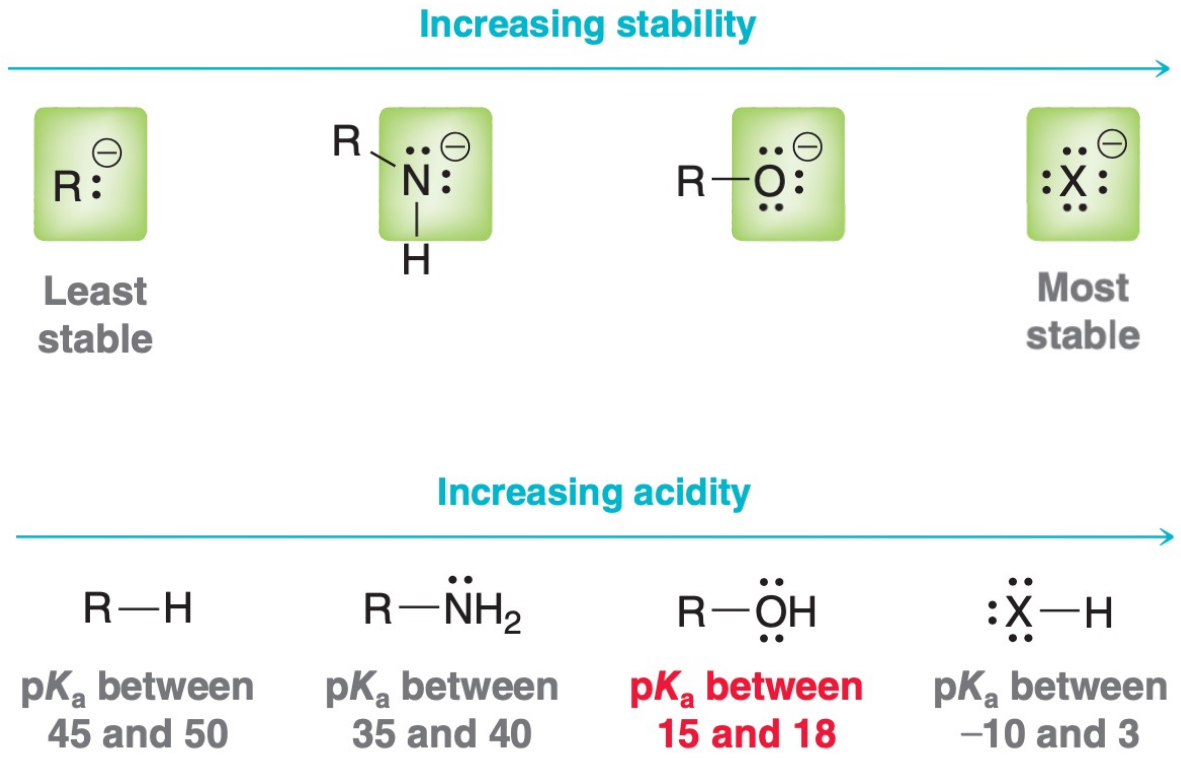


soluble

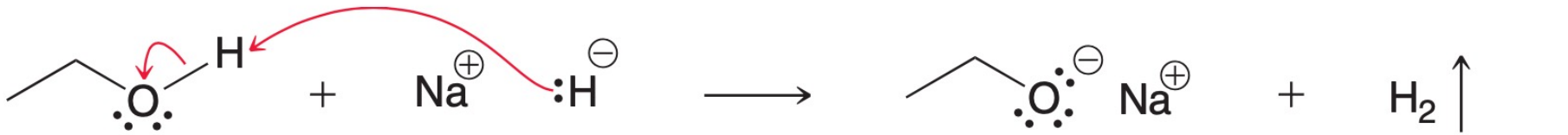
longer carbon chain – larger hydrophobic region – less soluble



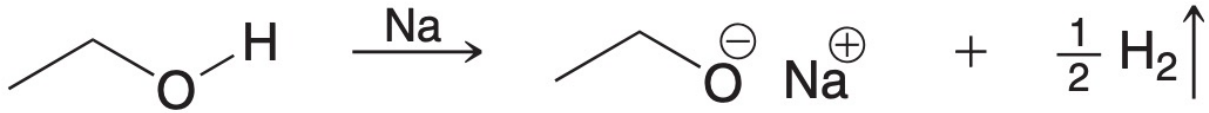
- Acidity of alcohols



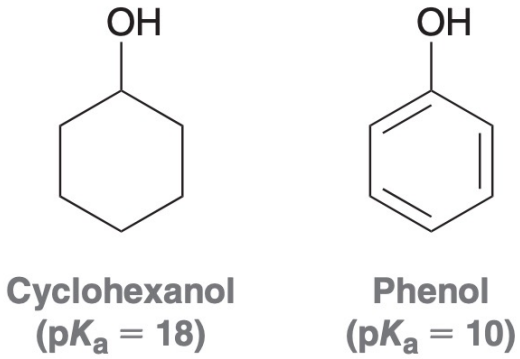
- Reagents for deprotonating an alcohol
  - either use a strong base…



  - …or use metals directly

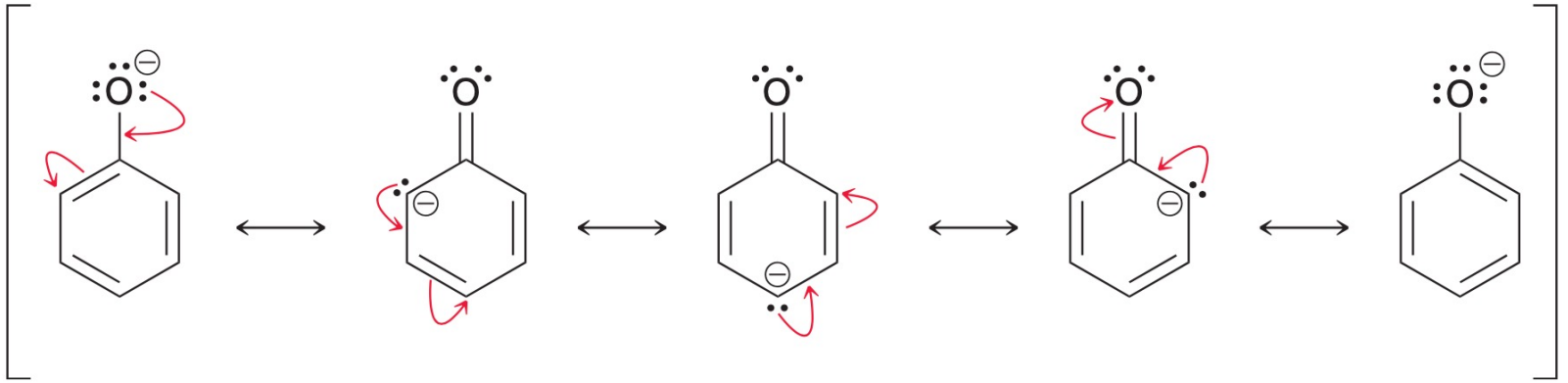


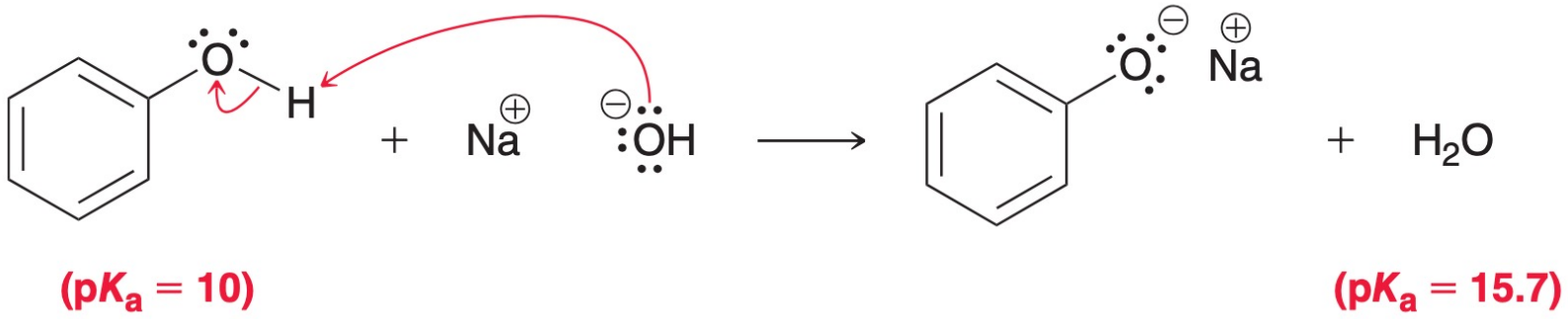
- Resonance stabilization



phenol is 100,000,000 times

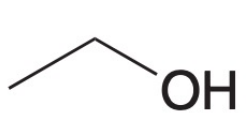
more acidic than cyclohexanol!



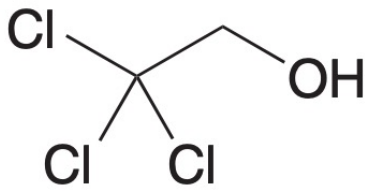


even using NaOH can deprotonate a phenol

- Induction effect



Ethanol
($pK_a = 16$)

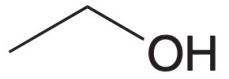


Trichloroethanol
($pK_a = 12.2$)

an alcohol having more electron-withdrawing group (near the α carbon of -OH)

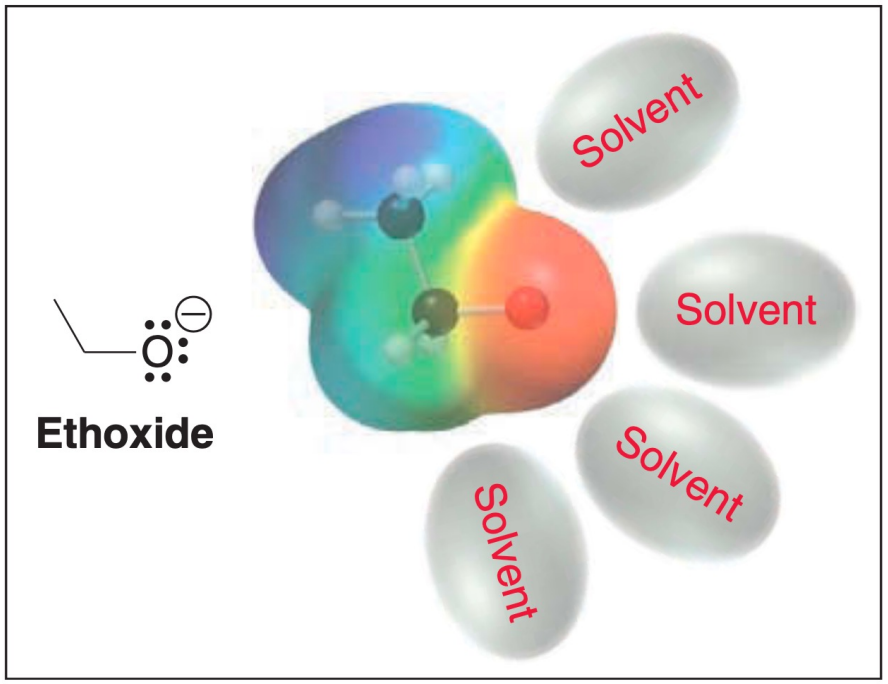
will have a greater acidity

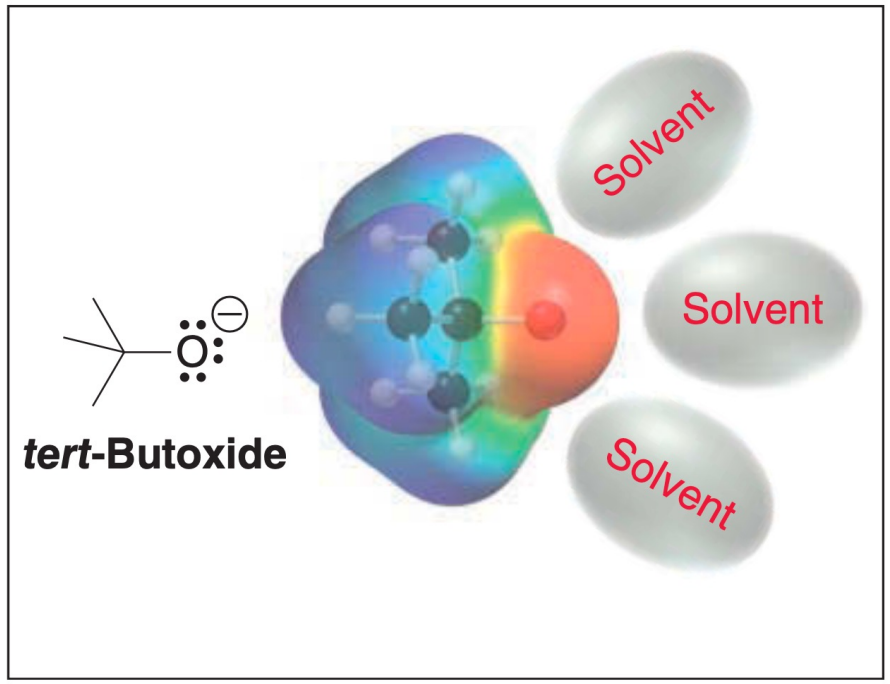
- Solvation effects



Ethanol
($pK_a = 16$)

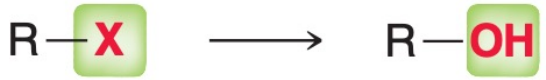
***tert*-Butanol**
($pK_a = 18$)





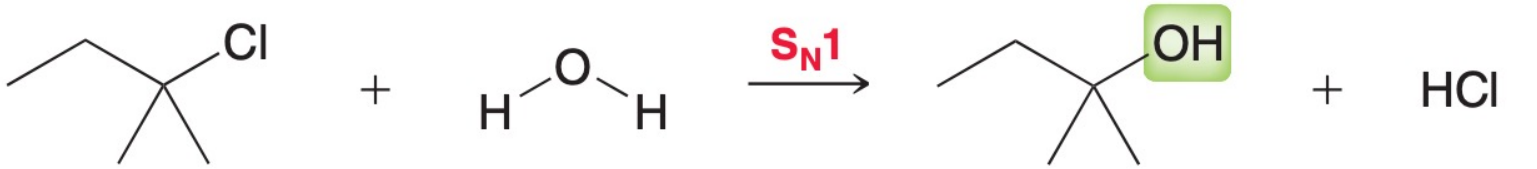
steric hinderance impede the solvation process, thus lowering the acidity

- Using substitution reactions

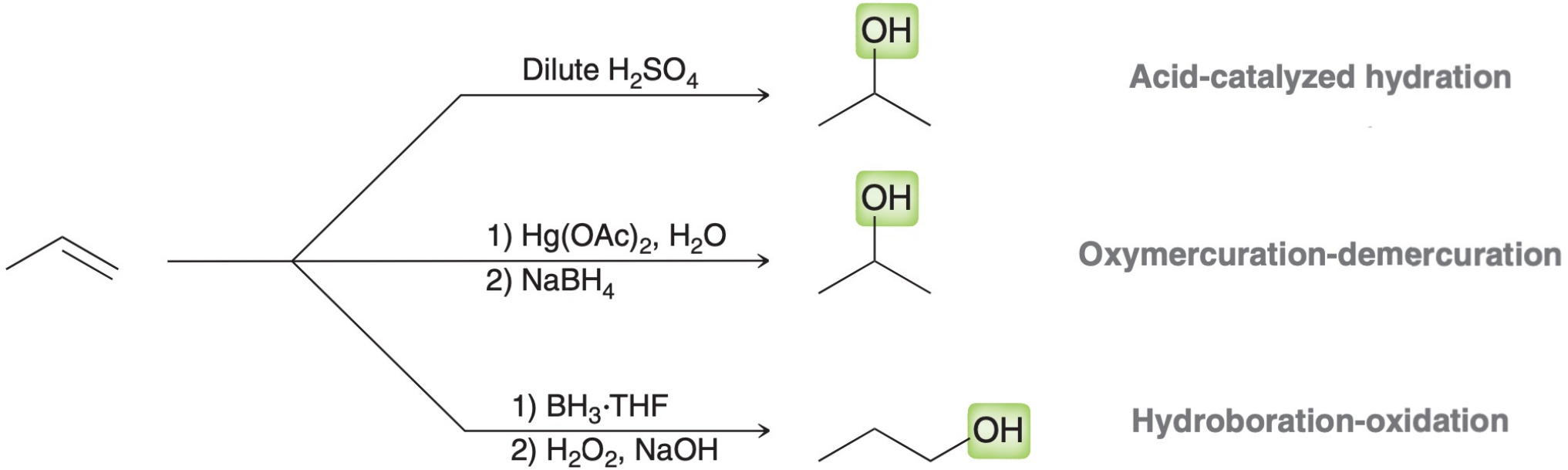


Primary:

Tertiary:



- Using addition reactions

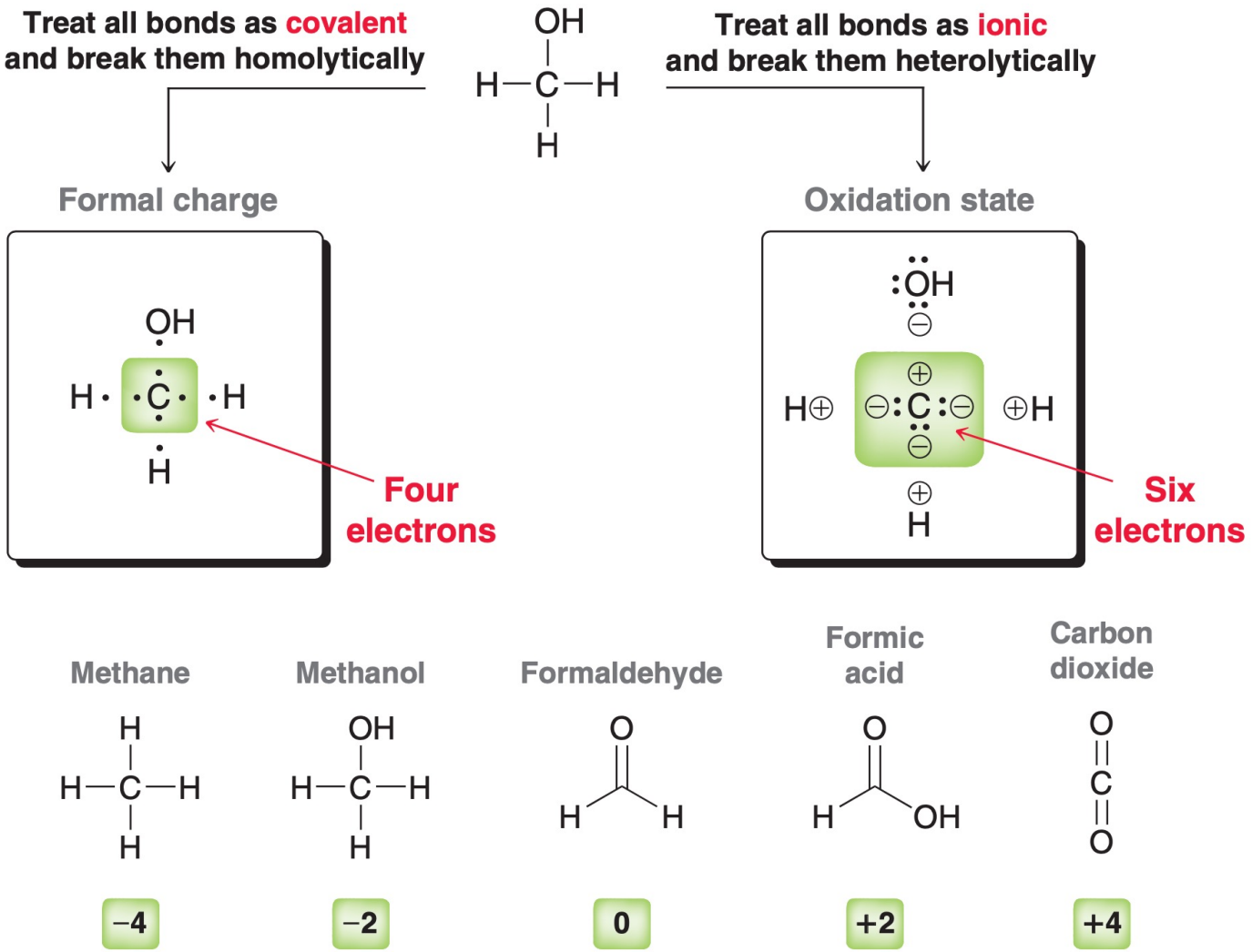


- Preparation via reduction

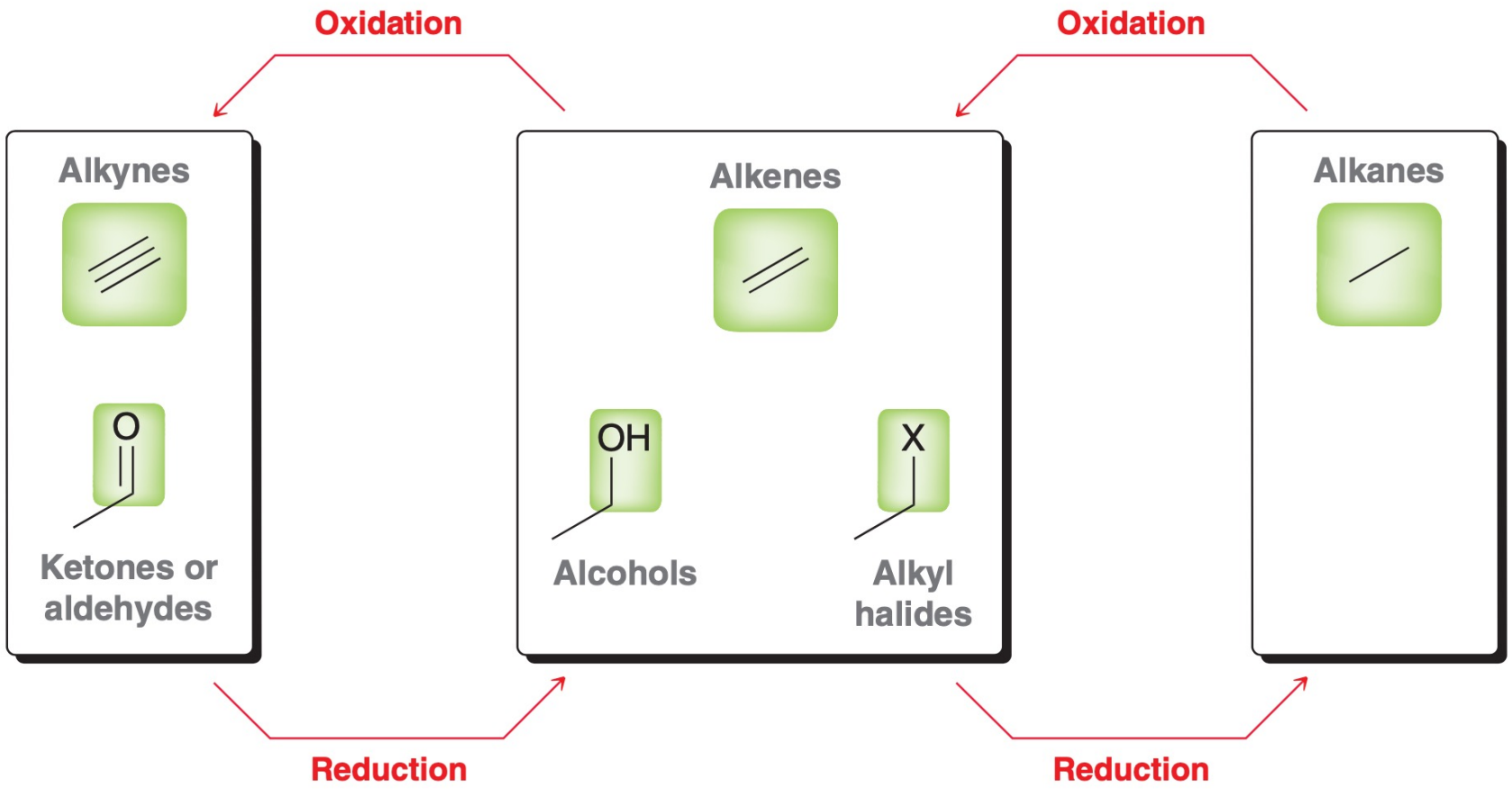
Recall the reduction reaction in your previous class…

What is the reduction reaction in organic chemistry?

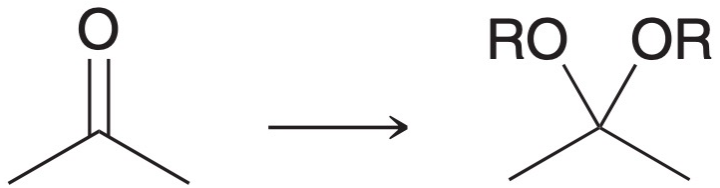
- Oxidation states in organic chemistry

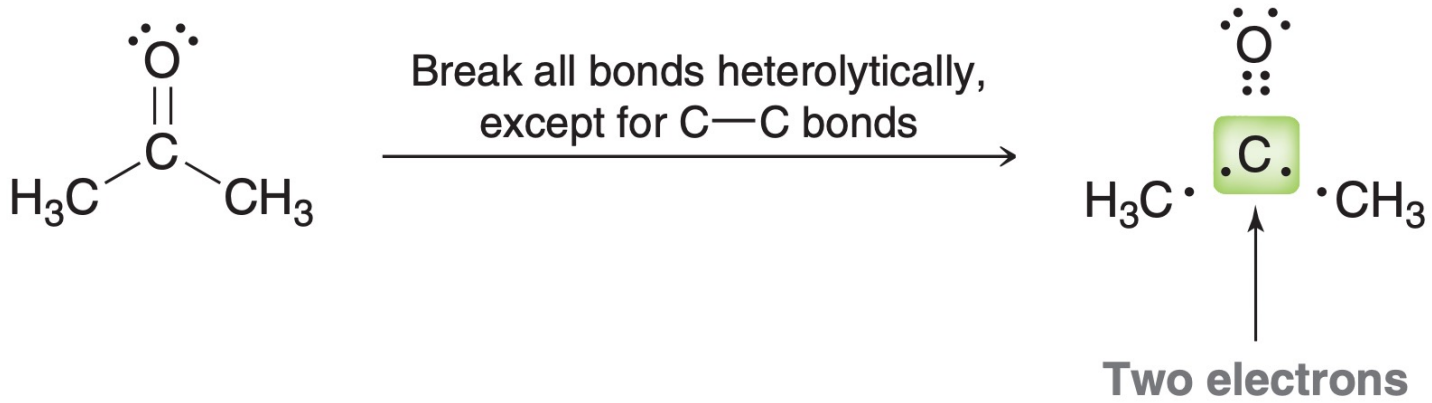


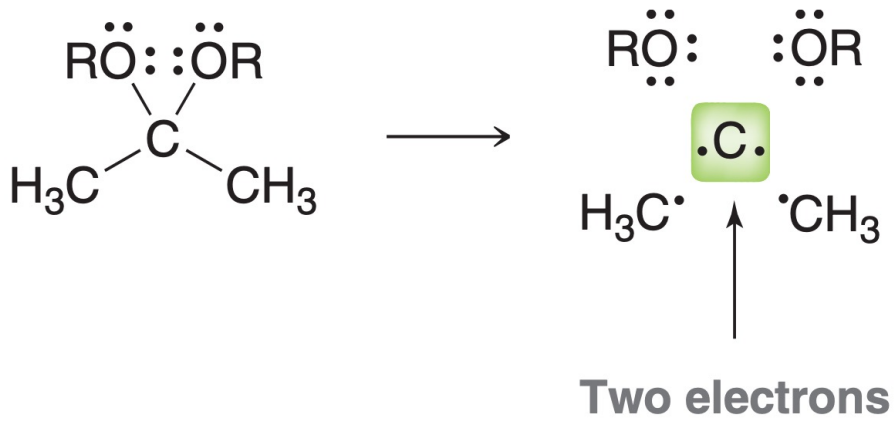
Oxidation States



- Practice: In the following transformation, identify whether the compound has been oxidized, reduced, or neither:

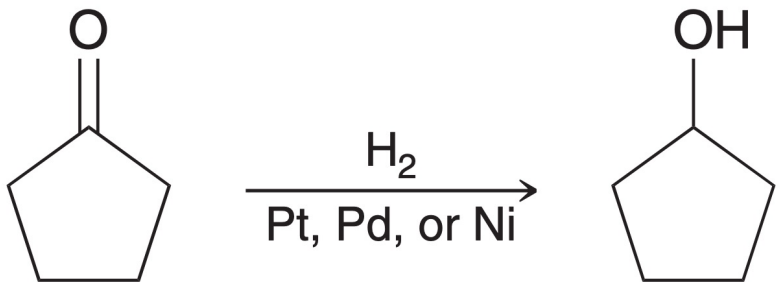



Break all bonds heterolytically,
except for C—C bonds
Two electrons


Two electrons

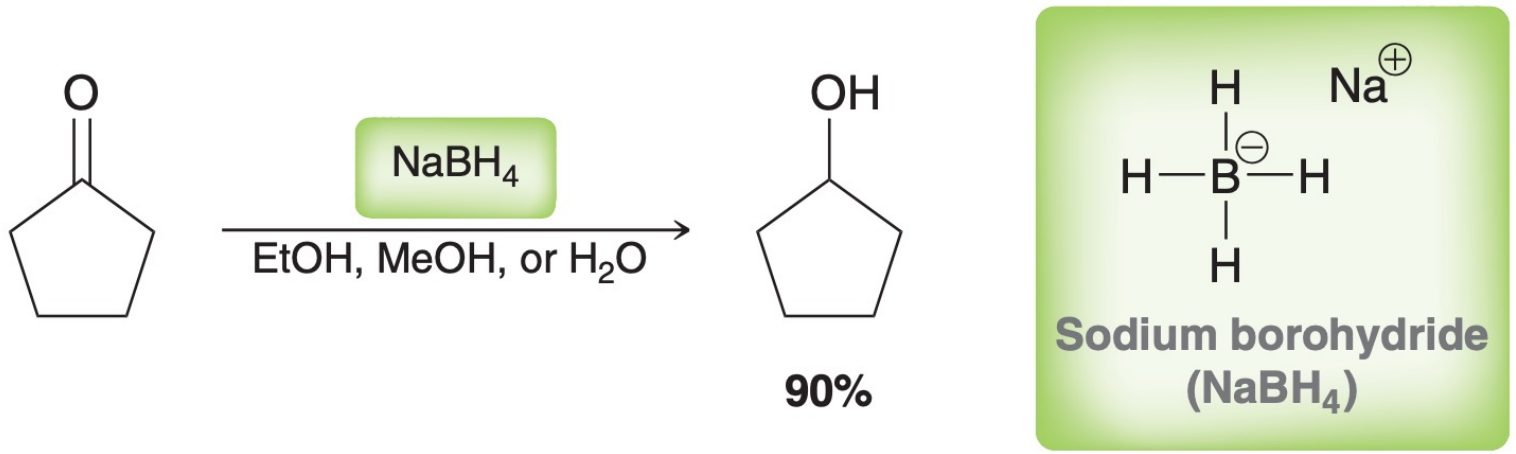
- Reduction of ketones (aldehydes)

- Reducing agents: metal catalyst

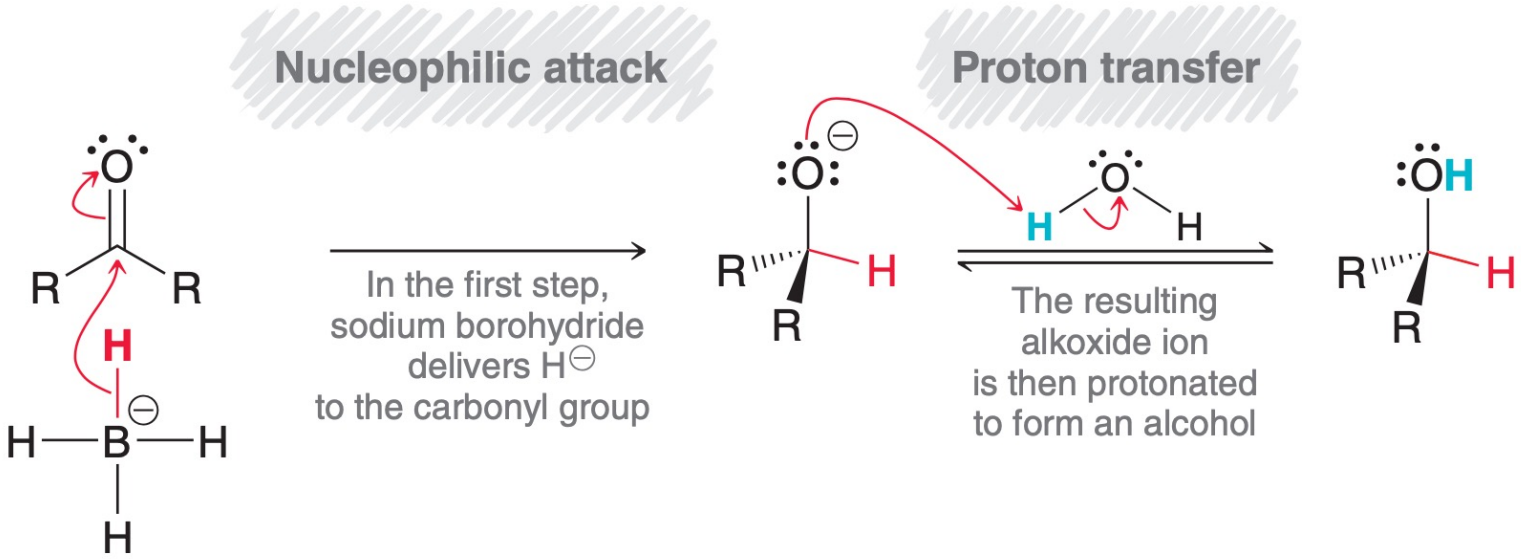


higher temperature and pressure are required!

- Reducing agents: $NaBH_4$

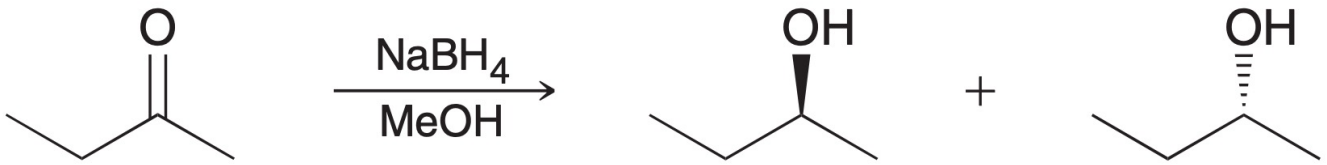


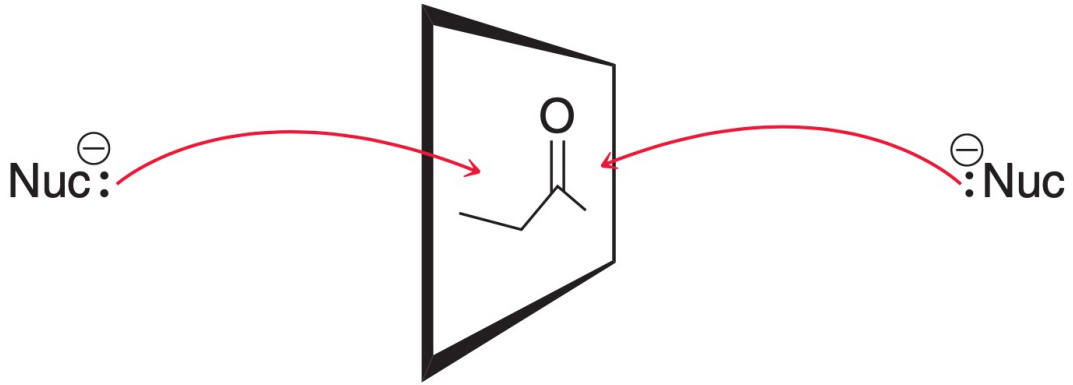
- **Mechanism: Reduction of a Ketone or Aldehyde with $NaBH_4$**



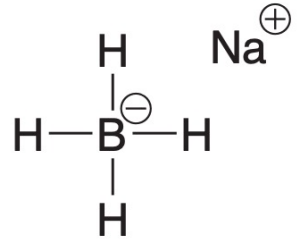
Why this H^- can function as a nucleophile?

- Stereochemistry outcomes of reduction with $NaBH_4$

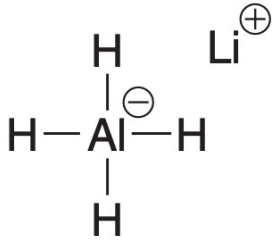




- Reducing agents: $LiAlH_4$

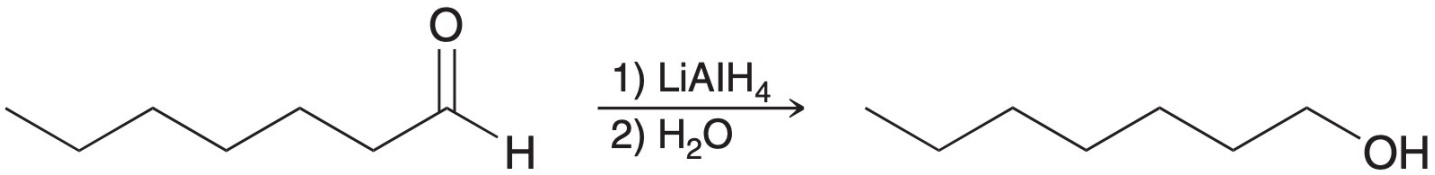


Sodium borohydride ($NaBH_4$)



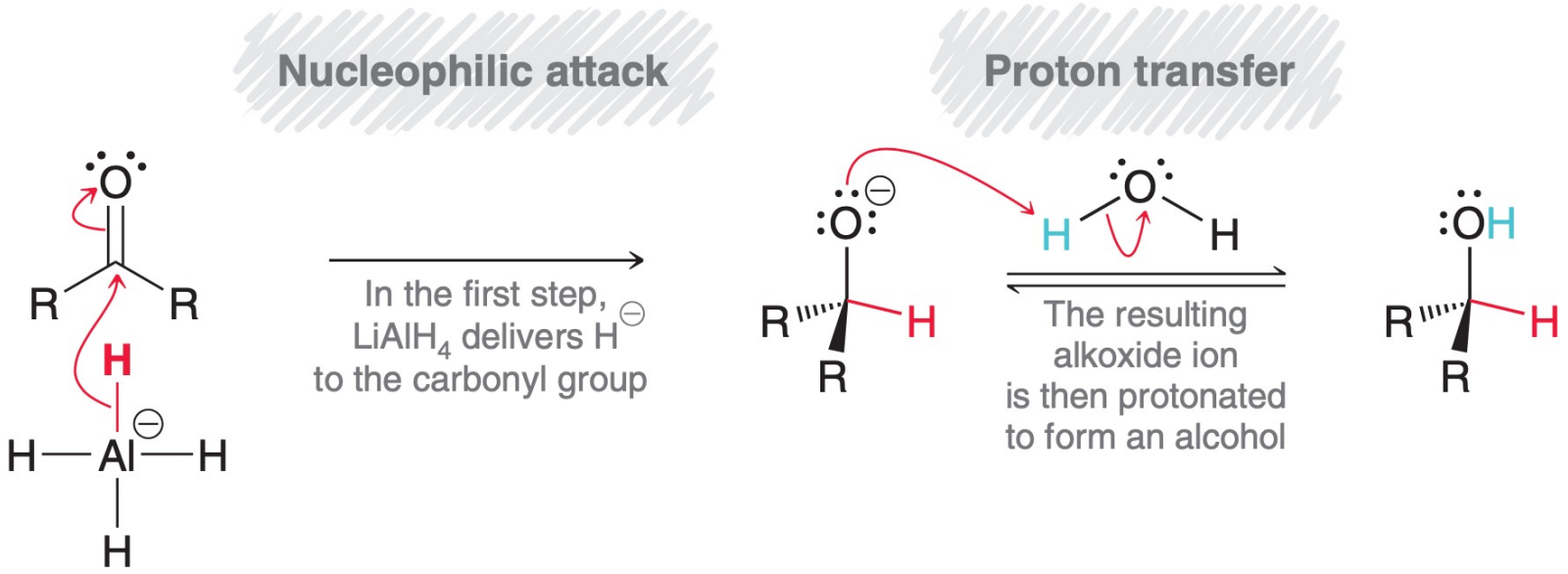
Lithium aluminum hydride ($LiAlH_4$)

abbreviated as LAH

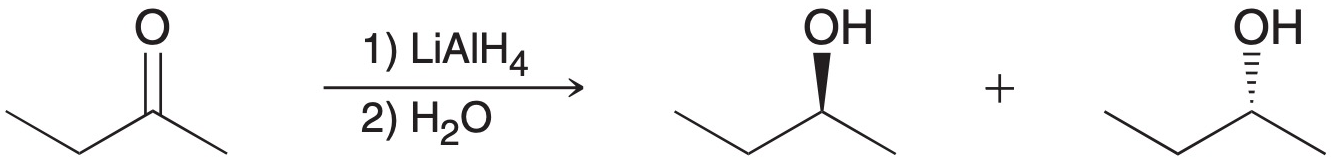


86%

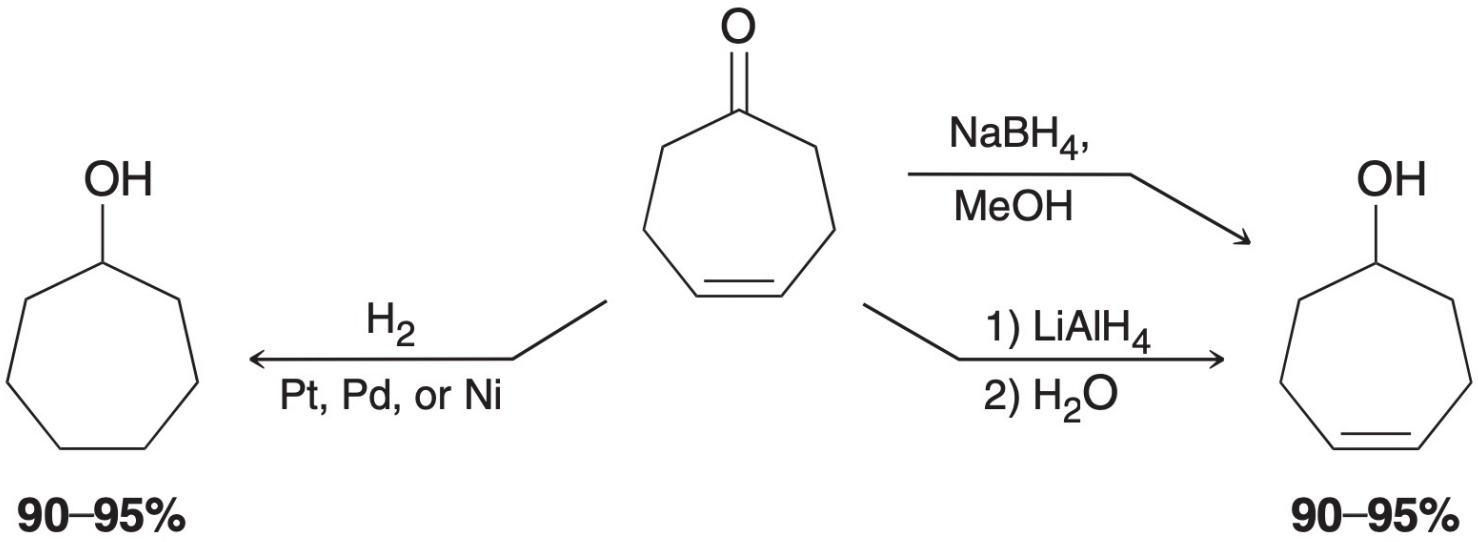
- **Mechanism: Reduction of a Ketone or Aldehyde with $LiAlH_4$**



- Stereochemistry outcomes of reduction with $LiAlH_4$



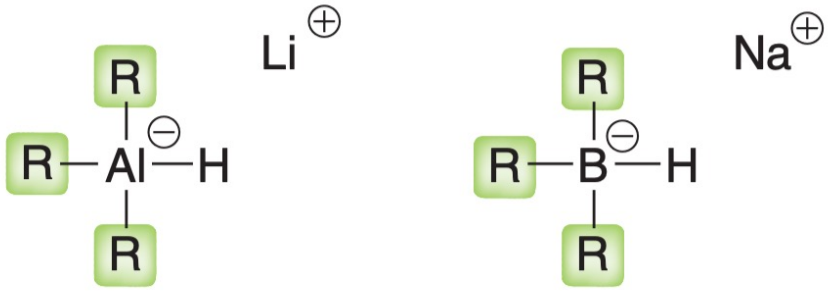
- Selectivity of hydride reduction



metal-catalyzed reduction **prefers** to reduce **non-polar** double bond

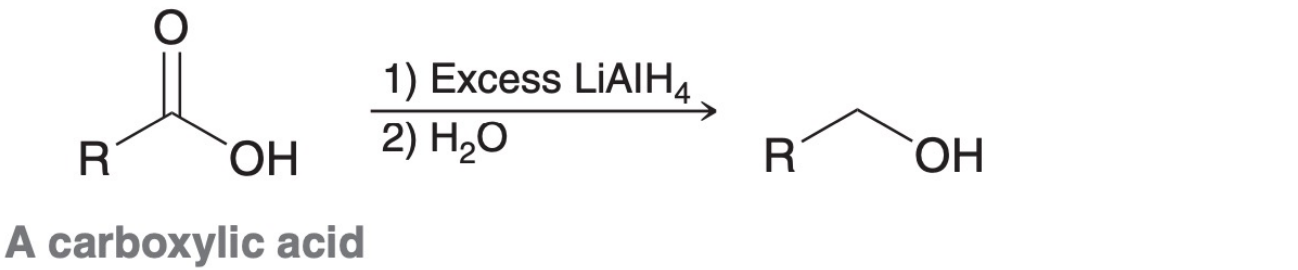
hydride reduction **only** reduces **polar** double bond

- Modified reducing agents

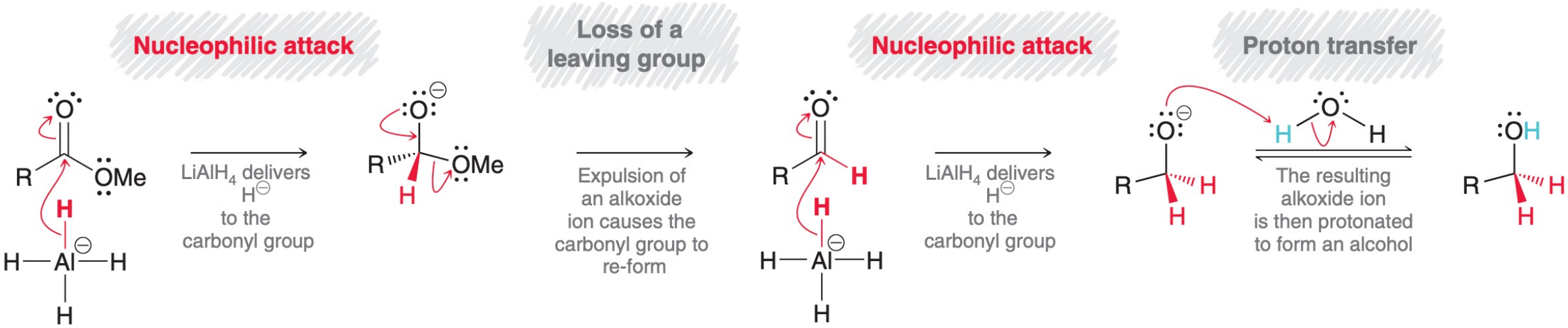


Change R group to…	
…an electron-donating group:	…an electron-withdrawing group:
alkyl group / amino group / alkoxy group…	cyano group / nitro group / acyl group…
…it will increase the reactivity of this reducing agent.	…it will decrease the reactivity of this reducing agent.

- Reduction of carboxylic acids and esters by using $LiAlH_4$



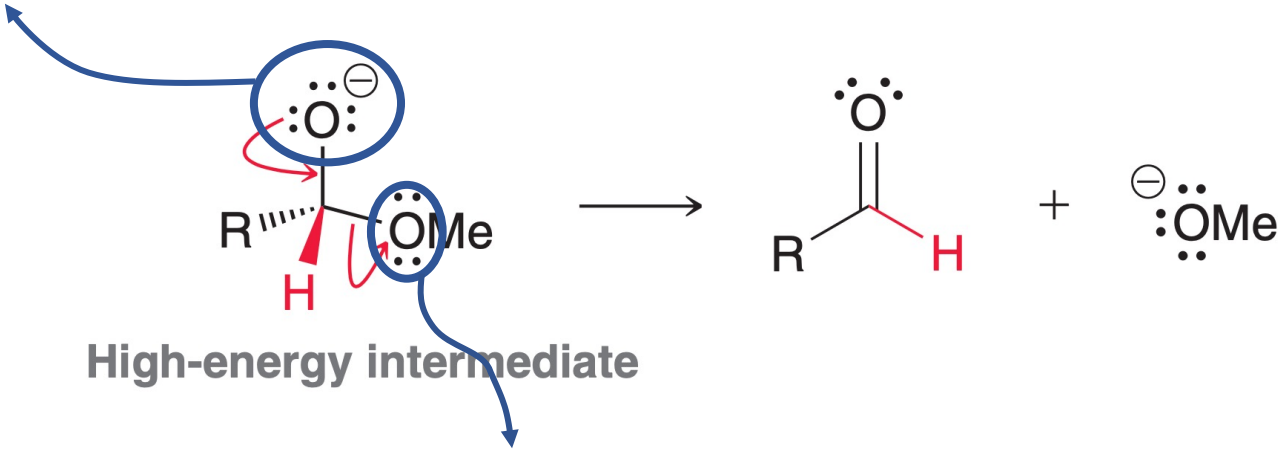
- **Mechanism: Reduction of an Ester or Aldehyde with $LiAlH_4$**



- Why -OR can function as a leaving group?

this oxygen contains negative charge

the LG form is O^{2-}, which is very unstable!

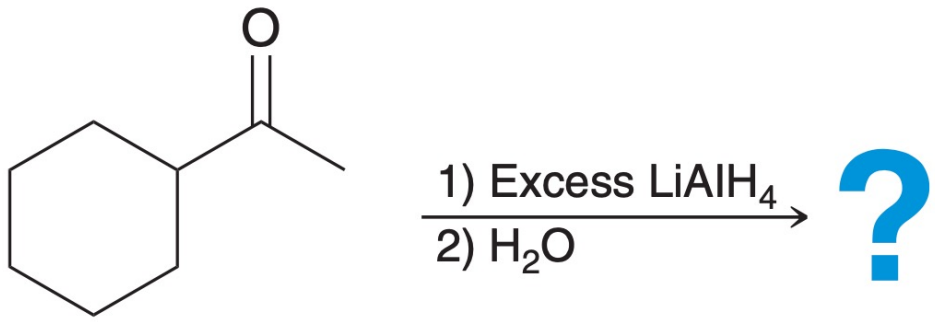


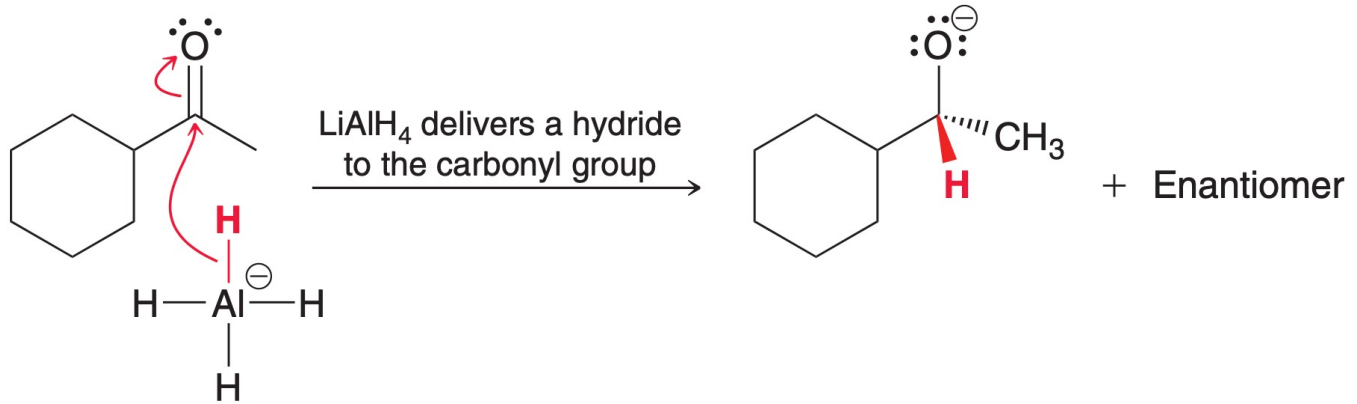
this oxygen links to an methyl group – it is neutral

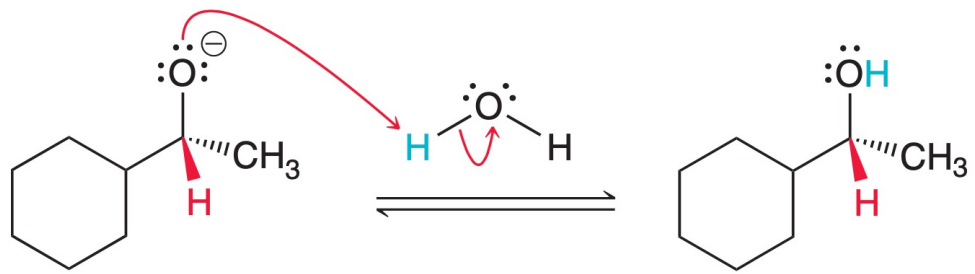
the LG is MeO^-, which is relatively stable (than O^{2-})

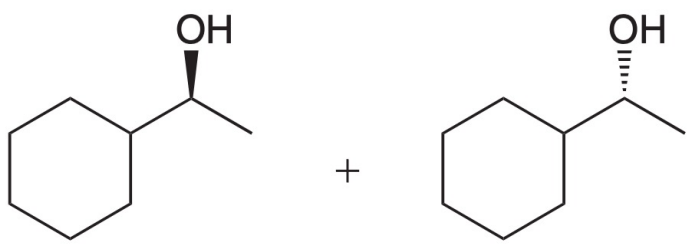
thus, the negative charge will transfer to -OMe, causing a loss of a leaving group

- Practice: draw a mechanism and predict the product for the following reaction:

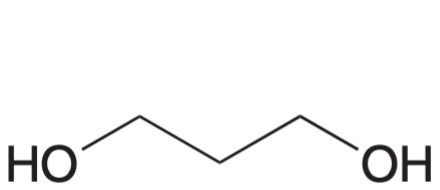



LiAlH4 delivers a hydride
to the carbonyl group
+ Enantiomer

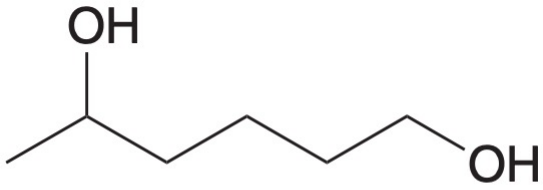

+ Enantiomer
+ Enantiomer


OH
OH

- Diols and their nomenclature
  - identify the position of both hydroxyl groups
  - add the suffix “diol” to the end of the name



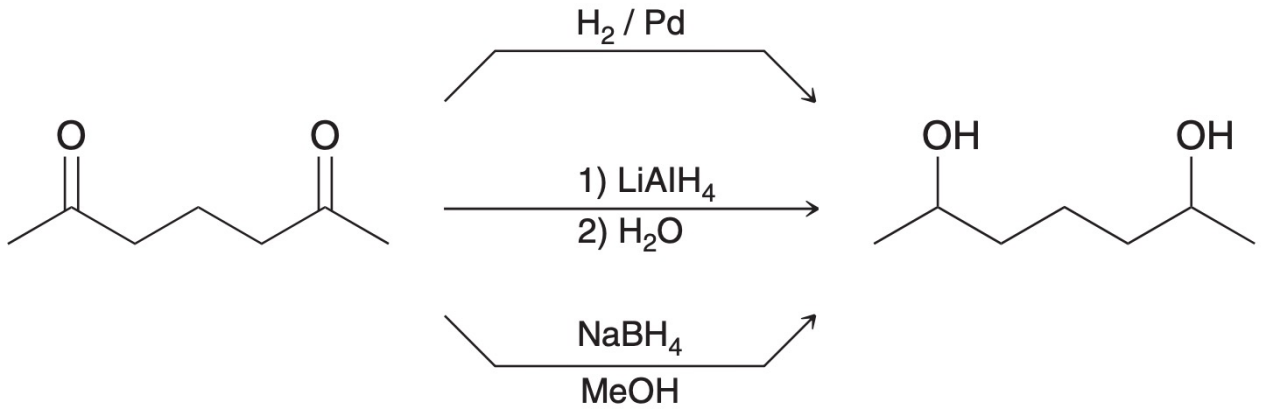
1,3-Propanediol



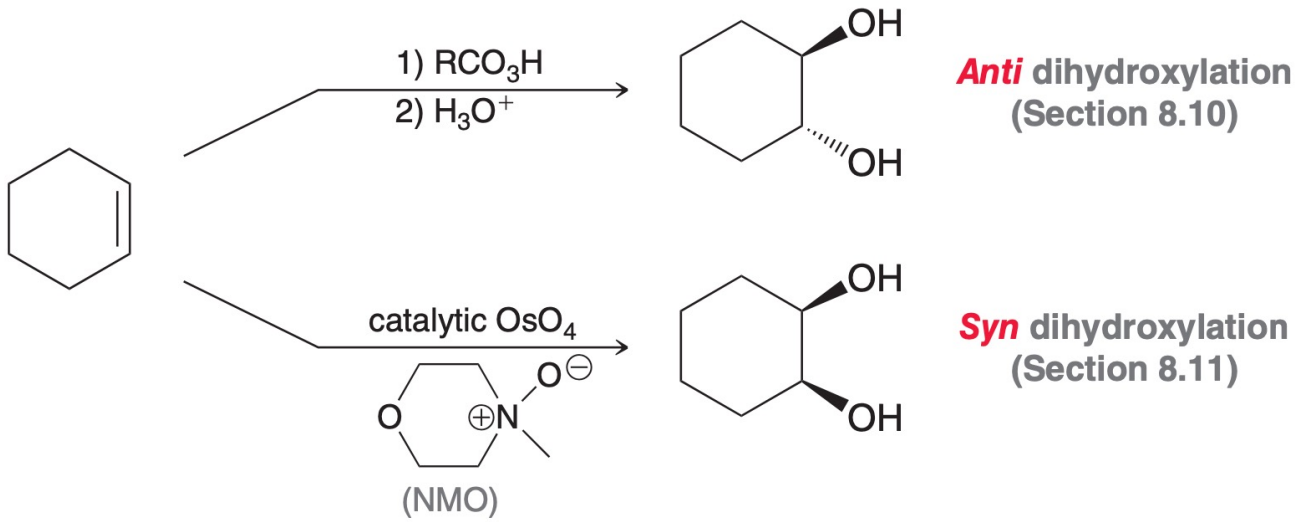
1,5-Hexanediol

- Preparation of diols

via reduction of diketones



via dihydroxylation of an alkene

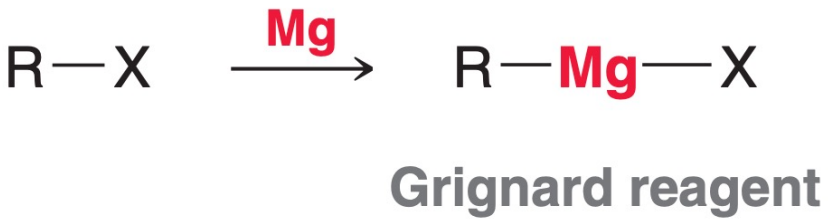


Anti **dihydroxylation (Section 8.10)**

Syn **dihydroxylation (Section 8.11)**

- Grignard Reagents

A Grignard reagent is formed by the reaction between an alkyl halide and magnesium.

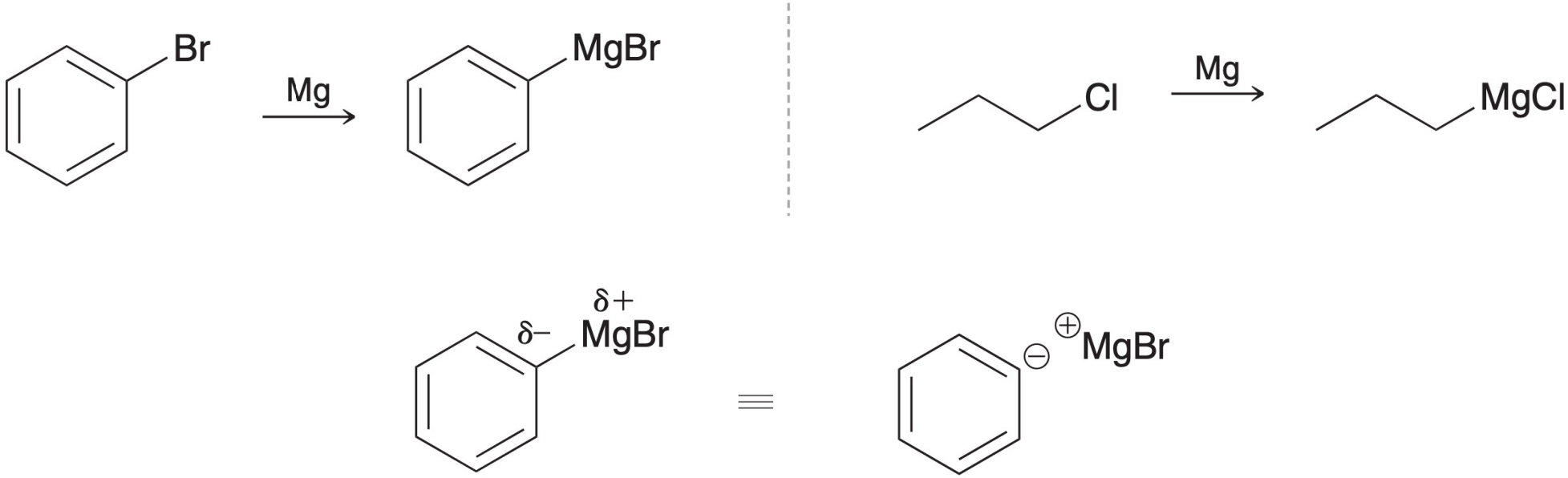


Nobel Prize in 1912

François Auguste Victor Grignard

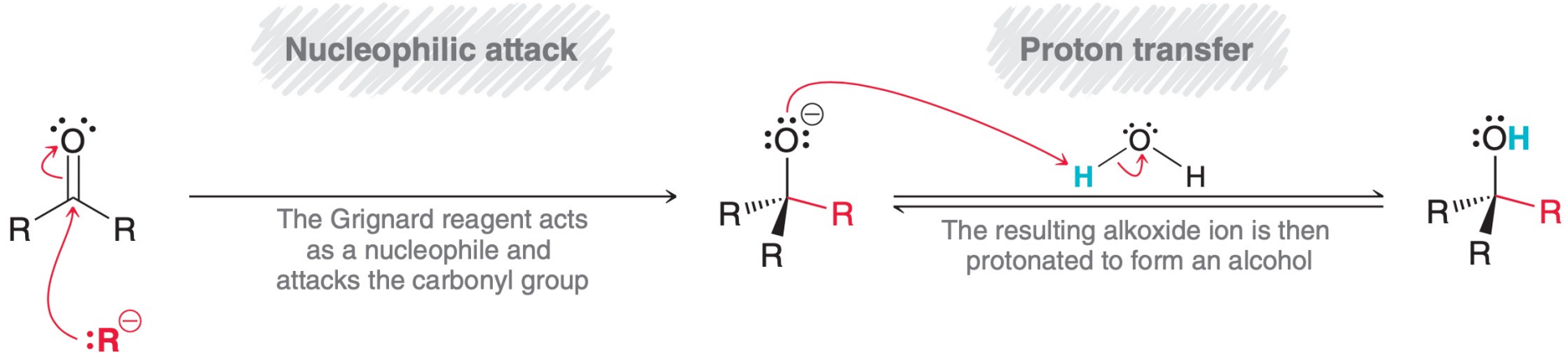
(1871-1935)

- Examples of Grignard reagents

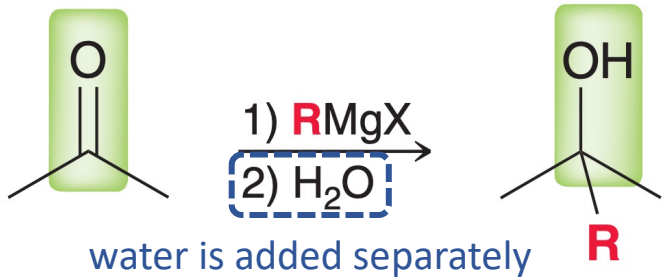


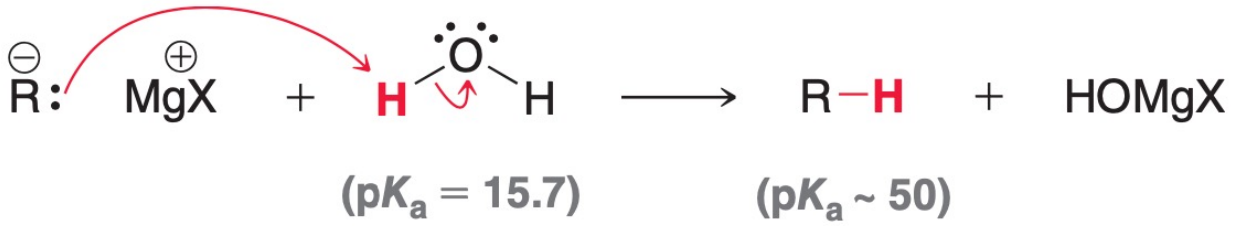
the bond between C and Mg can be represented by either covalent form or ionic form

- **Mechanism: The Reaction between a Grignard Reagent and a Ketone or Aldehyde**



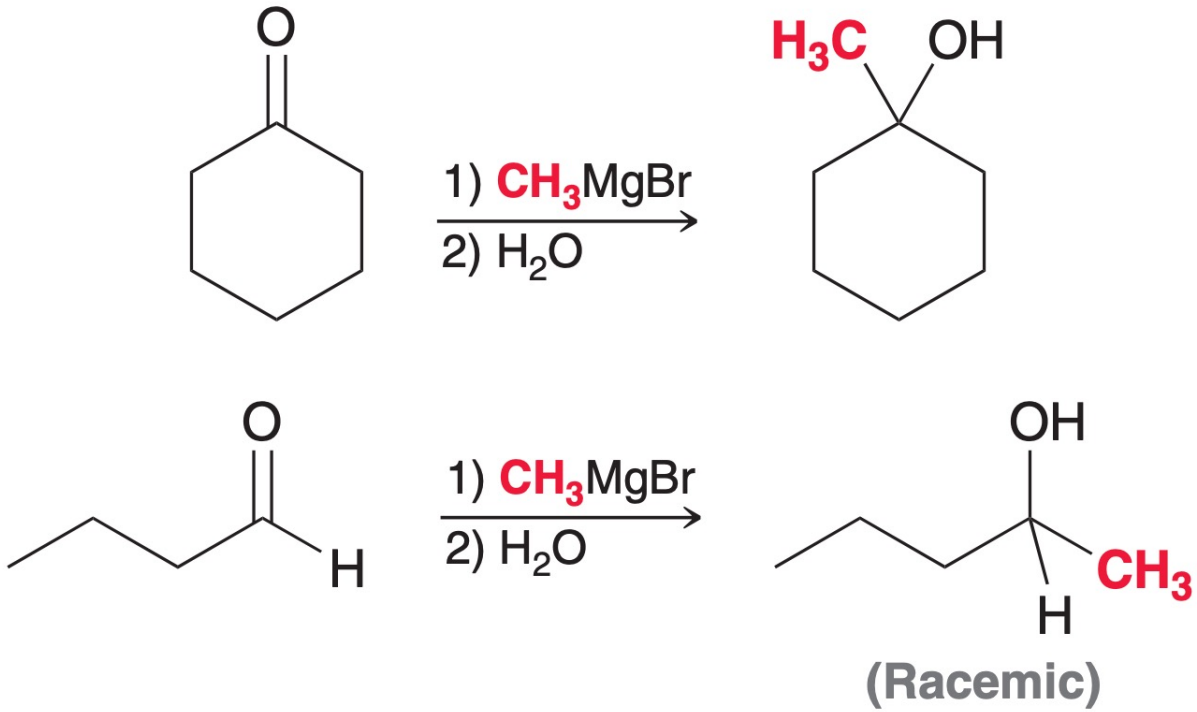
- Preparation via Grignard Reagents



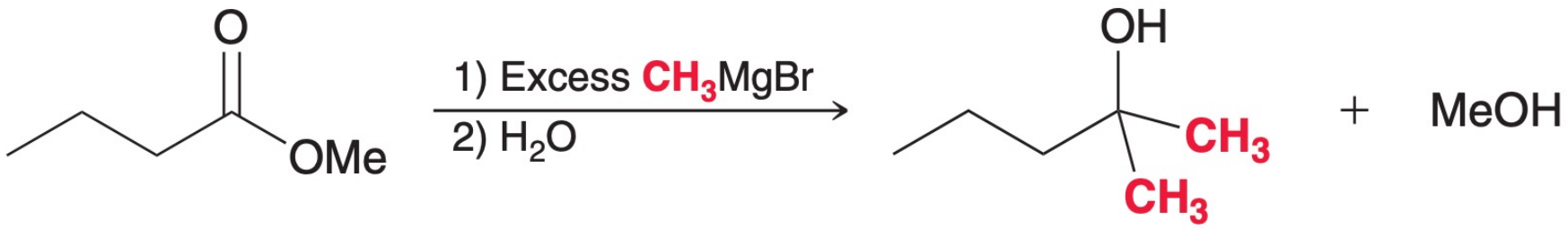


Grignard reagent is also a strong base and will deprotonate water!

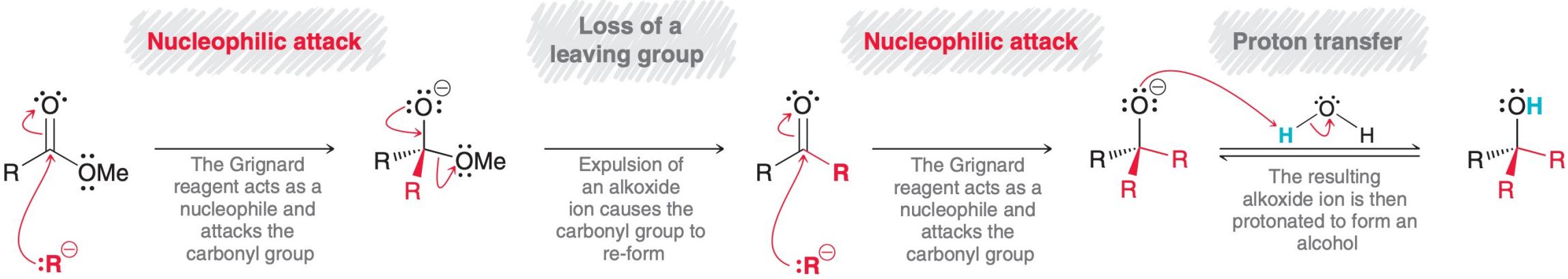
- More examples…



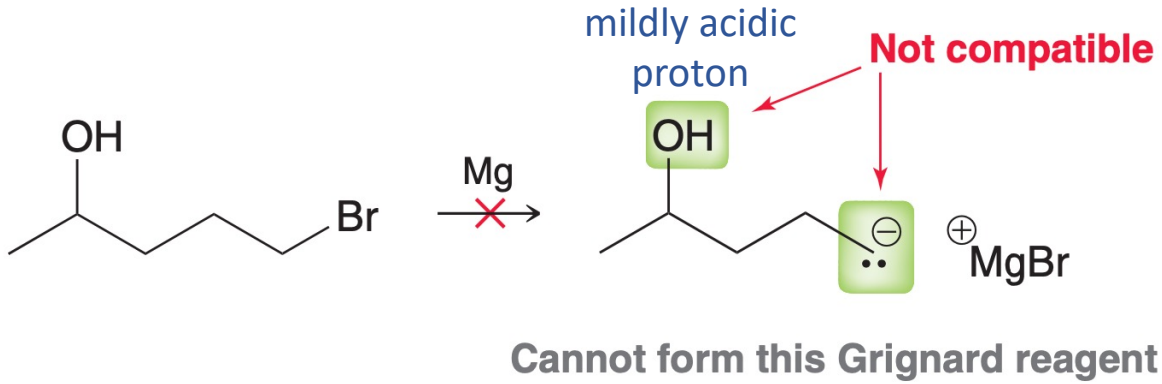
- Grignard reaction of esters



- **Mechanism: The Reaction between a Grignard Reagent and an Ester**

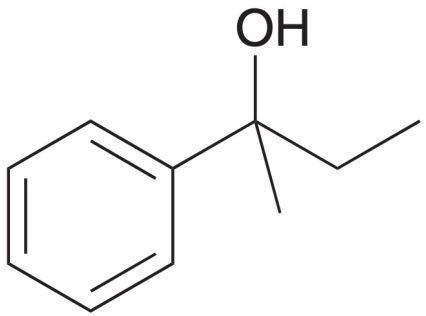


- Grignard reagents are incompatible with acidic protons

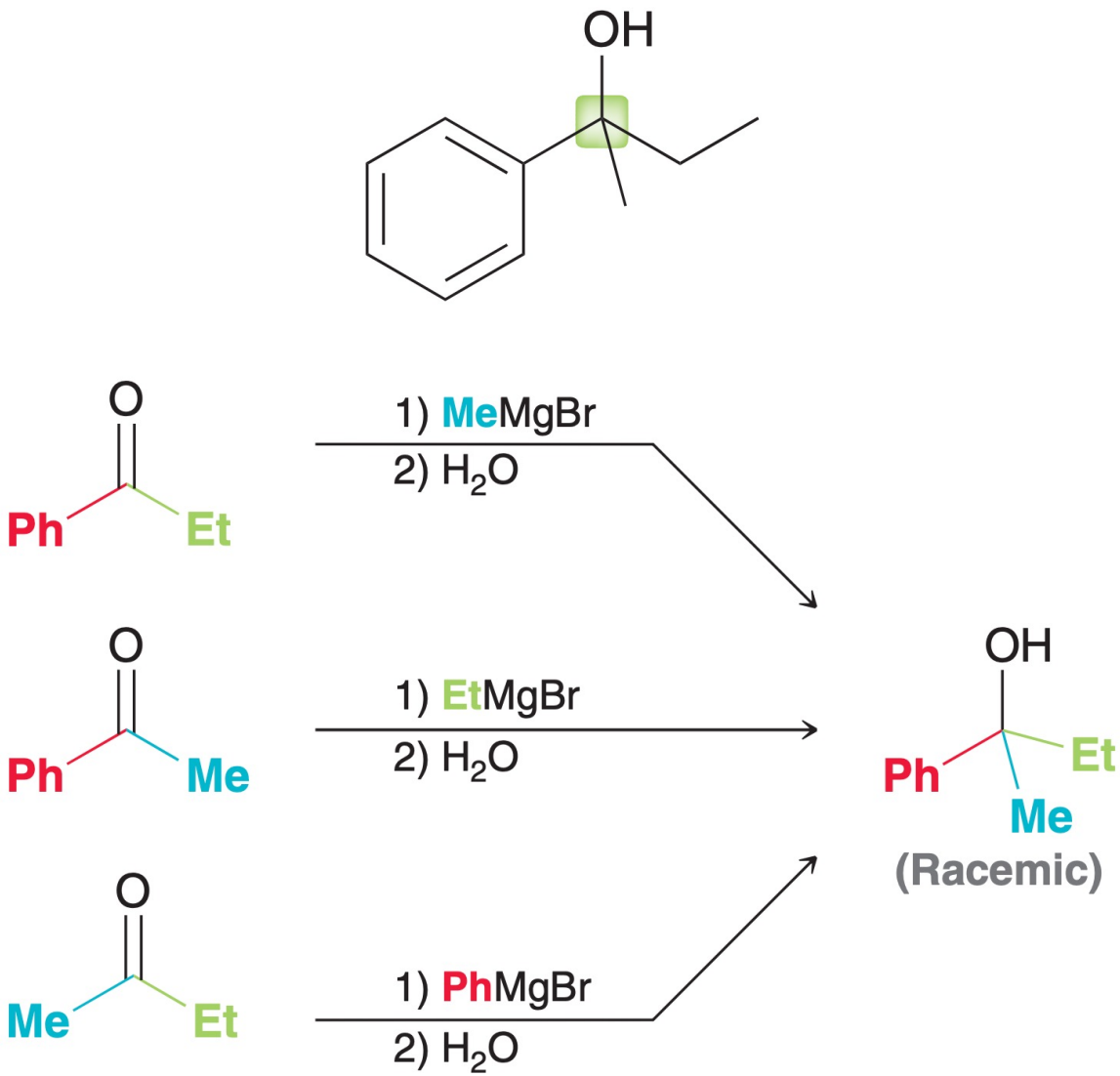


even mildly acidic protons are not compatible!

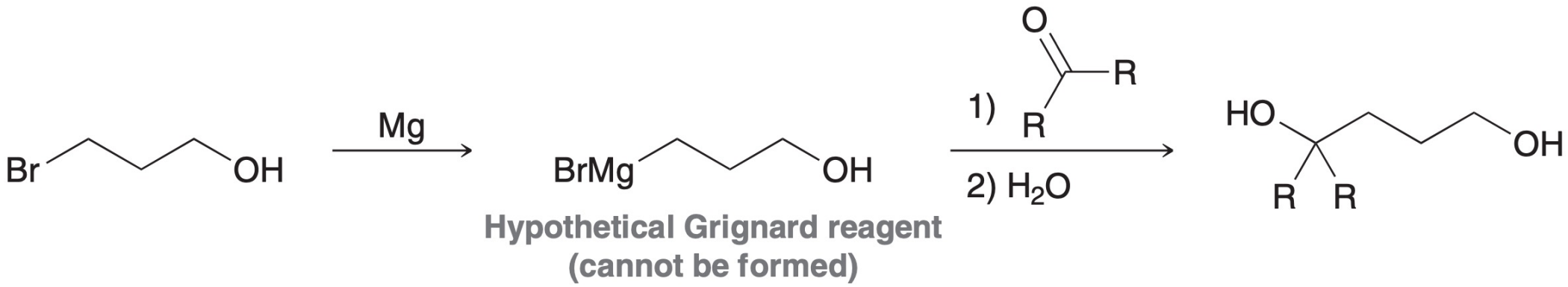
- Practice: show how you would use a Grignard reaction to prepare the following compound:



(Racemic)

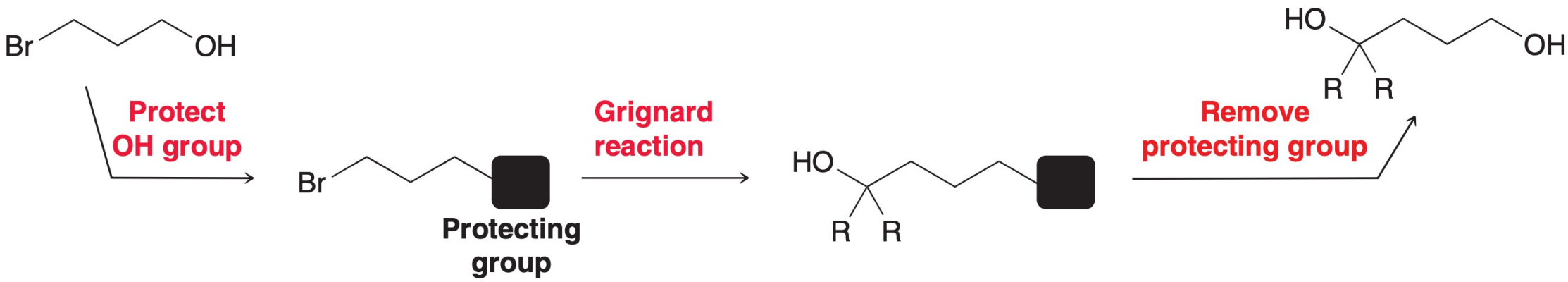

OH
O
Ph
Et
1) MeMgBr
2) H2O
O
Ph
Me
1) EtMgBr
2) H2O
O
Me
Et
1) PhMgBr
2) H2O
OH
Ph
Et
Me
(Racemic)

- How to make this reaction practical?

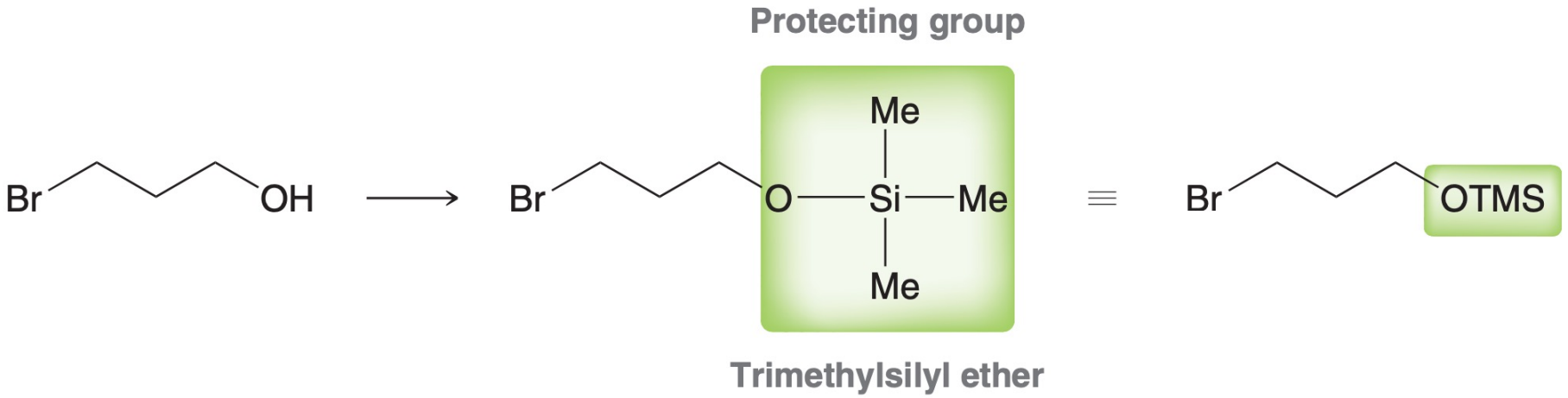


- Using protecting group to accomplish the reaction

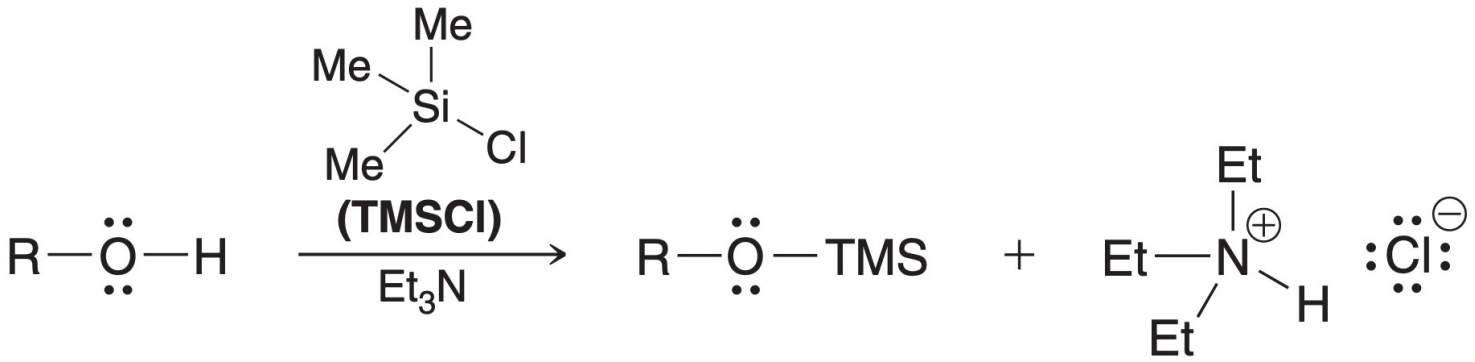
1. Protect the hydroxyl group by removing its proton and converting the hydroxyl group into a new group, called a **protecting group**, that is compatible with a Grignard reagent.
2. Form the Grignard reagent and perform the desired Grignard reaction.
3. Deprotect, by converting the protecting group back into a hydroxyl group.



- Silyl ether protecting groups



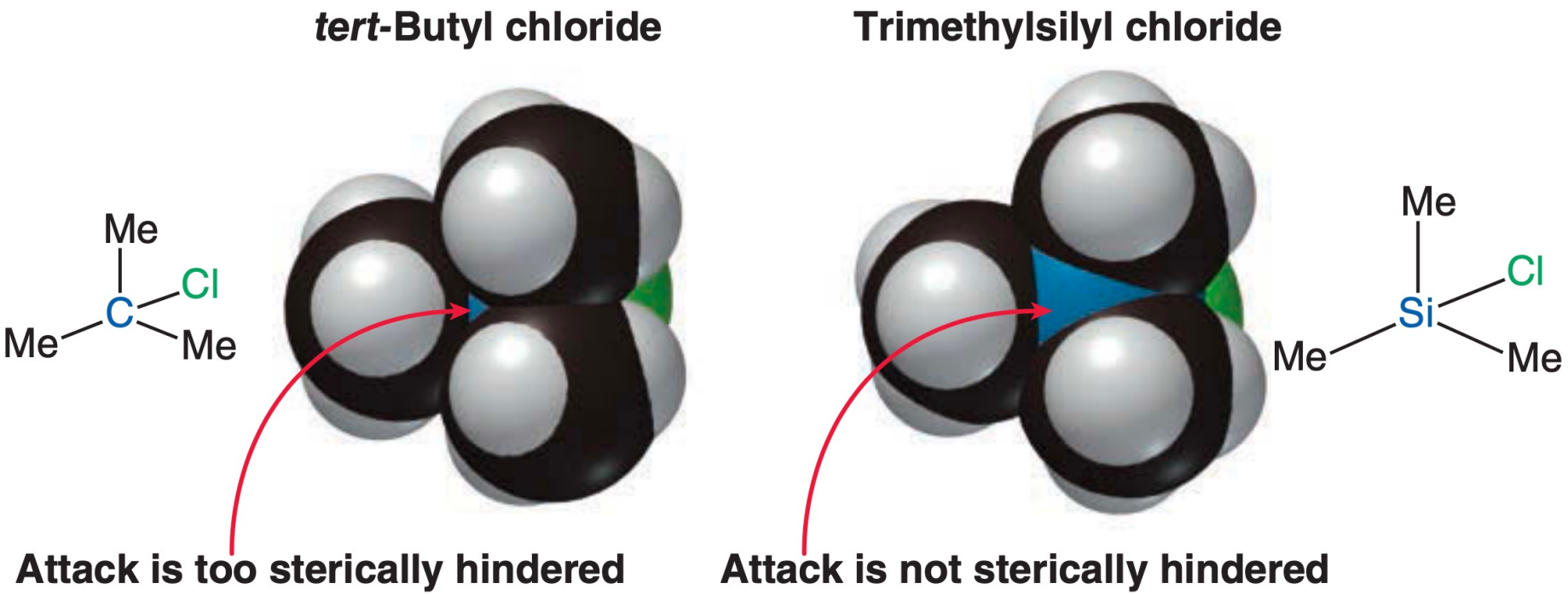
- Installation of the protecting group



TMSCl: trimethylsilyl chloride

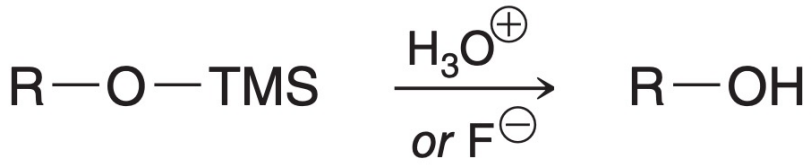
This is a S_N2-like process (called S_N2-Si): OH is the nucleophile, Cl is the leaving group…

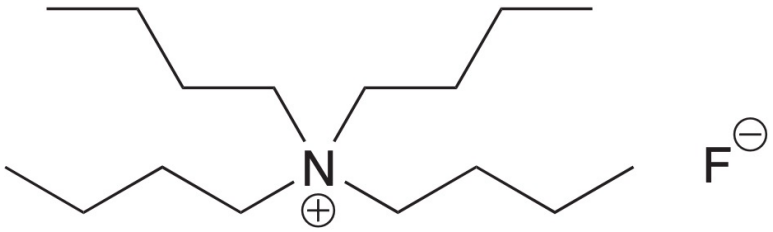
…but why S_N2 can occur at a **tertiary substrate**?



silicon atom is larger than carbon!

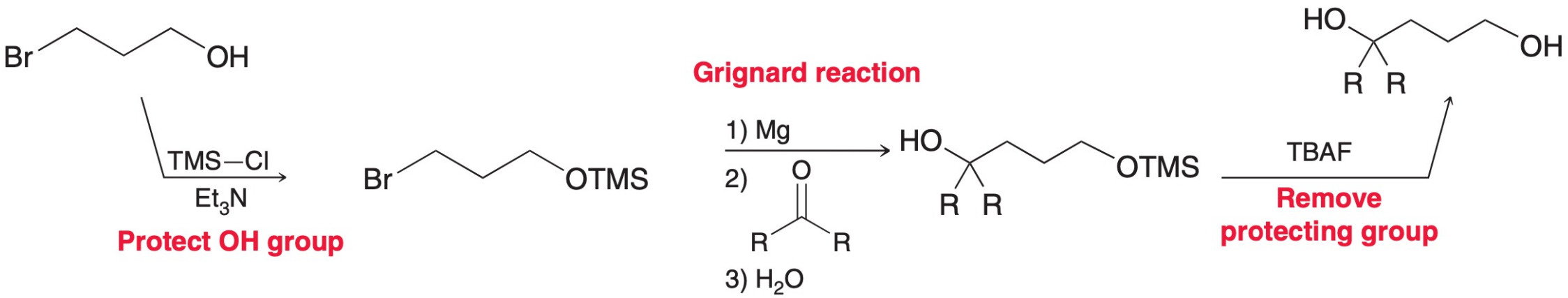
- Removal of the protecting group



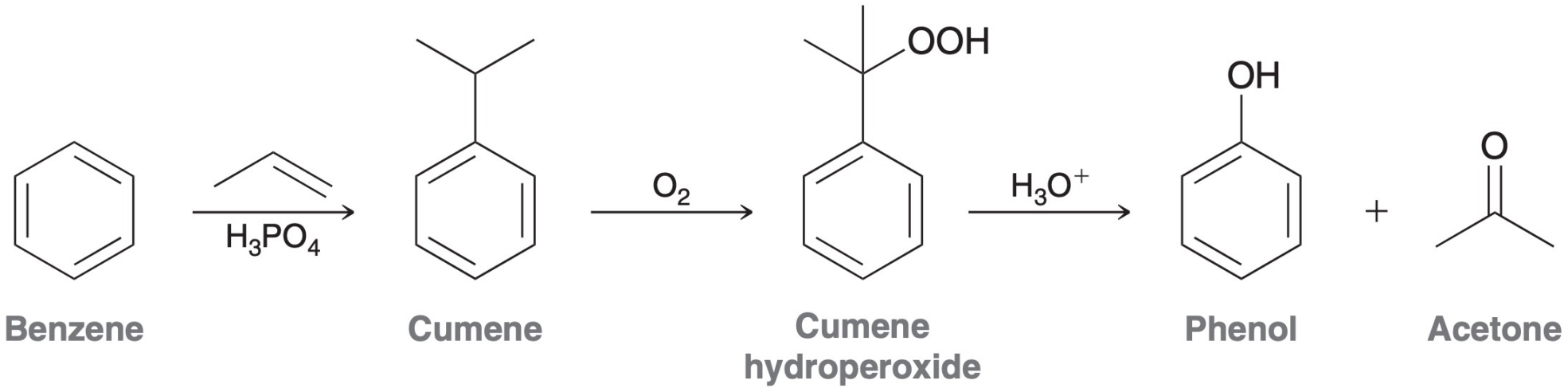


Tetrabutylammonium fluoride (TBAF)

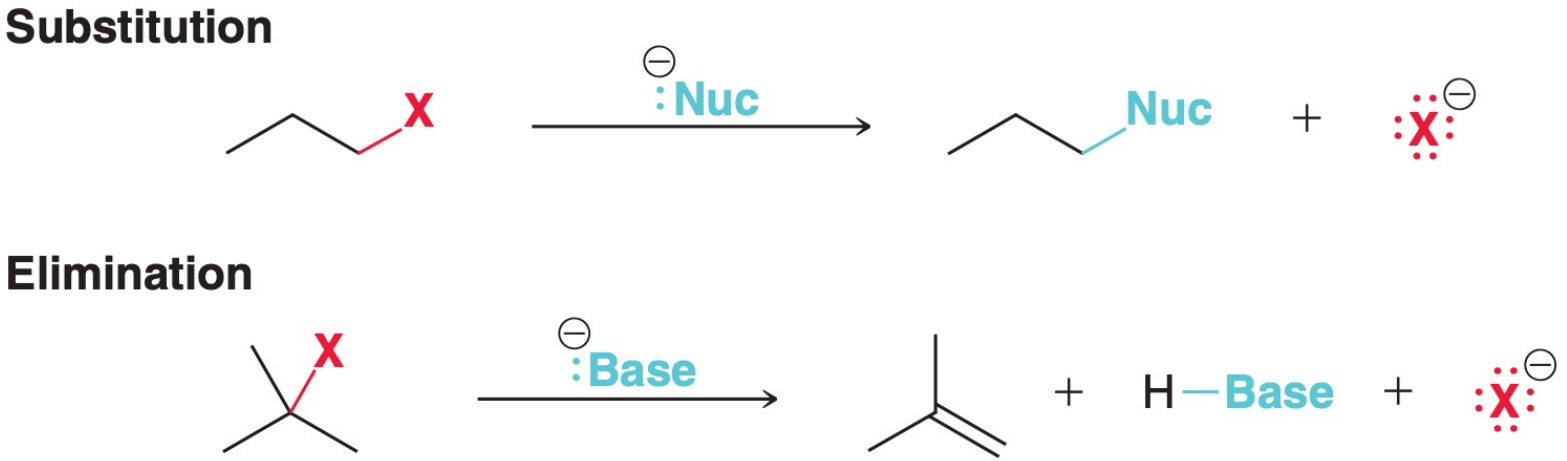
- An overall process using hydroxyl-protecting strategy



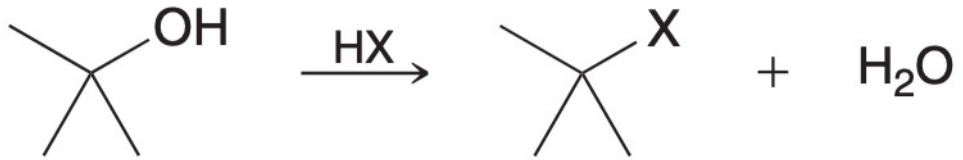
- Industrial synthesis of phenols

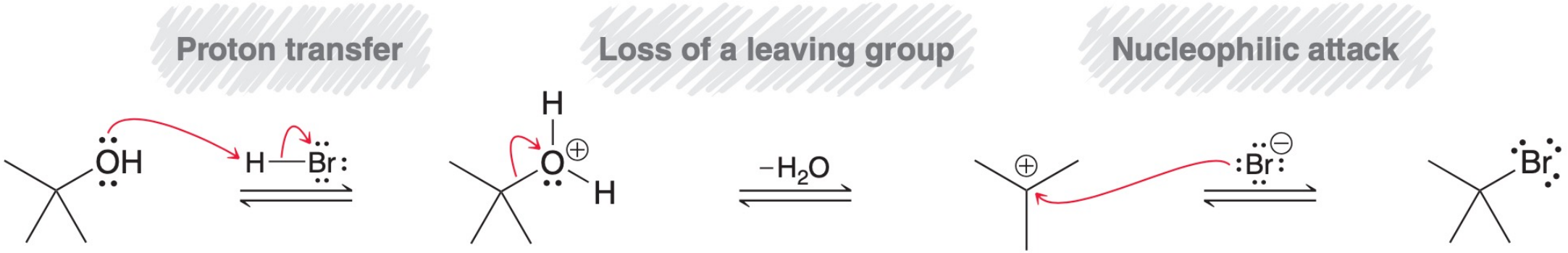


- Recall: substitutions and eliminations

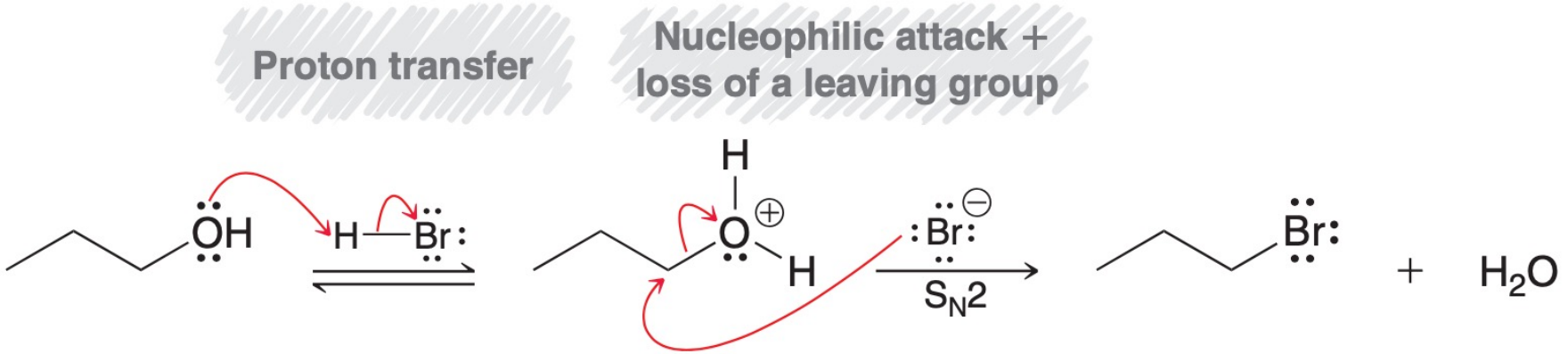


- S_N1 Reactions with Alcohols





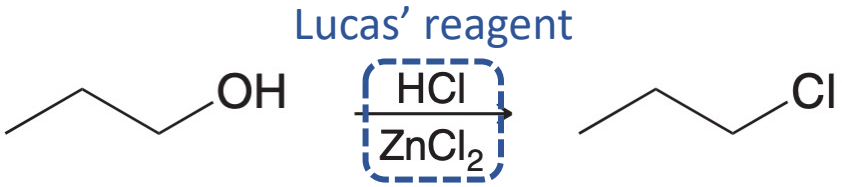
- S_N2 Reactions with Alcohols



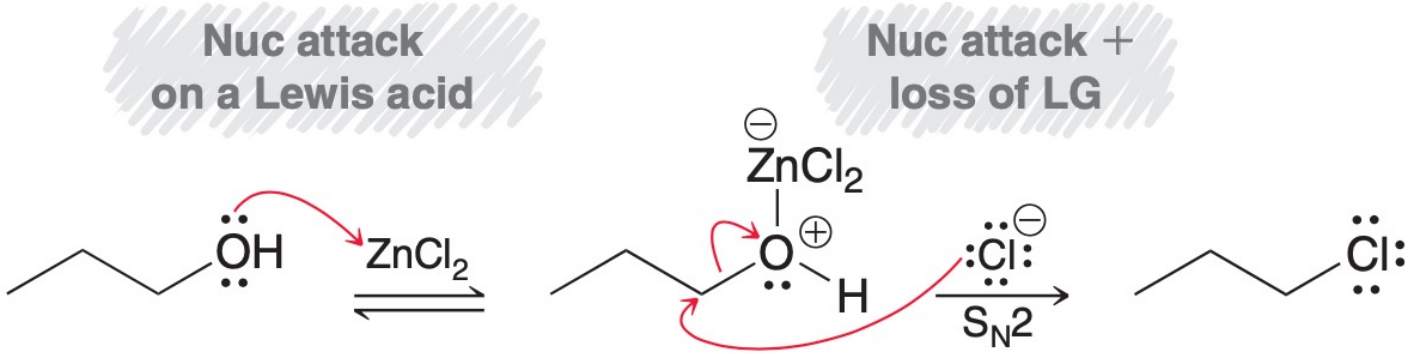
It does not work well for HCl…

Do we have any substituents to HCl?

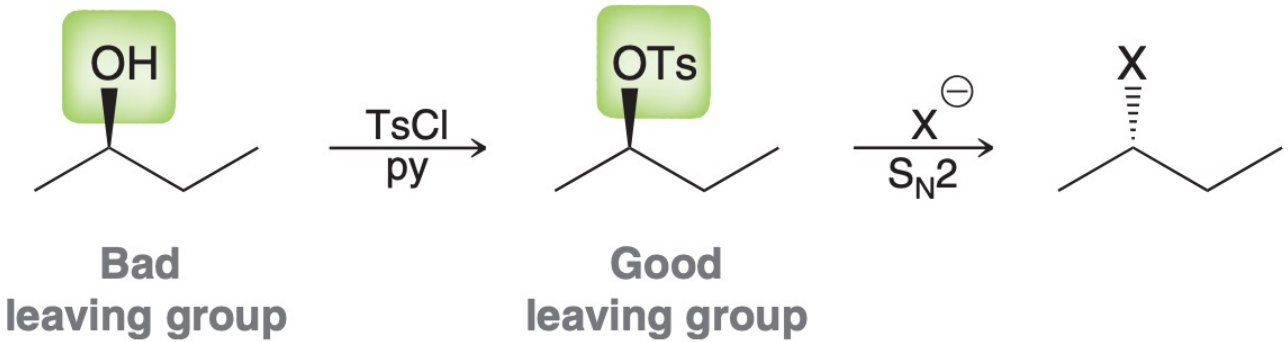
- For alcohol chlorination…

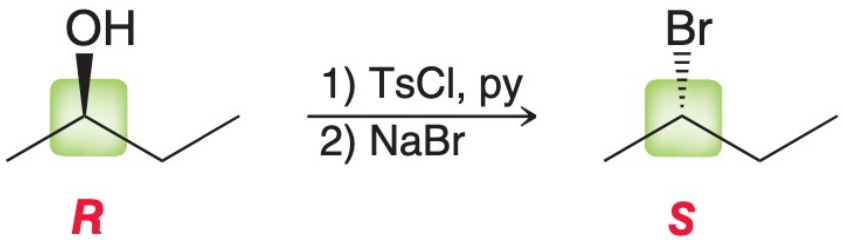


a proton transfer-likely process



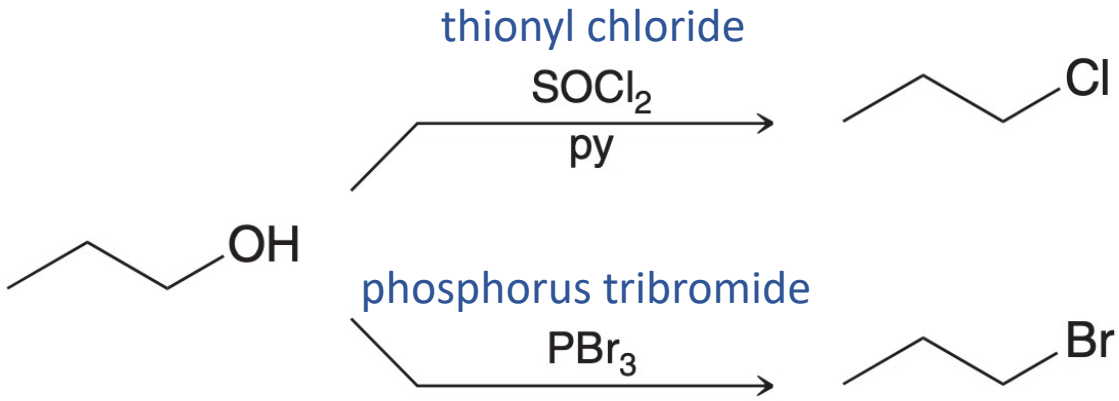
- Convert to tosylate – a good LG



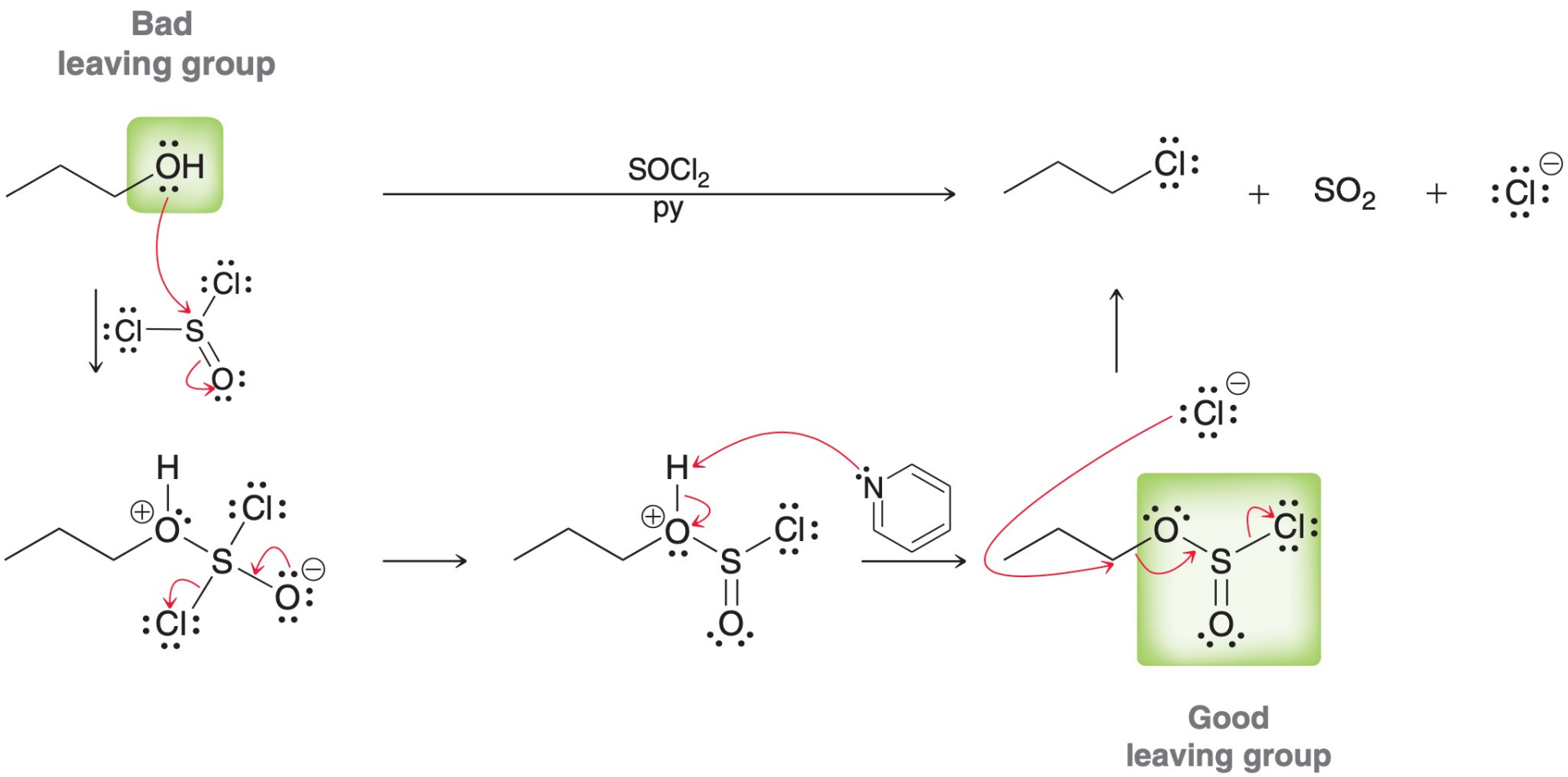


S_N2 – inversion of configuration

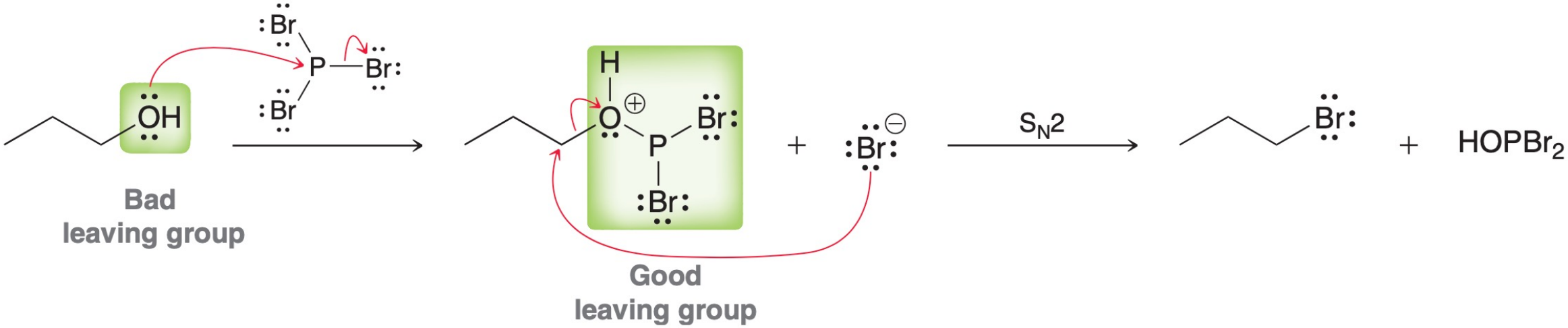
- Use $SOCl_2$ or PBr_3 to do halogenation



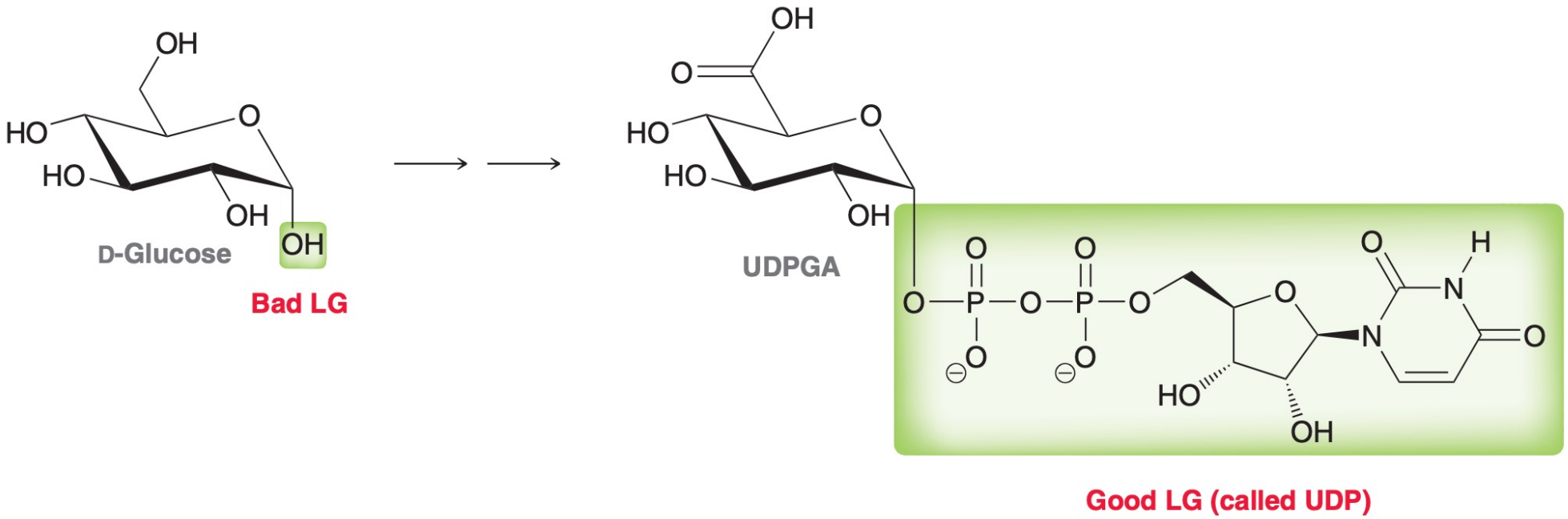
- **Mechanism: the Reaction between $SOCl_2$ and Alcohols**

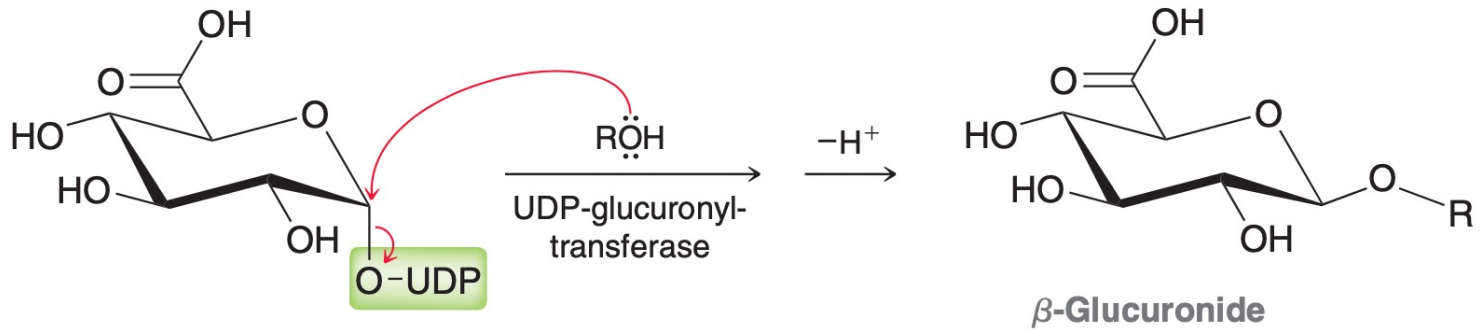


- **Mechanism: the Reaction between PBr_3 and Alcohols**



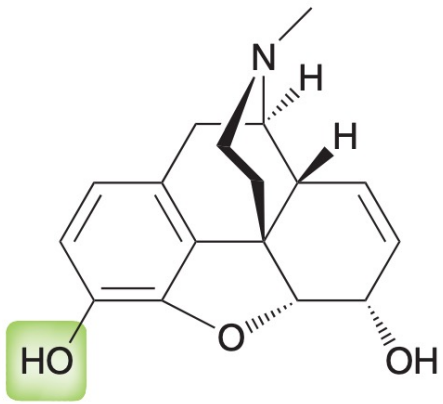
- Drug metabolism – glucuronic acid conjugation (glucuronidation)



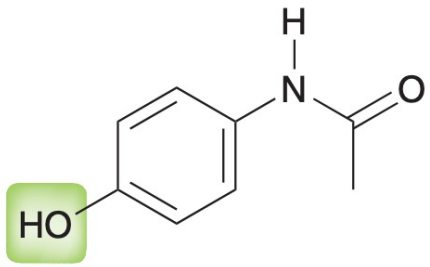


β-Glucuronide

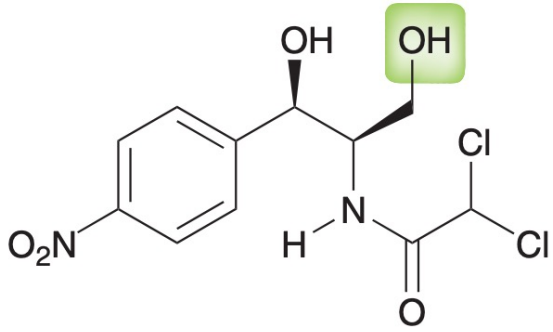
β-glucuronide is highly water soluble



Morphine
An opiate analgesic
used to treat severe pain



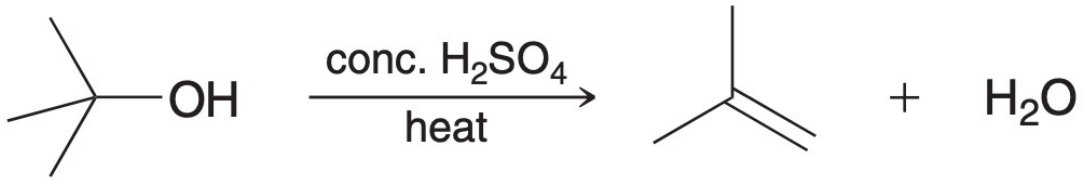
Acetaminophen
An analgesic (pain-relieving)
and antipyretic (fever-reducing) agent,
sold under the trade name Tylenol



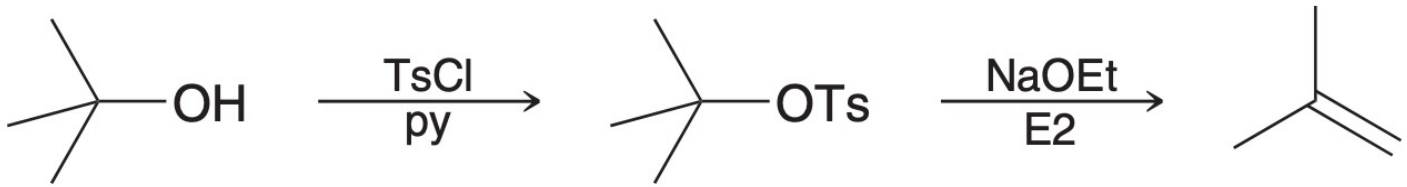
Chloramphenicol
An antibiotic used in eye drops
to treat bacterial conjuctivitis

- E1 and E2 reactions with alcohols

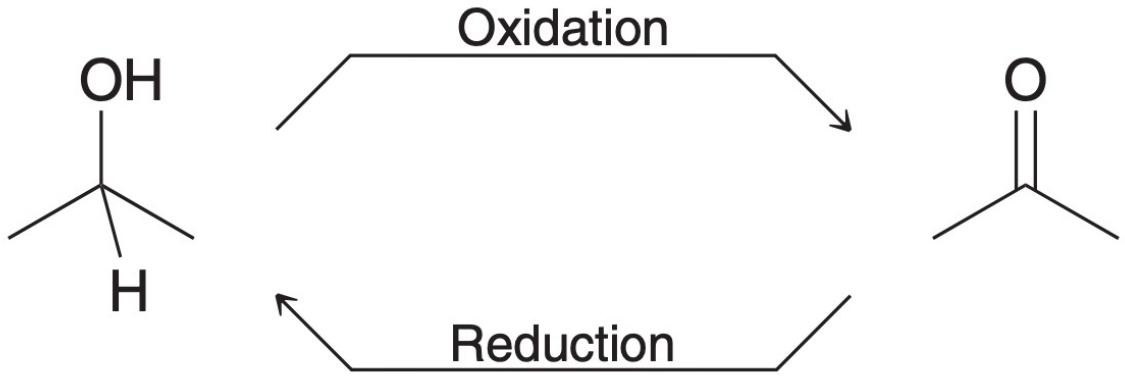
E1 process



E2 process

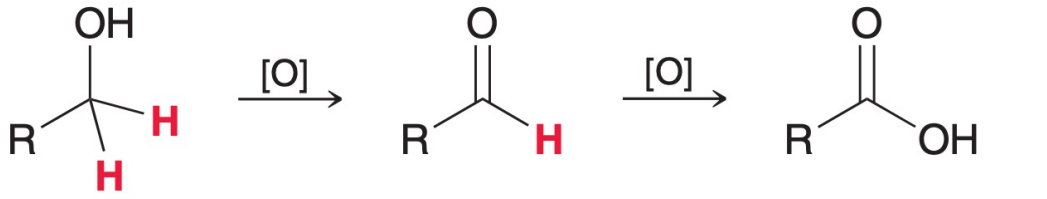


- Oxidation of alcohols



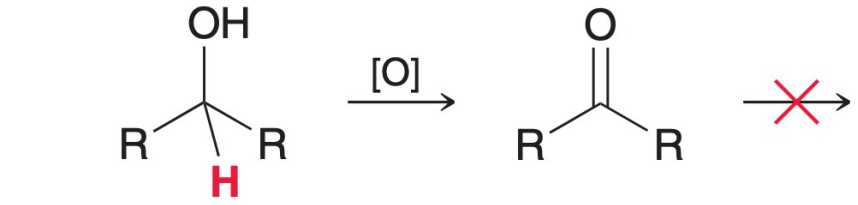
- The final product depends on the number of α-H

primary



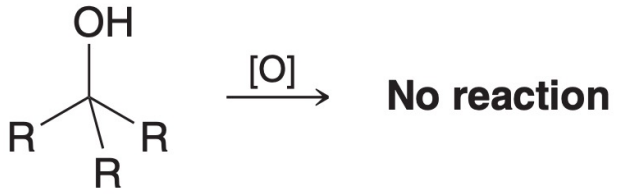
A primary alcohol An aldehyde A carboxylic acid

secondary



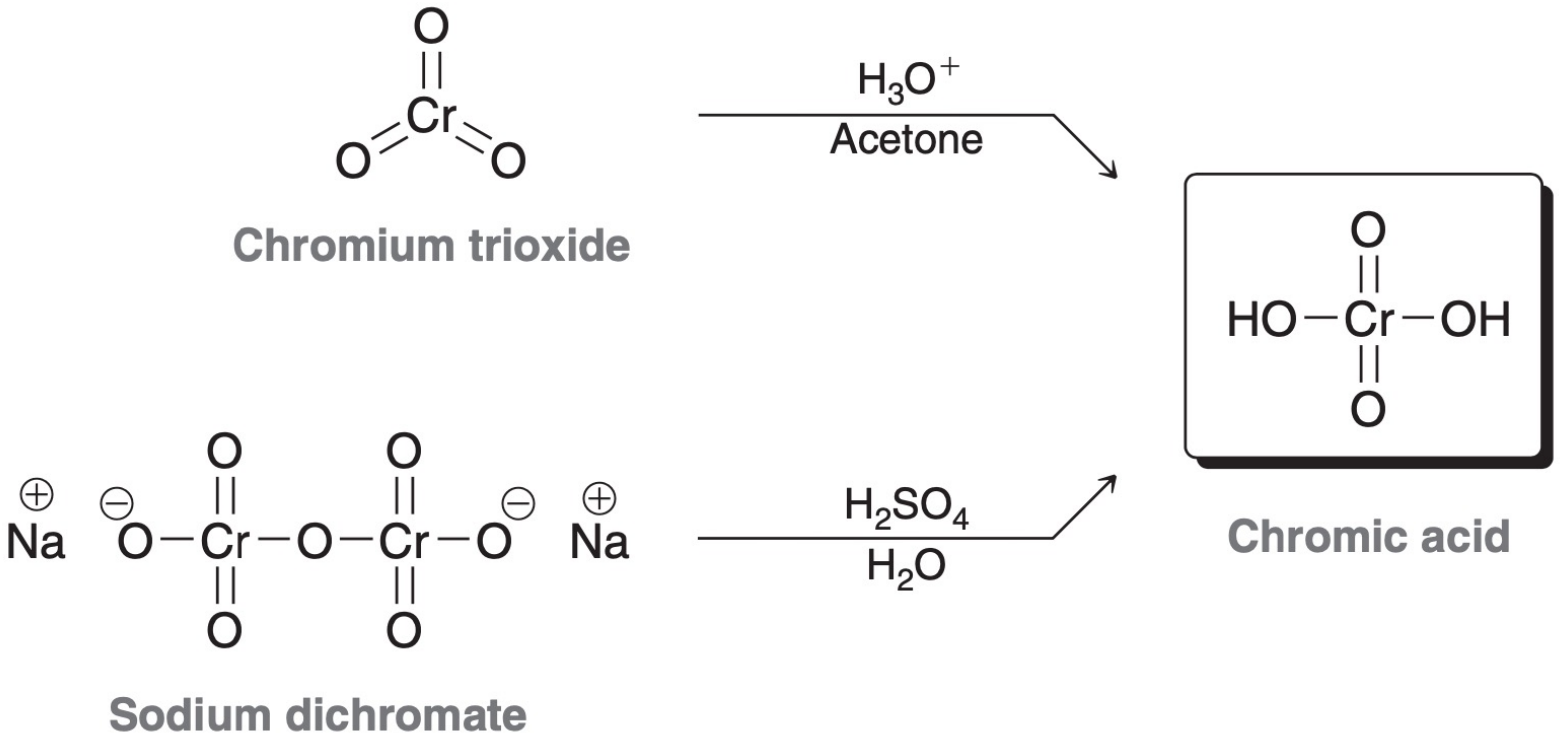
A secondary alcohol A ketone

tertiary



No reaction

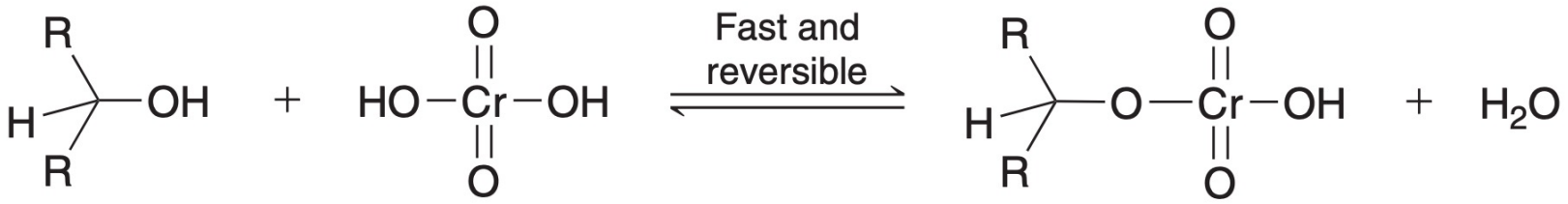
- Oxidizing agents: chromic acid (H_2CrO_4)



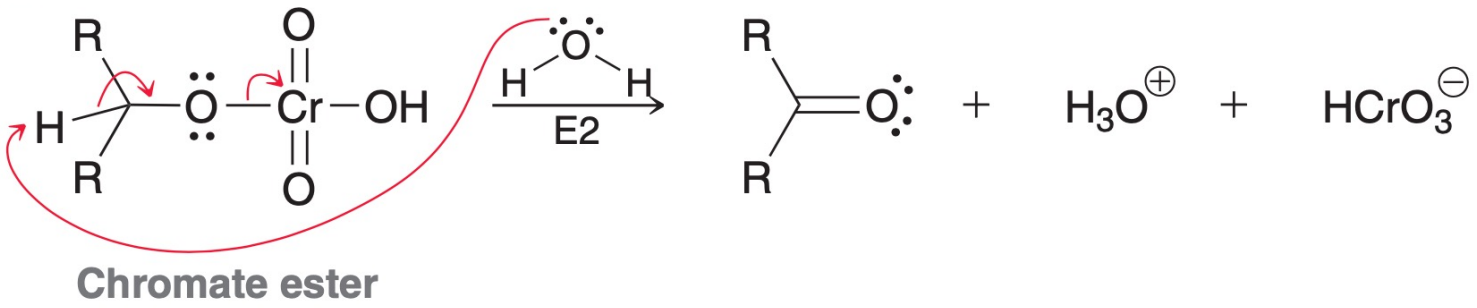
preparation of H_2CrO_4: using CrO_3 or $Na_2Cr_2O_7$

- Mechanism: Oxidation of an Alcohol with Chromic Acid

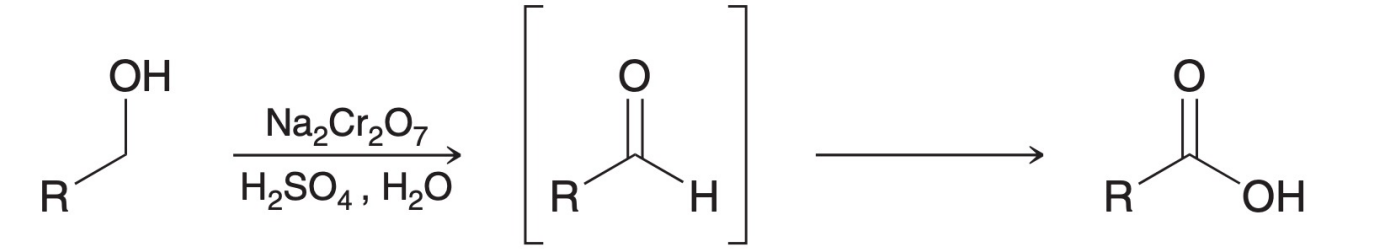
Stage 1



Stage 2

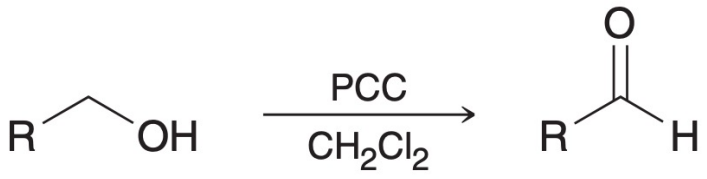


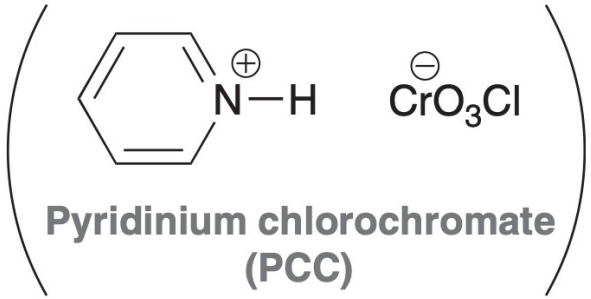
- Selective oxidation: pyridinium chlorochromate (PCC)



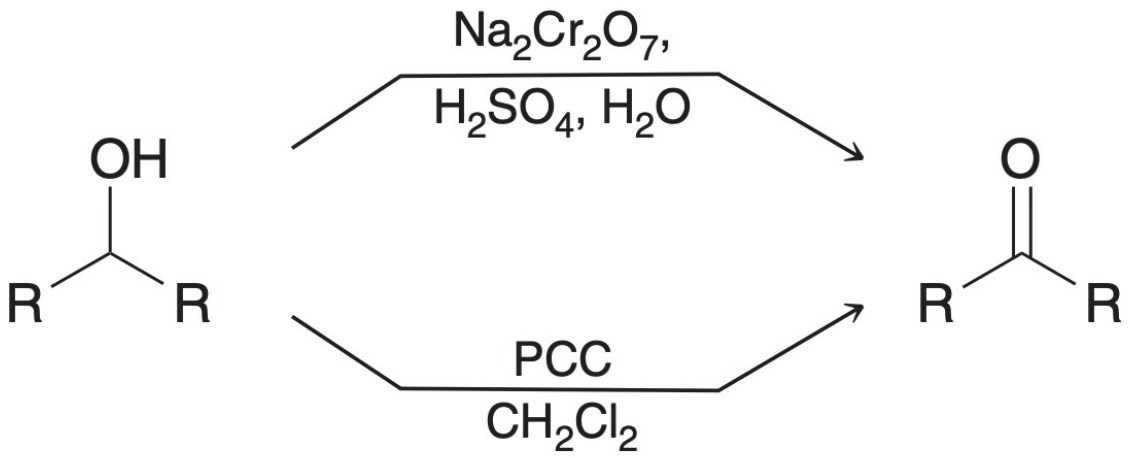
for primary alcohol, chromic acid often causes further oxidation (to carboxylic acid)

if we want an aldehyde…

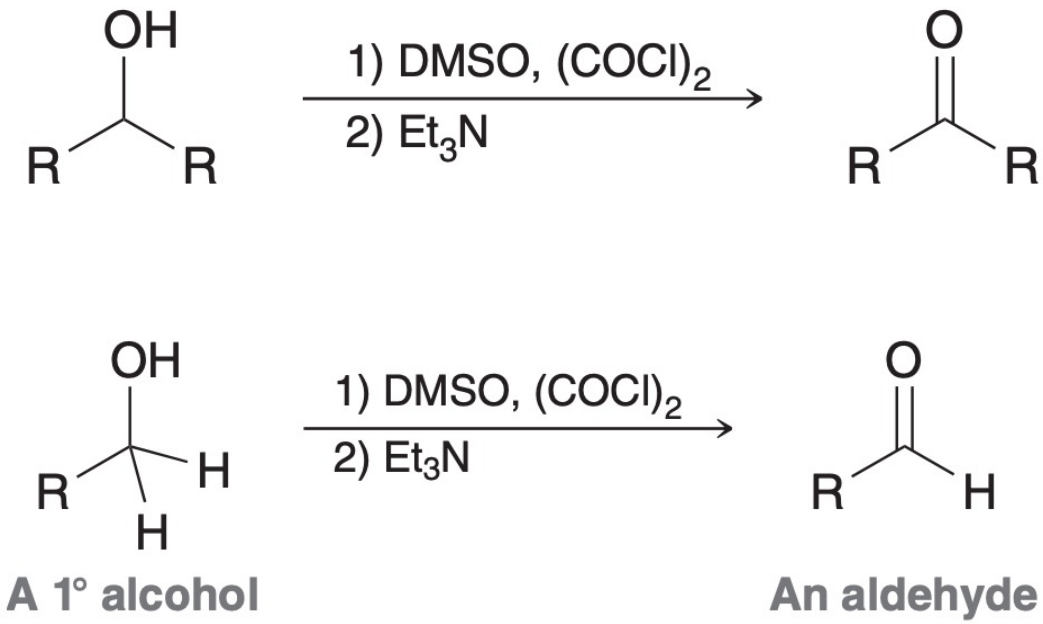




- Secondary alcohols can use either H_2CrO_4 or PCC

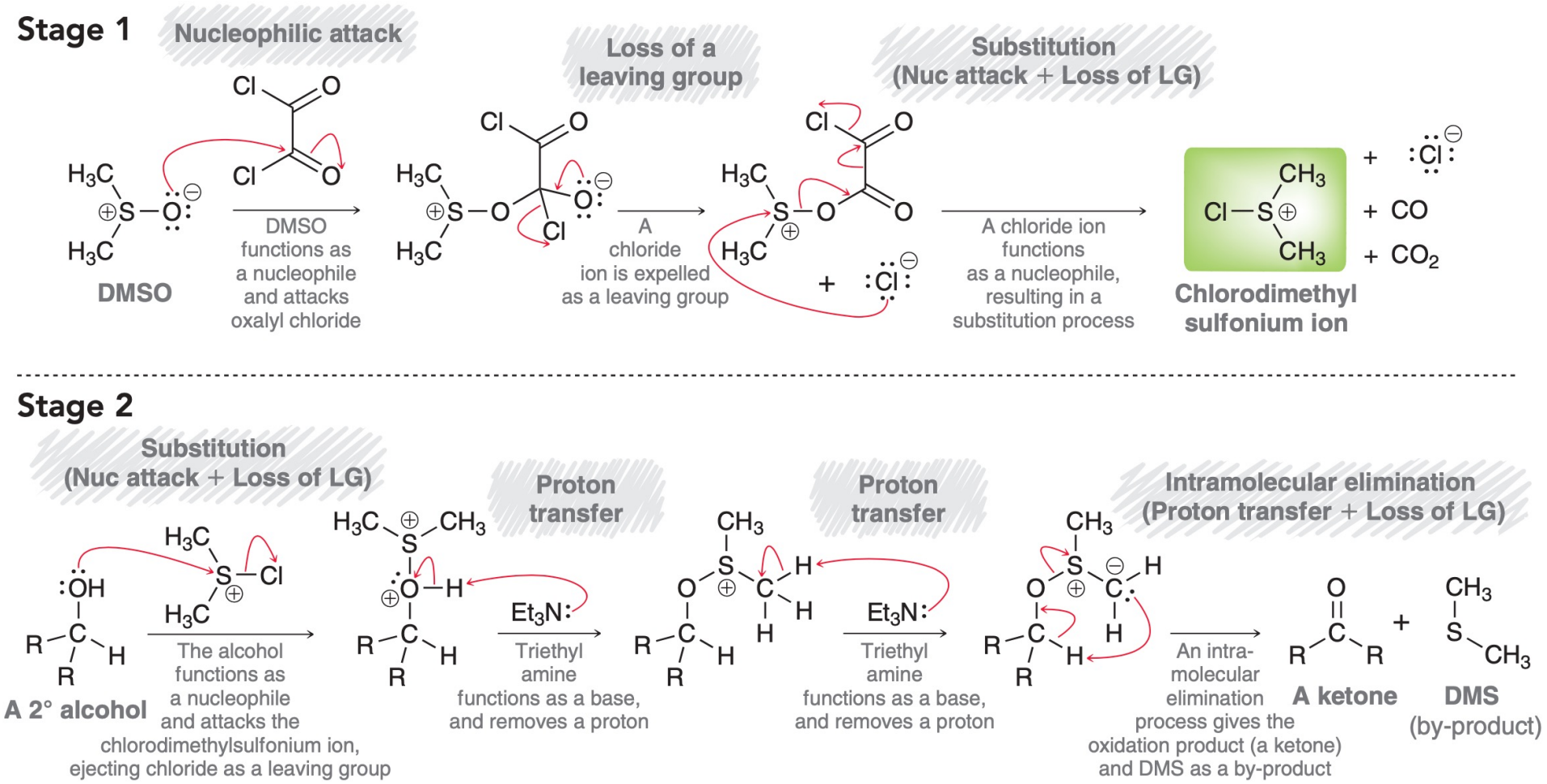


- Greener oxidation: *Swern* oxidation

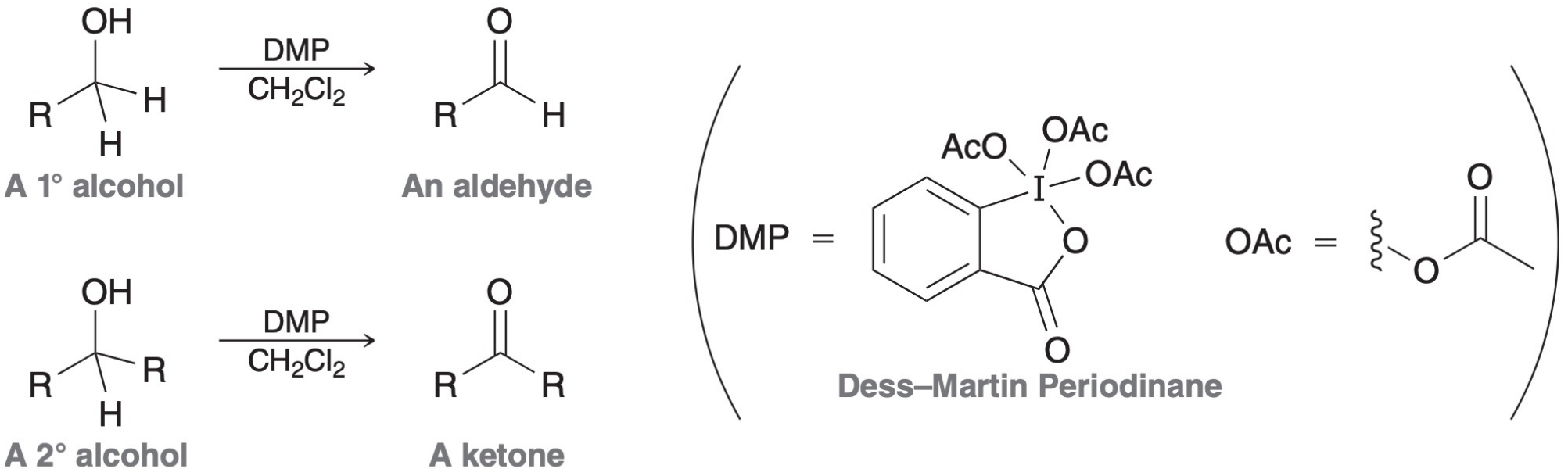


does not have further oxidations!

- Mechanism: *Swern* Oxidation



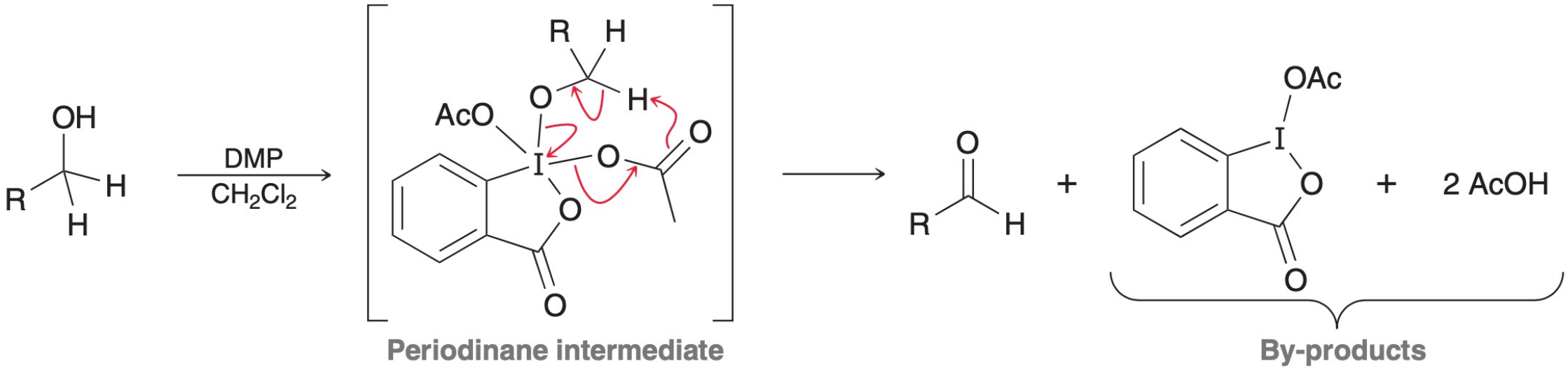
- Greener oxidation: *Dess-Martin* (DMP) oxidation



also, does not have further oxidations:)

neutral pH compared to Cr-based oxidations

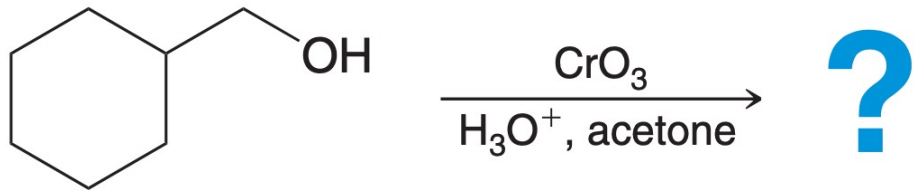
- DMP includes a periodinane intermediate

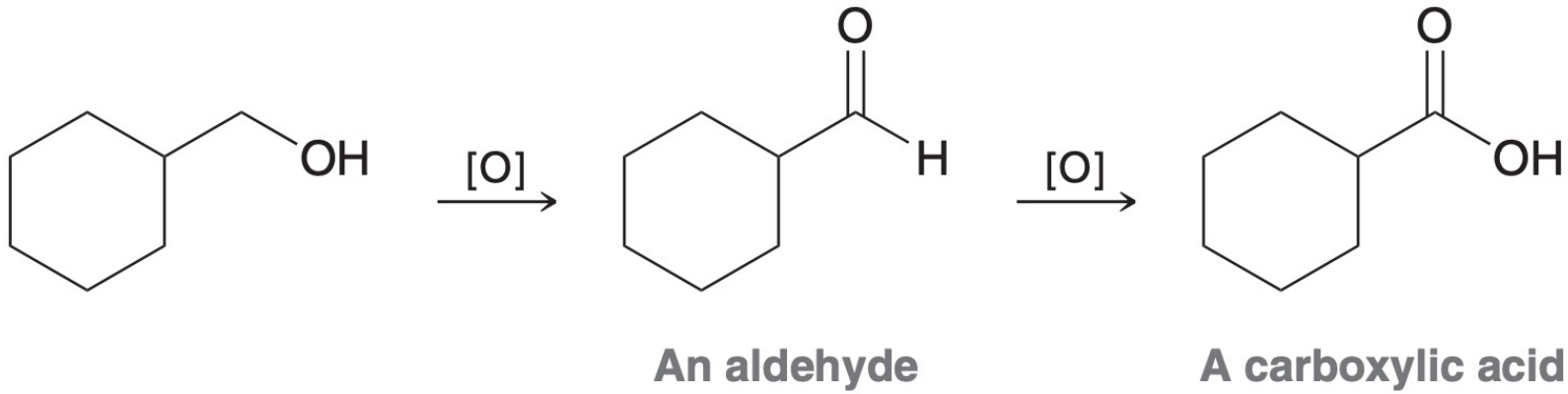


- Comparison of Alcohol Oxidations

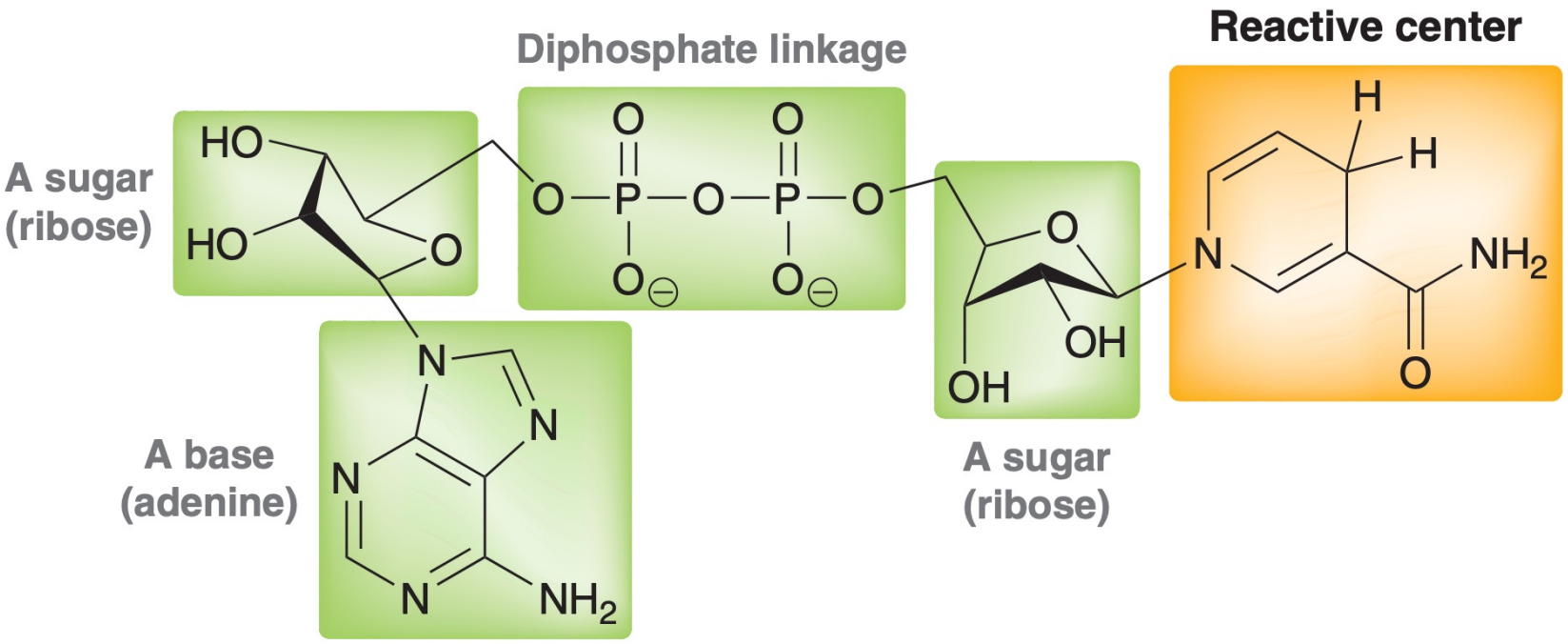
Type	Reagents	"Greenness"	Additional Information
Chromium-based Oxidation	H_3O^+, CrO_3 or H_3O^+, $Na_2Cr_2O_7$	**NOT** green (chromium remaining – heavy metals)	• acidic environment needed • relatively higher atomic economy
Swern Oxidation	1) DMSO, $(COCl)_2$ 2) Et_3N	greener (no heavy metals)	• produce foul-odored by-product (DMS) • poor atomic economy
DMP-based Oxidation	DMP, CH_2Cl_2	greener (no heavy metals)	• neutral reaction pH • DMP is explosive • poor atomic economy

- Practice: predict the major organic product of the following reaction:

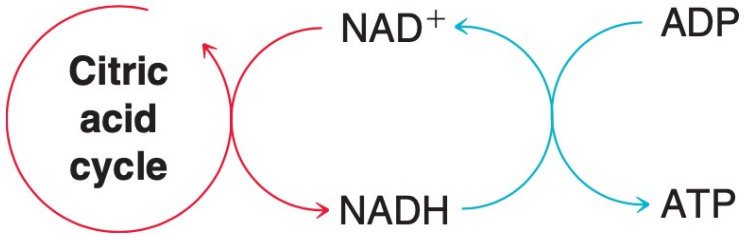


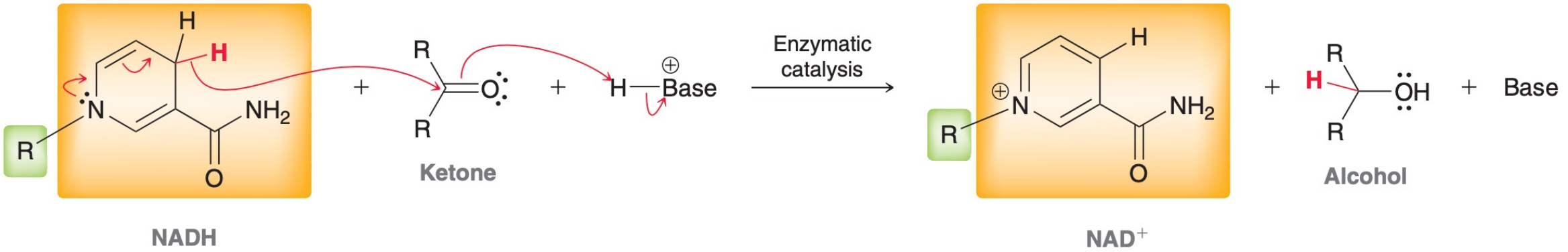


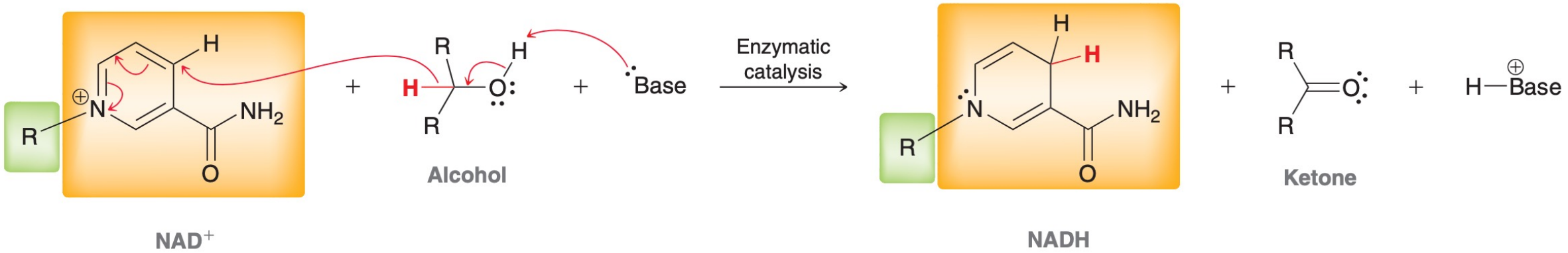
- Biological redox reactions



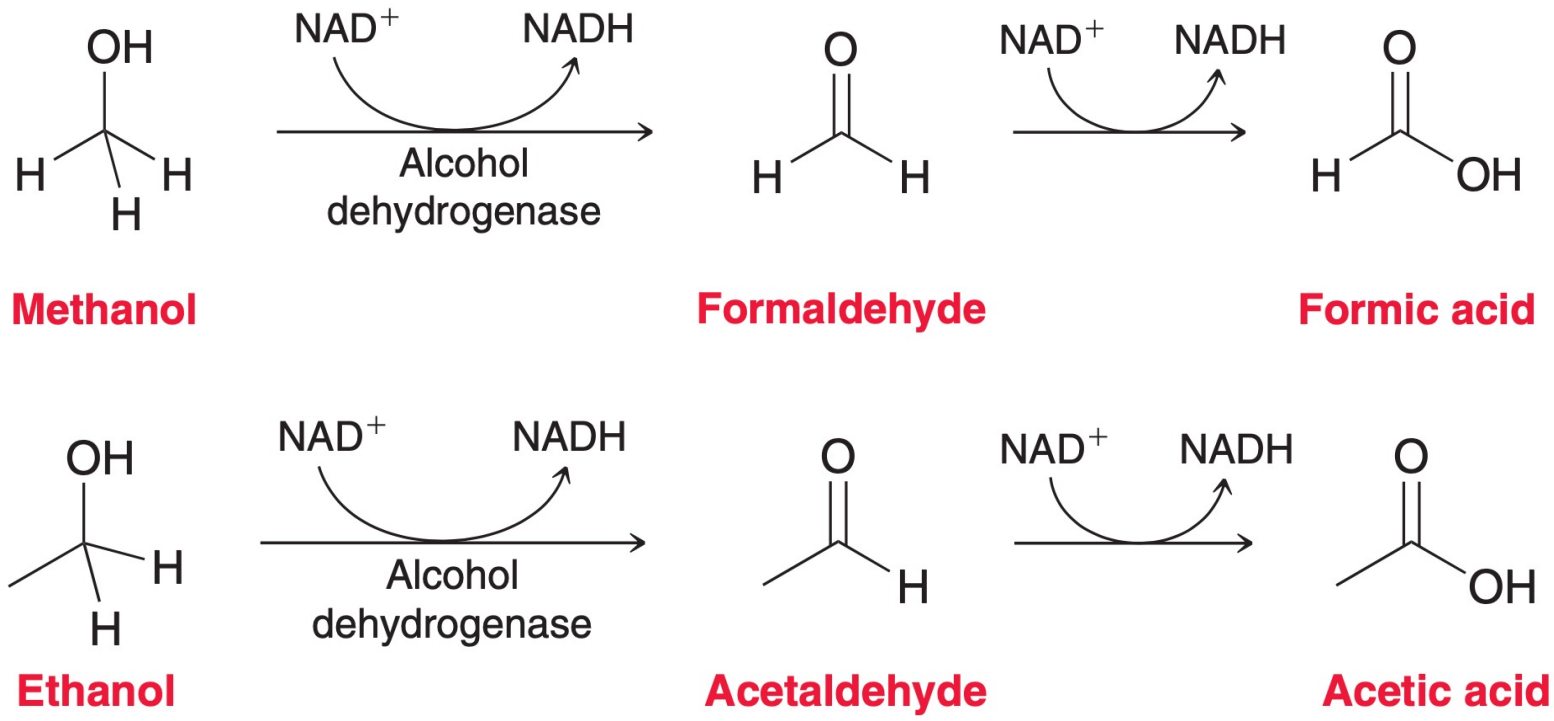
NADH


Citric acid cycle
NAD+
ADP
NADH
ATP

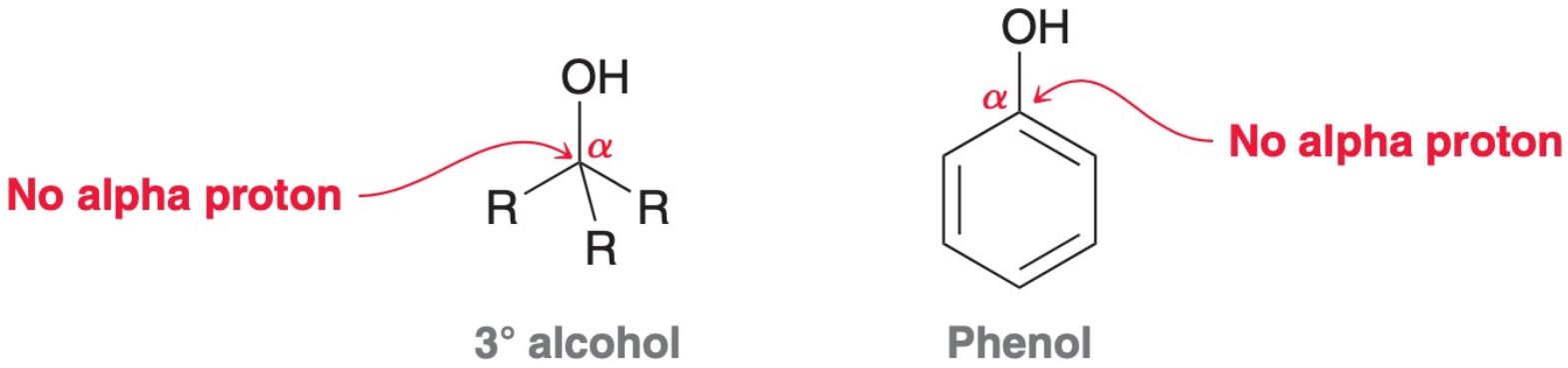

H
H
N
NH2
R
O
NADH
R
O
H
Base
Ketone
Enzymatic catalysis
NAD+
R
H
OH
Alcohol
Base


H
N
NH2
R
O
NAD+
R
H
O
H
Base
Alcohol
Enzymatic catalysis
NADH
R
O
Ketone
H
Base

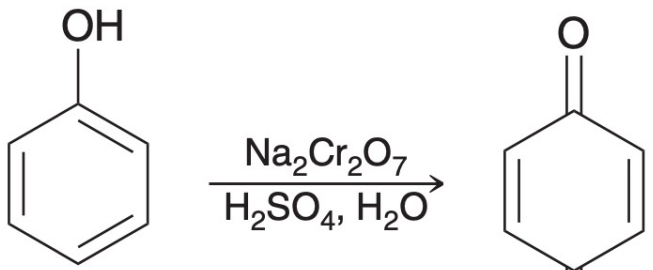
- Biological oxidation of methanol and ethanol



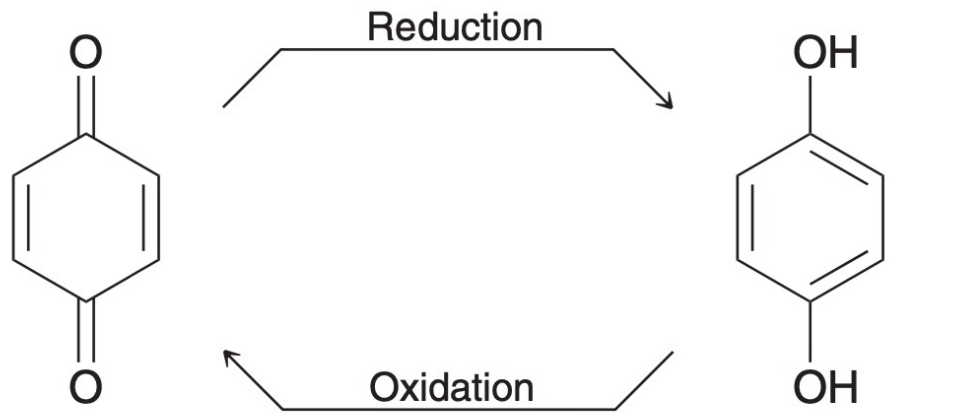
- Oxidation of phenol



Can phenol be oxidized?



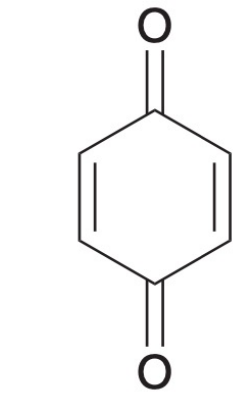
Phenol **Benzoquinone**



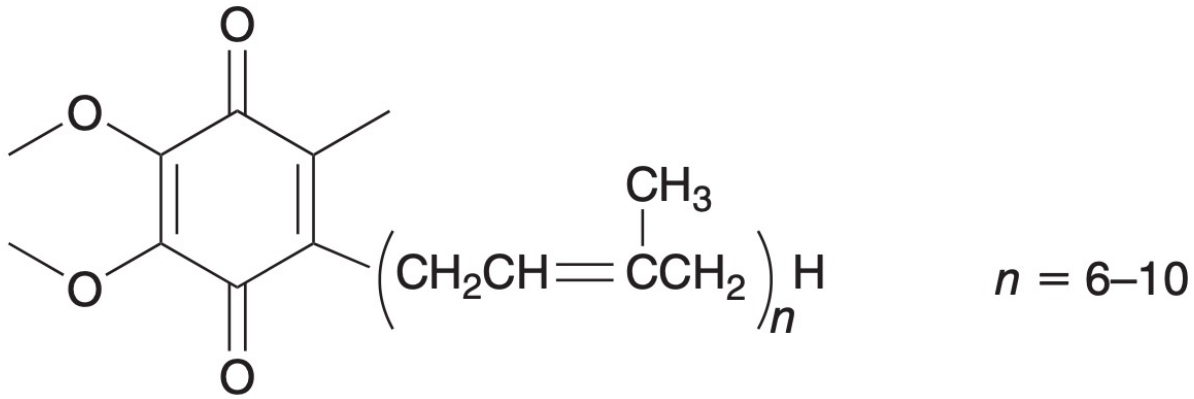
Benzoquinone **Hydroquinone**

Nobel Prize in 1978

- Biological quinones: ubiquinones



Benzoquinone

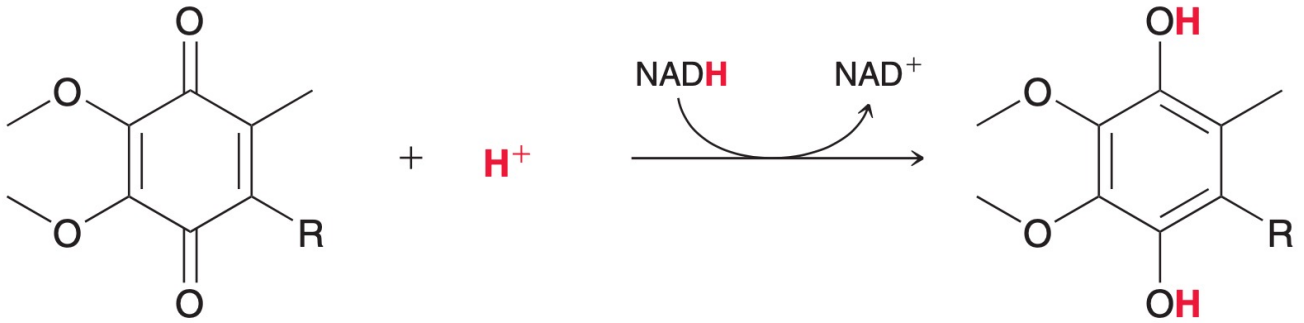


Ubiquinones

$n = 6–10$

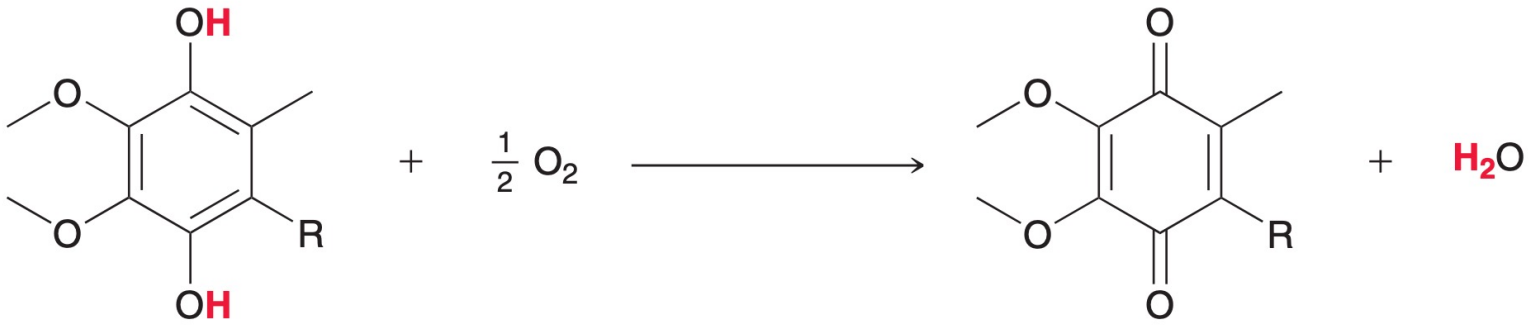
- Cellular respirations

Step 1:



Ubiquinone

Step 2:



Ubiquinone

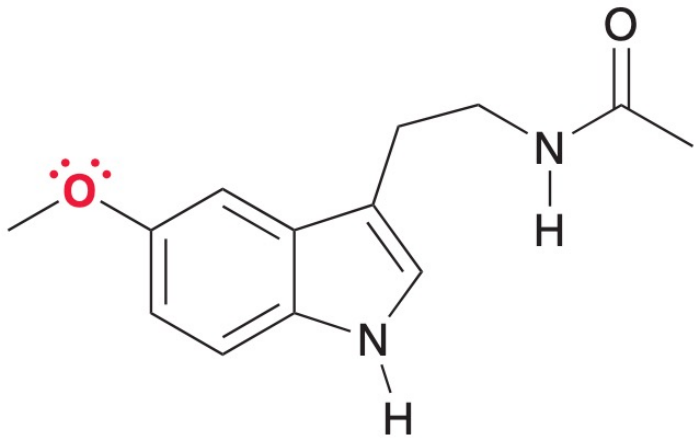
Net reaction: $NADH + \frac{1}{2} O_2 + H^+ \longrightarrow NAD^+ + H_2O$

Ethers

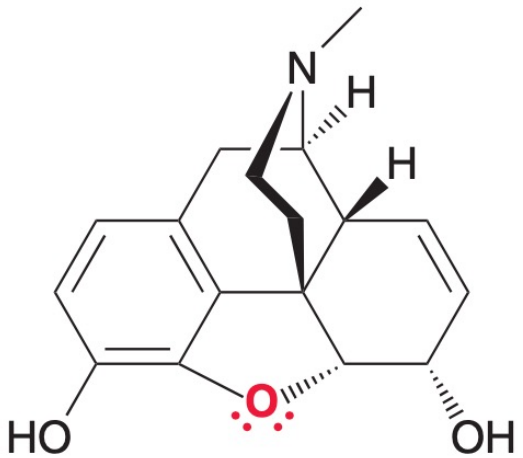
Basic Physical & Chemical Properties, Preparations, Reactions

Ethers are compounds that exhibit an oxygen atom bonded to two R groups, where each R group can be an alkyl, aryl, or vinyl group:

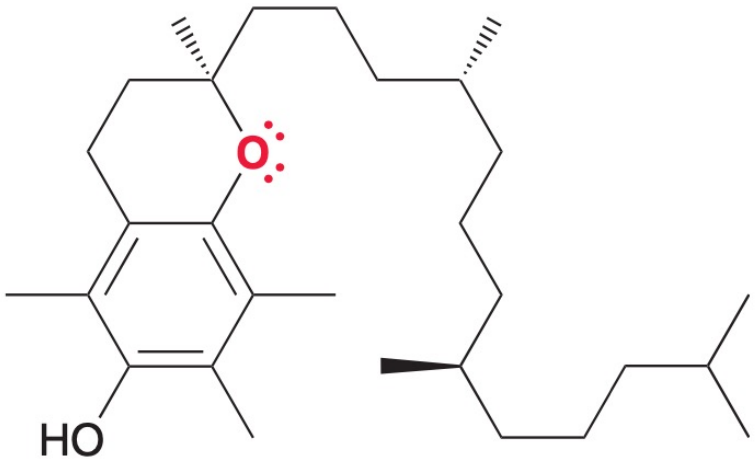
An ether



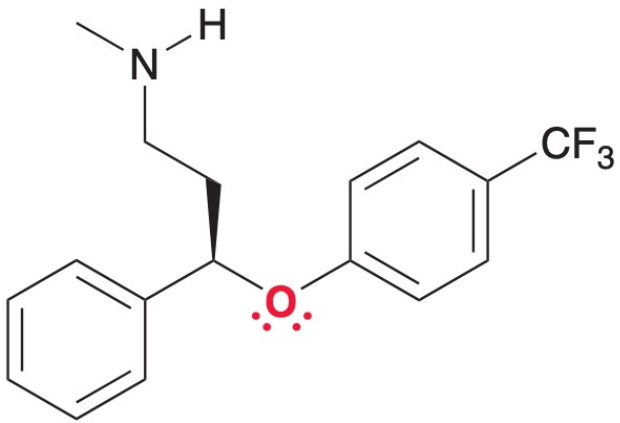
Melatonin
A hormone that is believed to regulate the sleep cycle



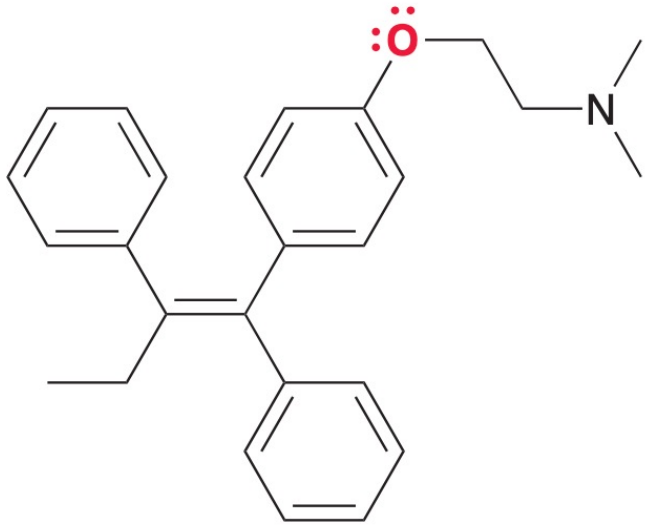
Morphine
An opiate analgesic used to treat severe pain



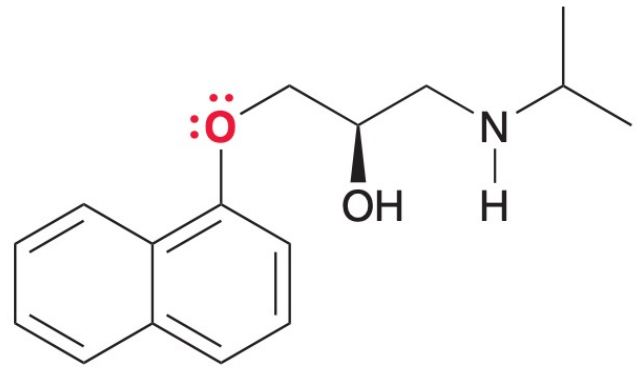
Vitamin E
An antioxidant



(*R*)-Fluoxetine
A powerful antidepressant
sold under the trade name Prozac

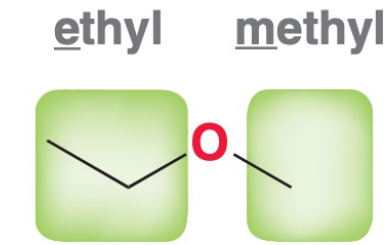


Tamoxifen
Inhibits the growth
of some breast tumors

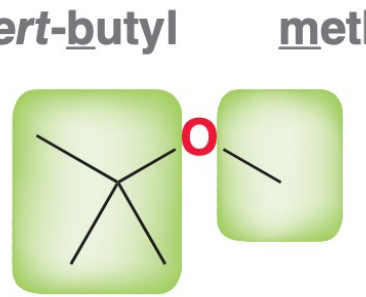


Propanolol
Used in the treatment
of high blood pressure

- Common nomenclature



Ethyl methyl ether



tert-Butyl methyl ether

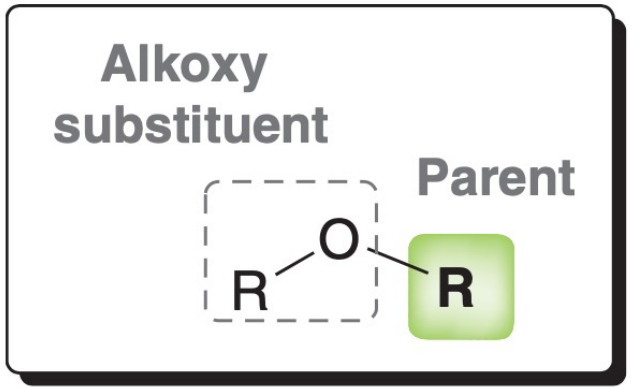
unsymmetrical ether

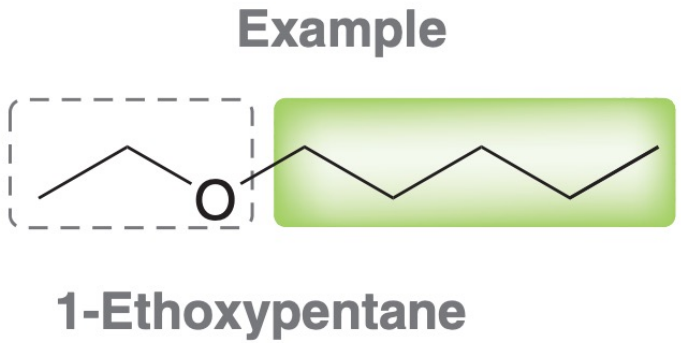
$(CH_3CH_2)_2O$

diethyl ether

symmetrical ether

- Systematic nomenclature

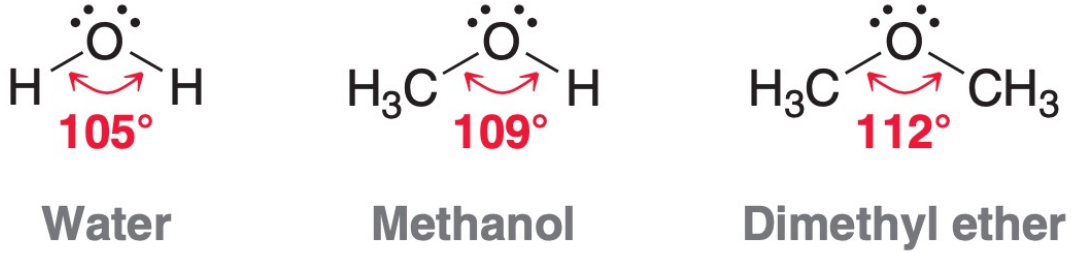


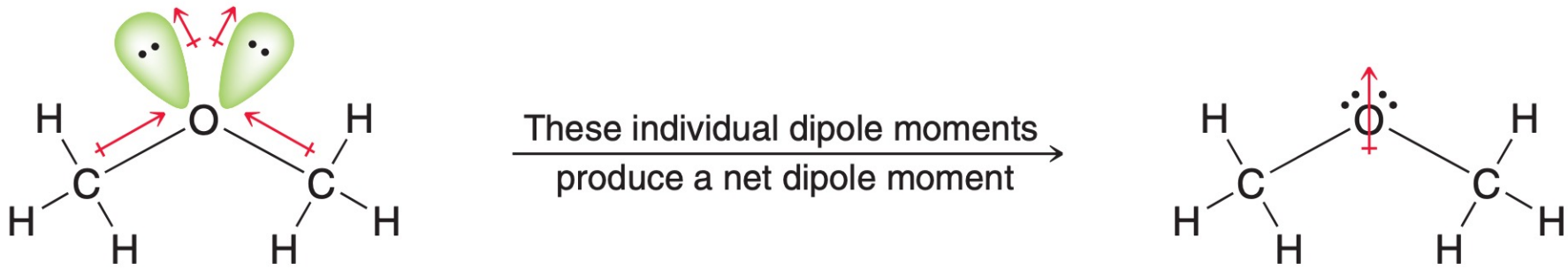


choose the larger part as the parent

the remaining part is the **alkoxy substituent**

- Bond angle

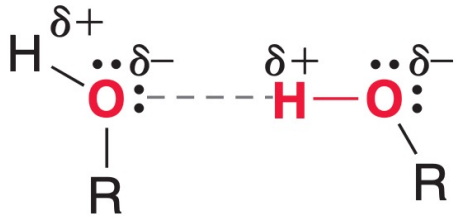




polar molecules

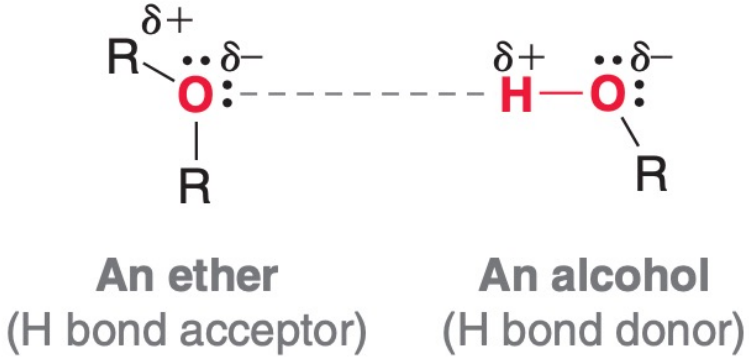
- Hydrogen bonding

*ethers can only function as hydrogen bonding **acceptors**!*



hydrogen bonding

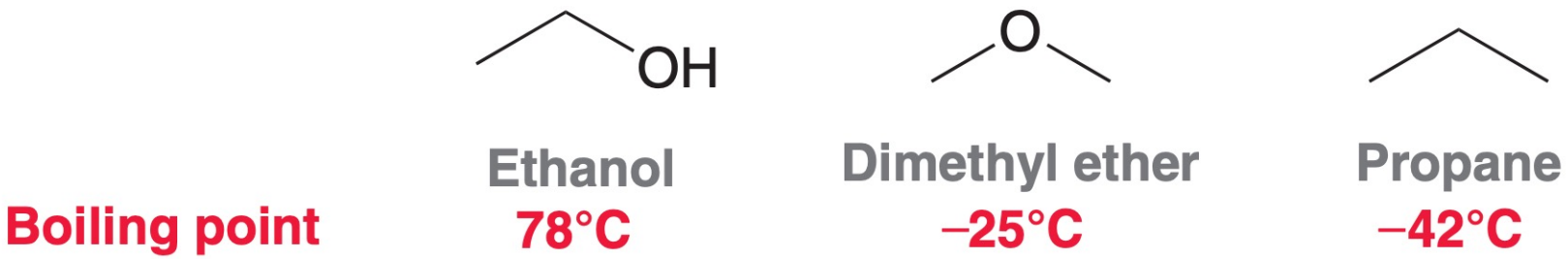
between alcohols



hydrogen bonding

between ethers and alcohols

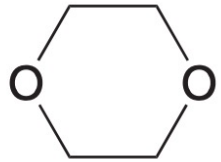
- B.P of ethers are lower than their *isomeric alcohols*



- Ethers as solvents

Diethyl ether

Tetrahydrofuran

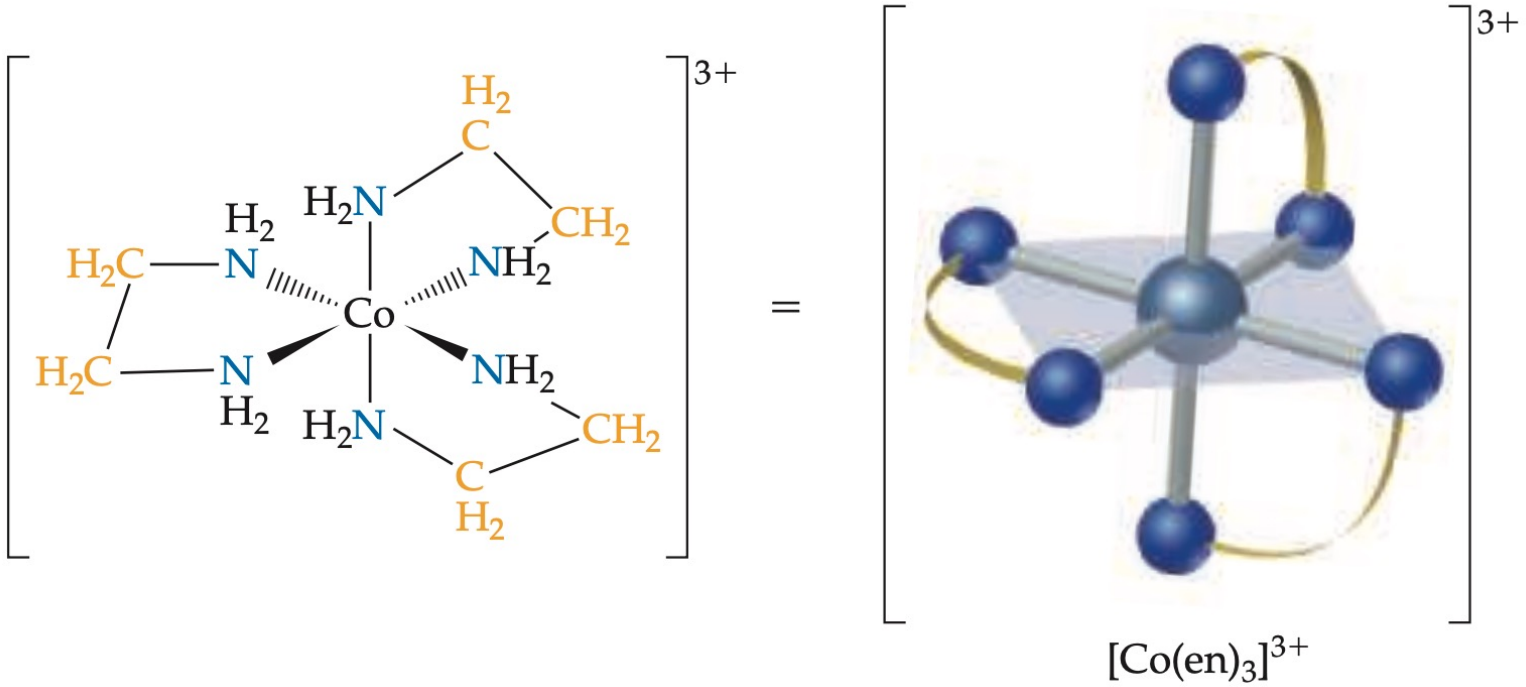


1,4-Dioxane

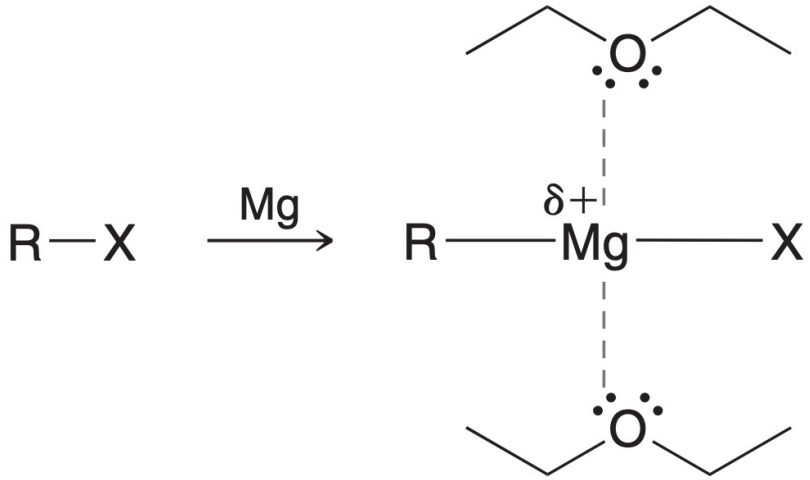
Ethers are good solvents because:

- fairly unreactive
- good dissolving ability
- low B.P

- Coordinate effect and coordinate bond



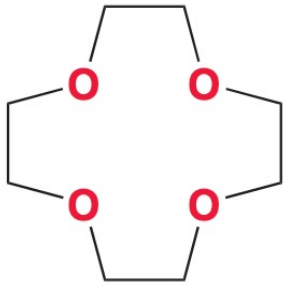
- Coordinate effect in solvation process



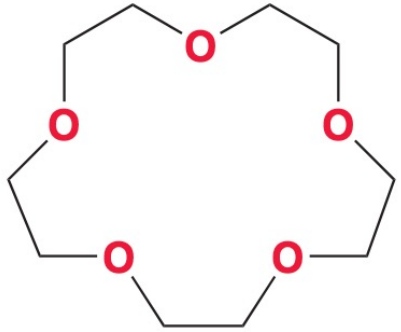
dimethyl ether is used as the solvent for Grignard reaction

to stabilize the Mg atom

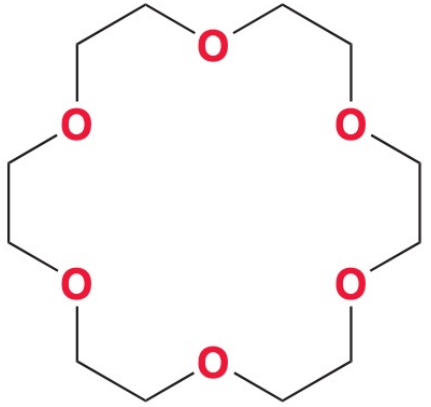
- Crown ethers



12-Crown-4

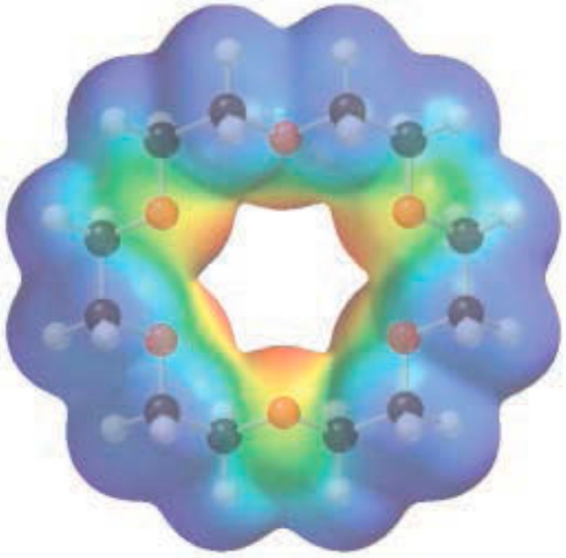


15-Crown-5



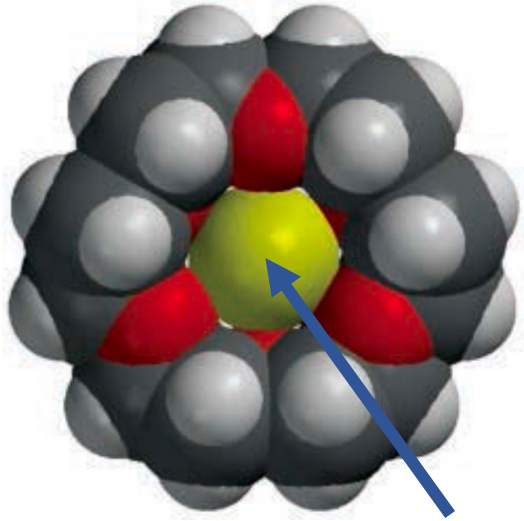
18-Crown-6

- “The natural container”

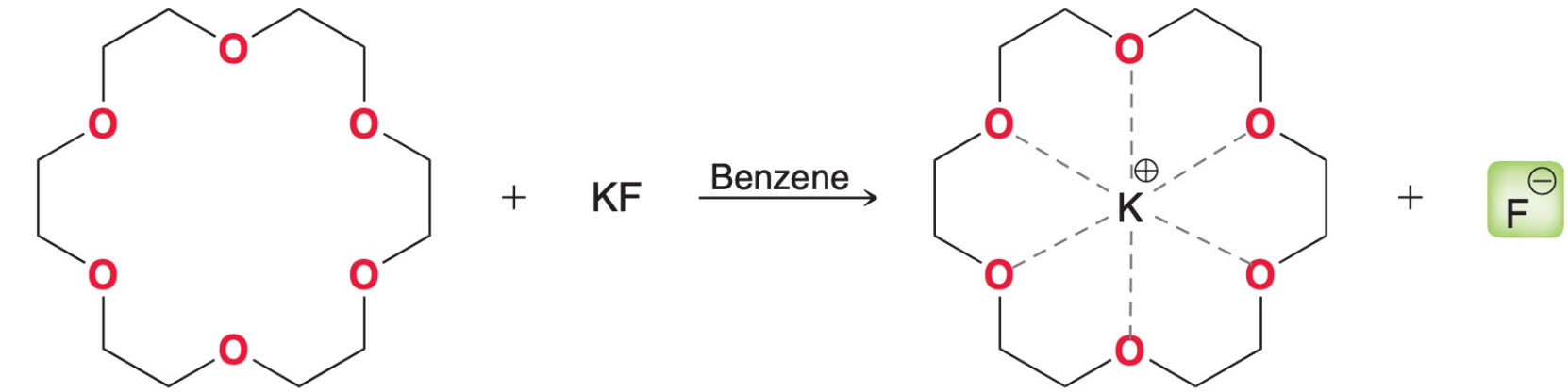


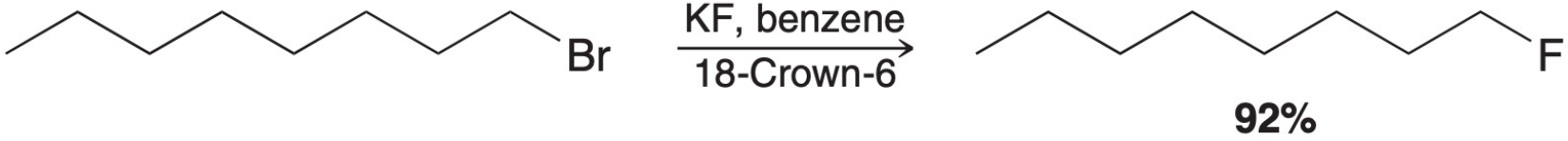
the electrostatic potential map

of 18-crown-6

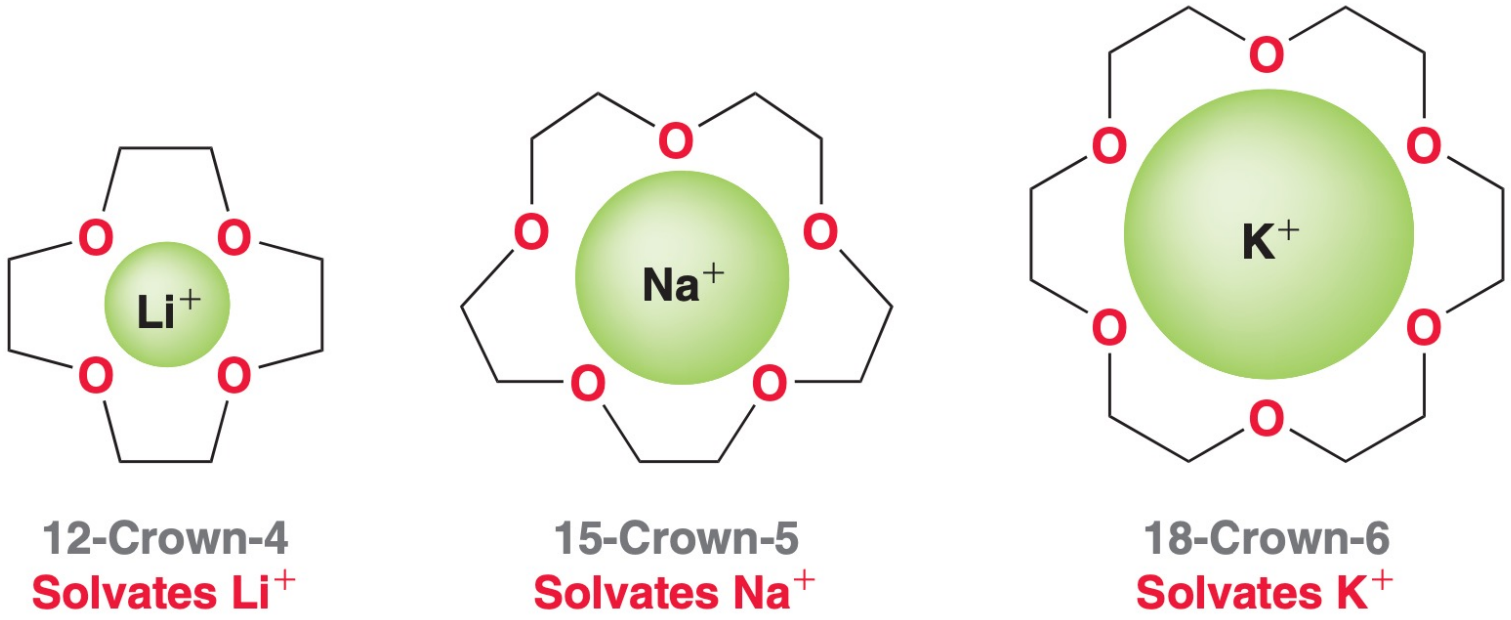


- K^+ ion can be coordinated at the center of 18-crown-6

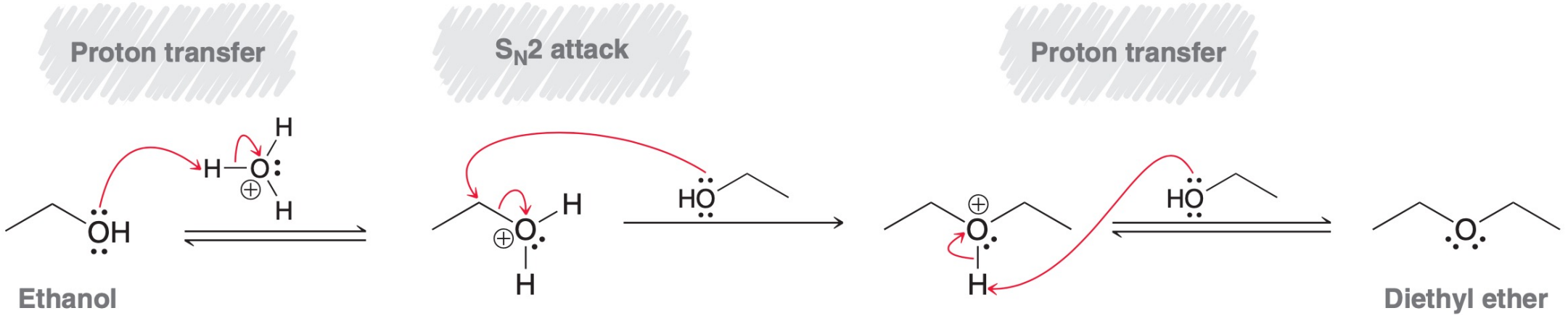




- Relative size comparison

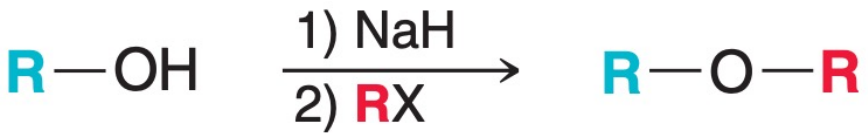


- Industrial preparation of Et_2O

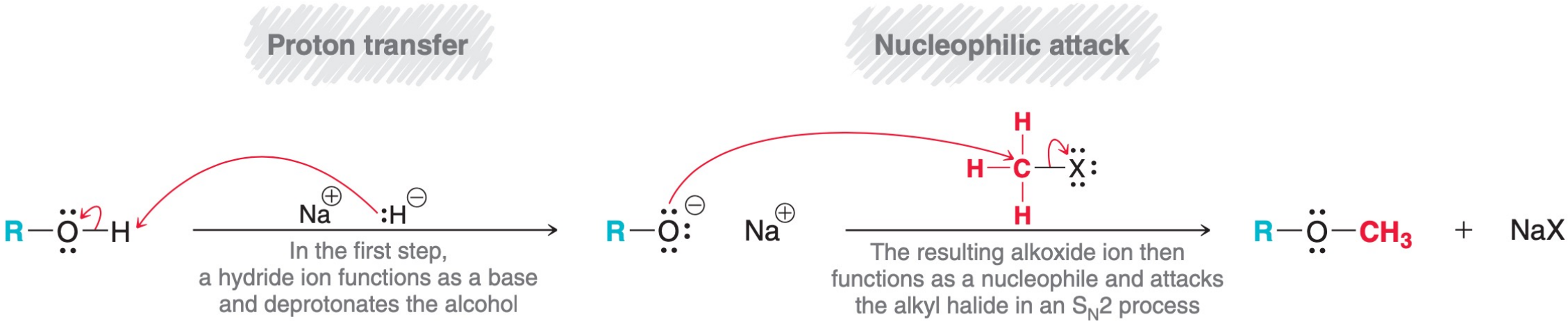


an S_N2 process

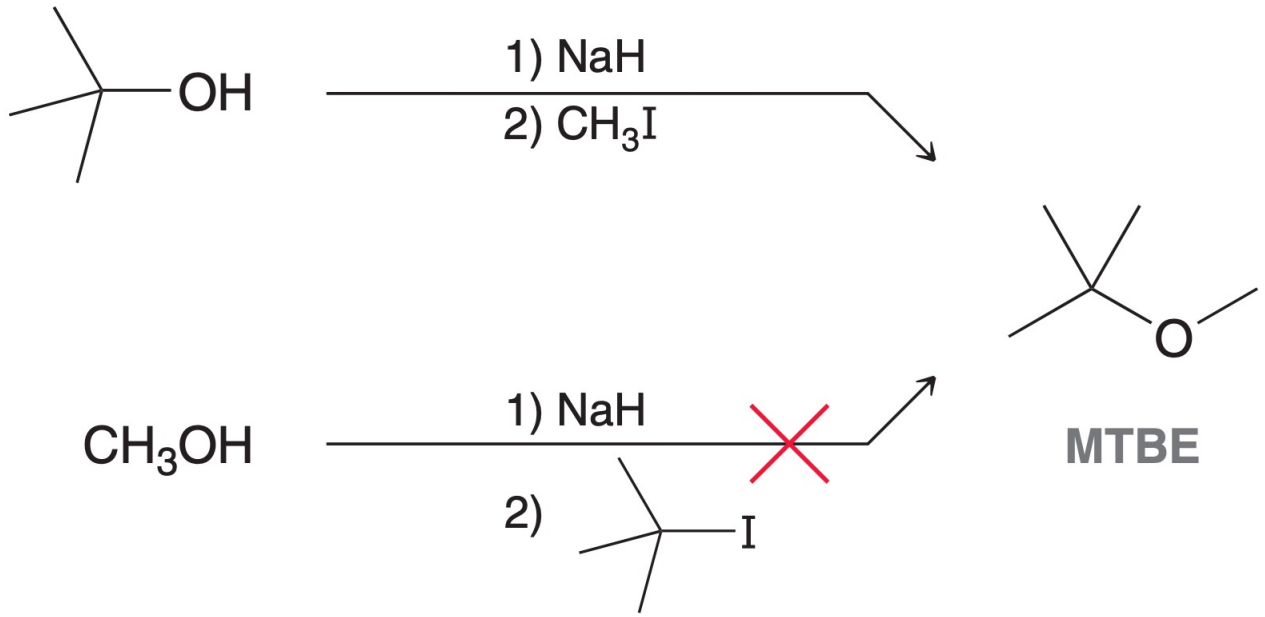
- Williamson Ether Synthesis



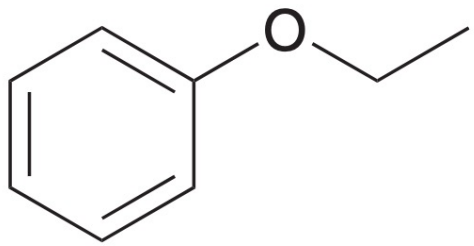
- **Mechanism: the Williamson Ether Synthesis**

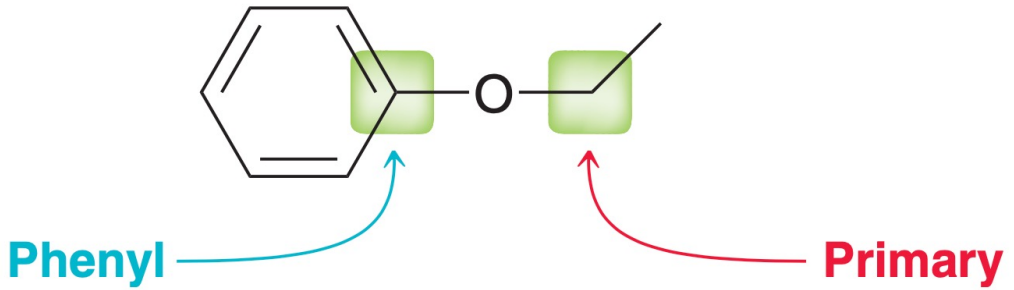


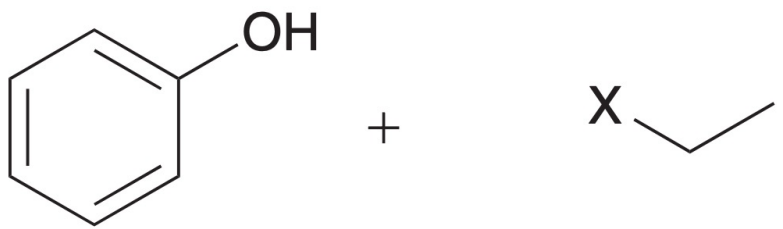
- Tertiary substrate is not applicable!

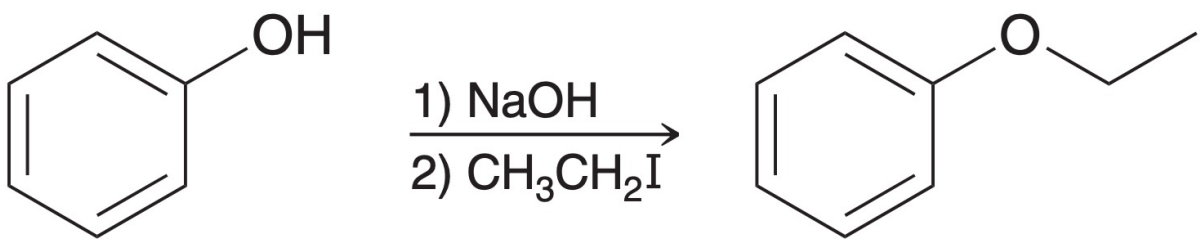


- Practice: show reagents that you could use to prepare the following ether via a Williamson ether synthesis:

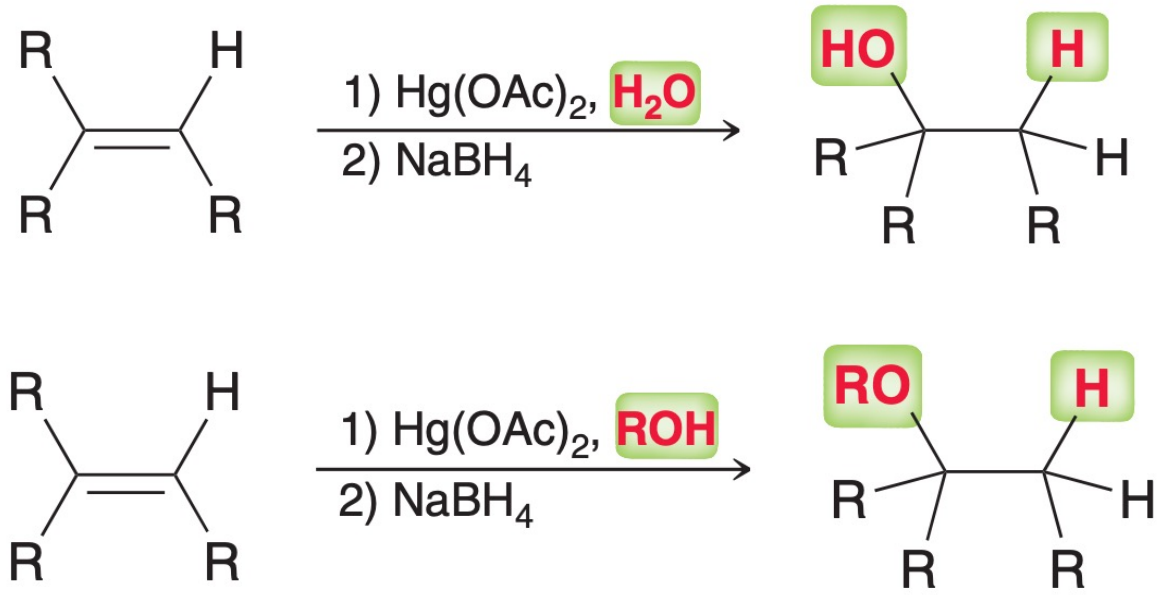



O
Phenyl
Primary


OH
+
X


OH
1) NaOH
2) CH3CH2I
O

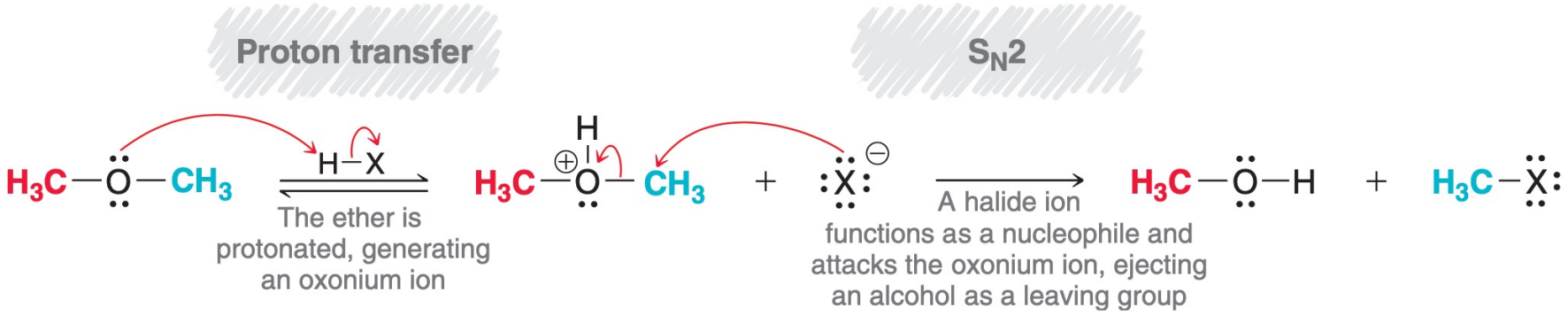
- Alkoxymercuration-demercuration



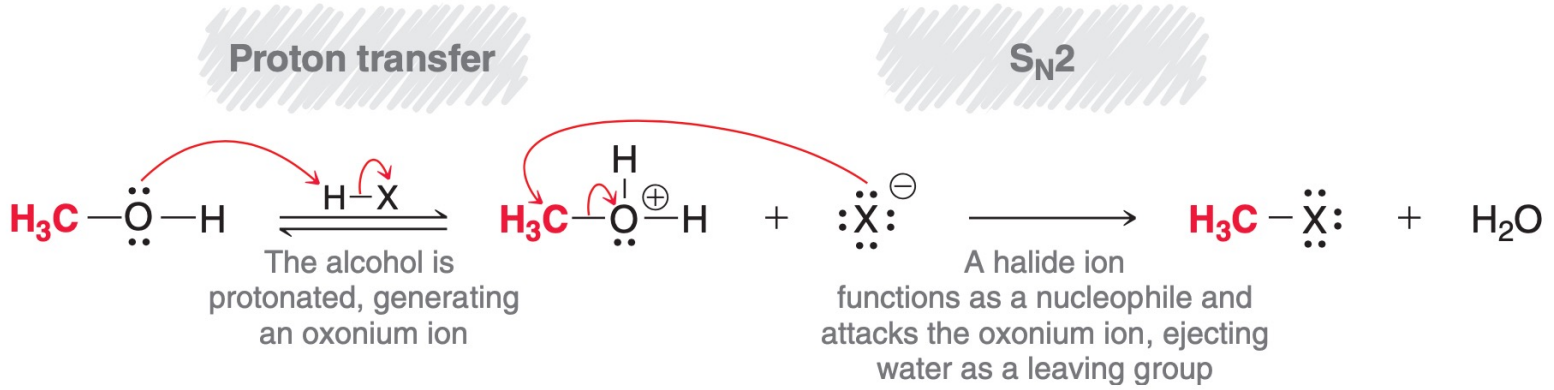
- Acidic cleavage

- **Mechanism: Acidic Cleverage of An Ether**

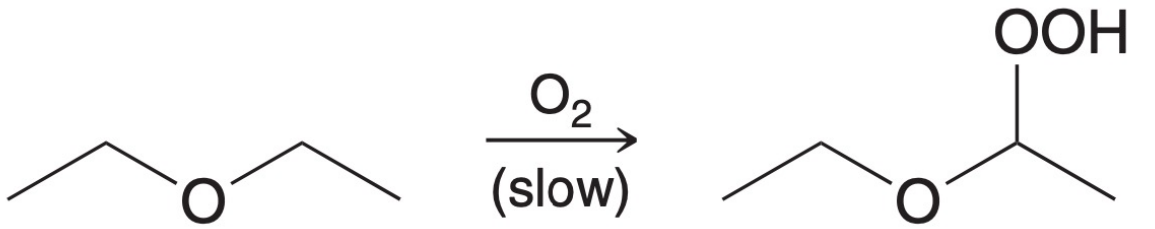
FORMATION OF FIRST ALKYL HALIDE



FORMATION OF SECOND ALKYL HALIDE



- Autooxidation



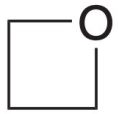
A hydroperoxide

this is a free-radical reaction

we will talk about the mechanism later…

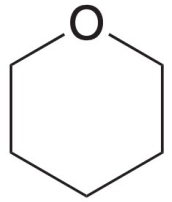
- Epoxides – cyclic ethers

Oxirane ring system

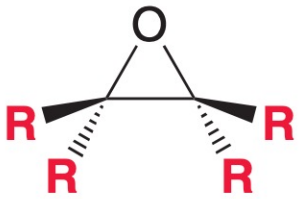


Oxetane ring system

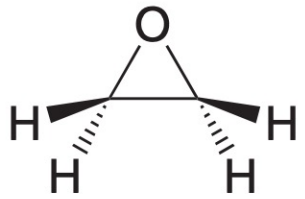
Oxolane ring system



Oxane ring system

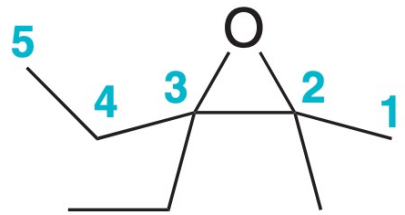


A substituted oxirane
(an epoxide)



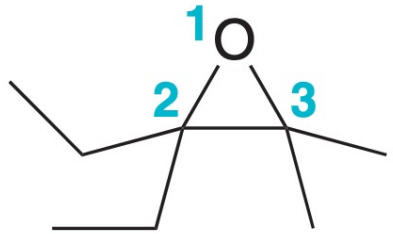
Ethylene oxide
(the simplest epoxide)

- O as a substituent



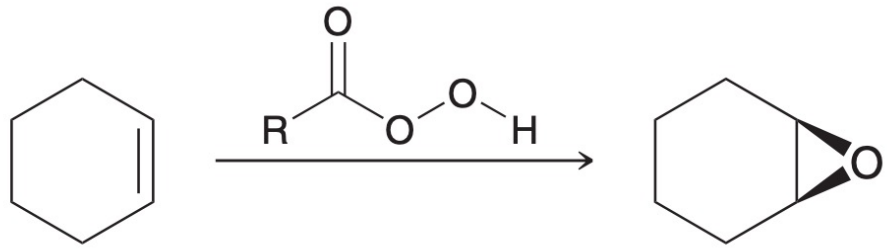
3-Ethyl-2-methyl-2,3-epoxypentane

- Oxirane as the parent

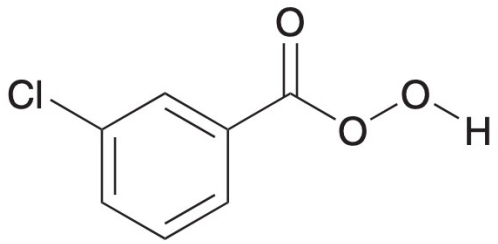


2,2-Diethyl-3,3-dimethyloxirane

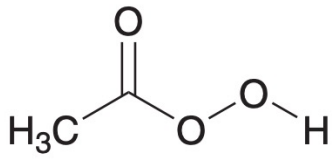
- Preparation with peroxy acids



commonly used peroxy acids:

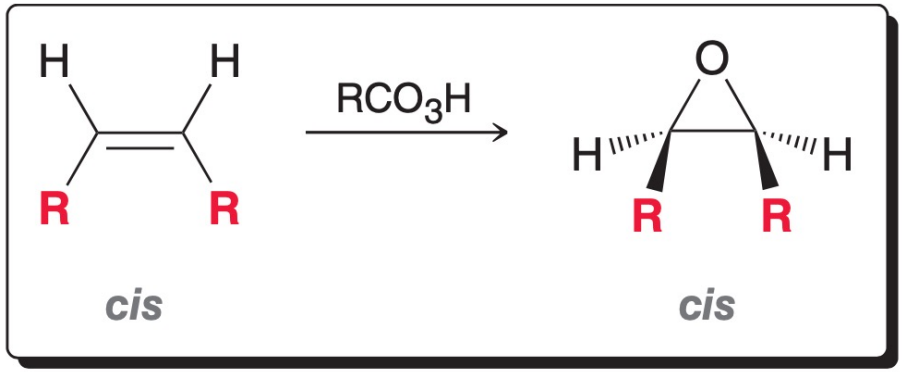


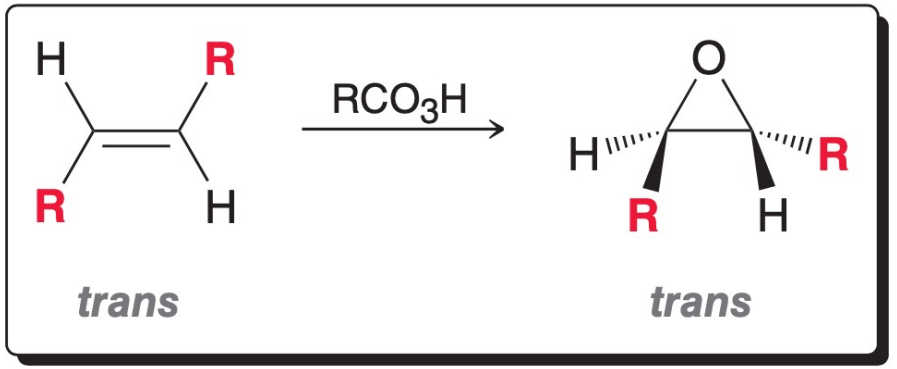
***meta*-Chloroperoxybenzoic acid (MCPBA)**



Peroxyacetic acid

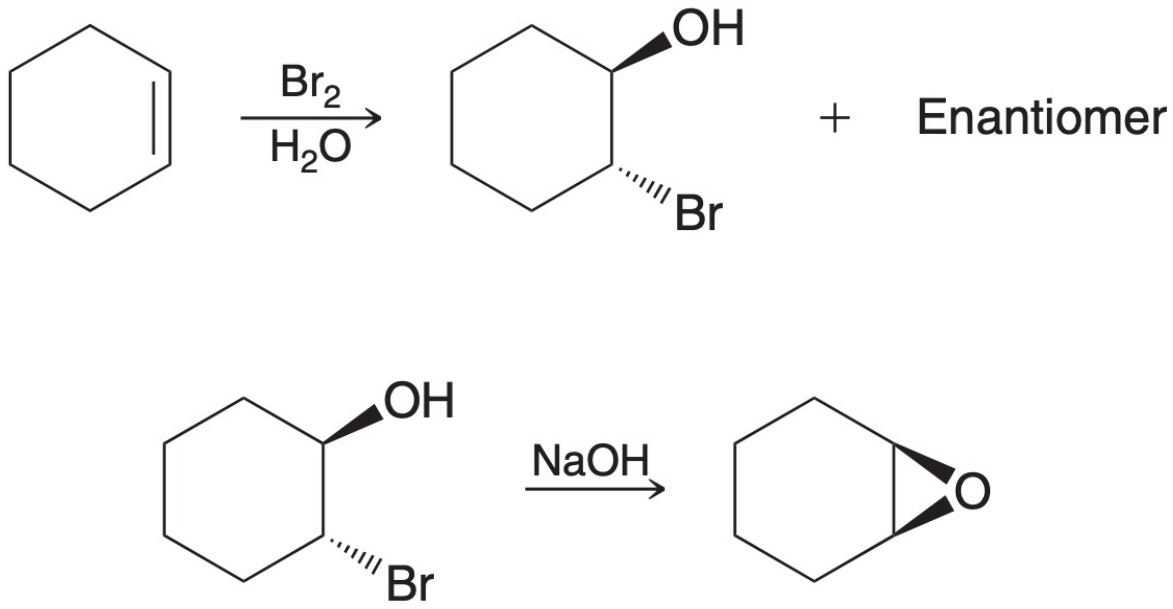
- Stereospecificity considerations



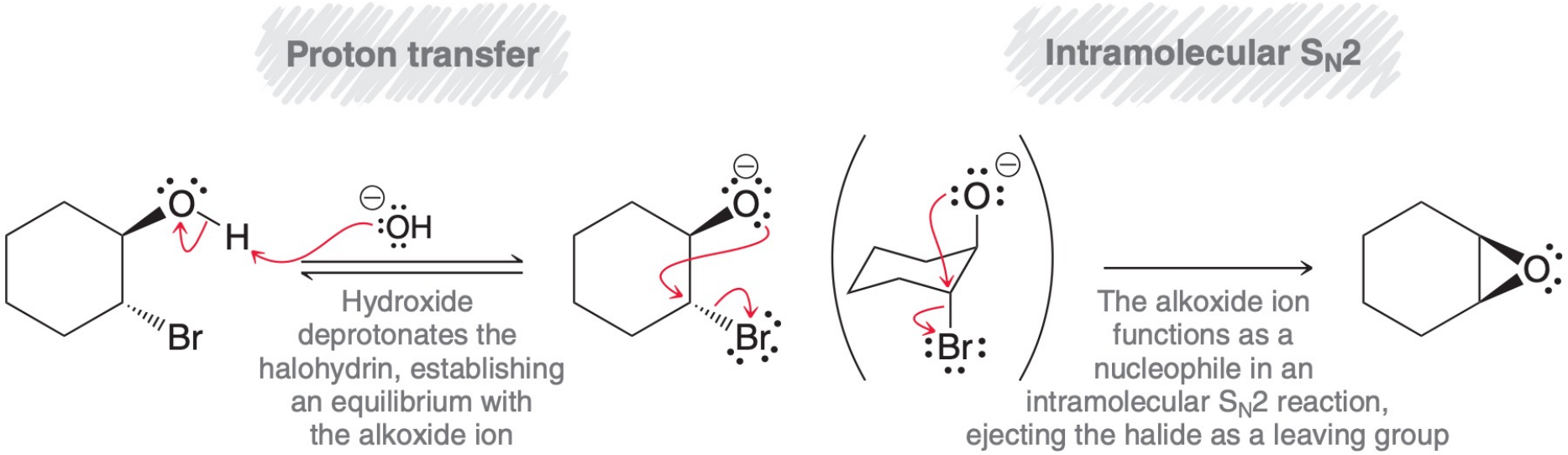


retention of configuration

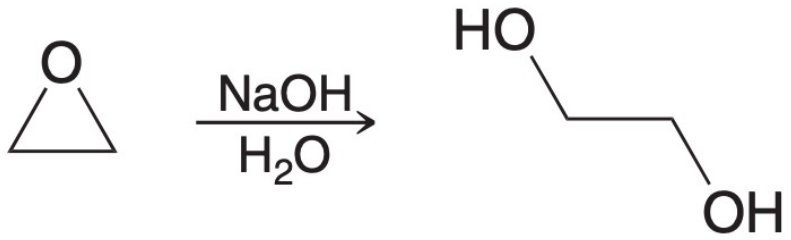
- Preparation from halohydrins



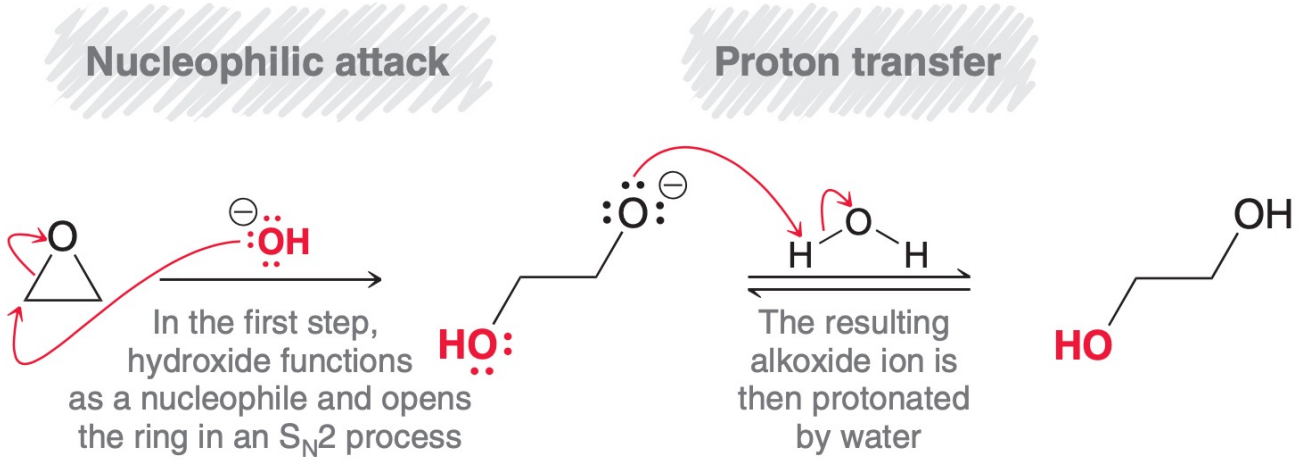
- **Mechanism: Epoxide Formation from Halohydrins**



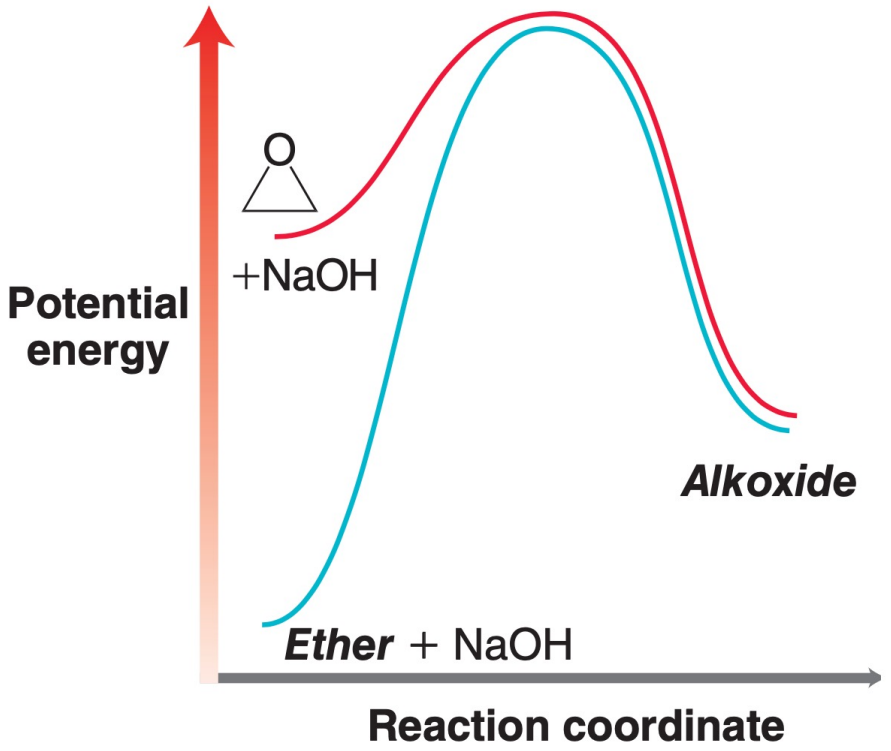
- Reactions of Epoxides with Strong Nucleophiles



- **Mechanism: Epoxide Ring Opening with a Strong Nucleophile**

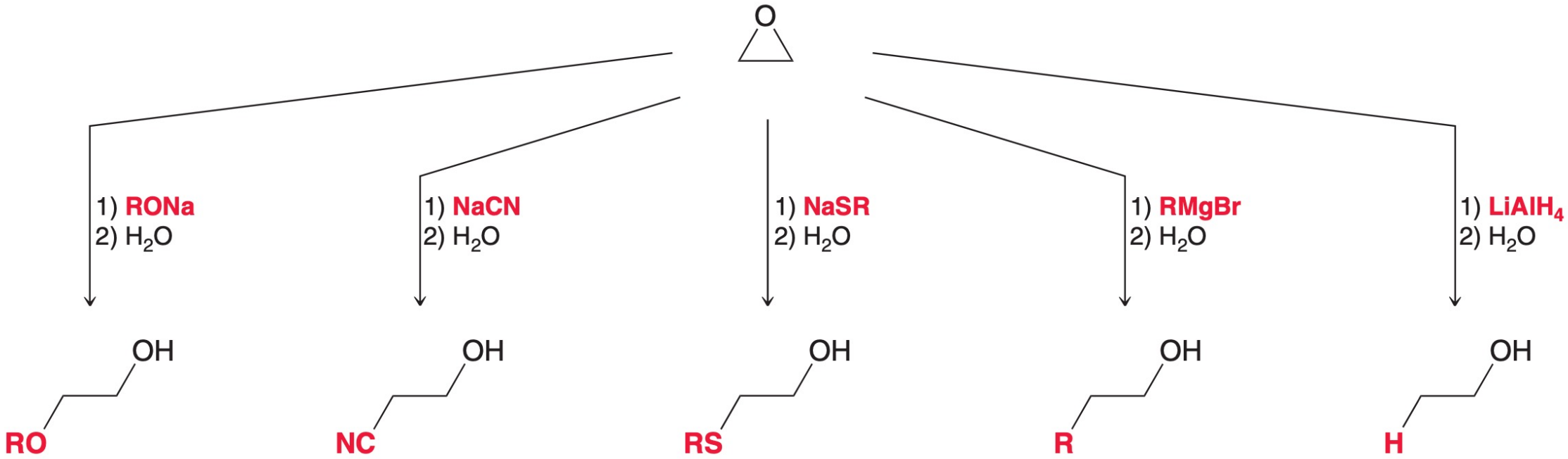


- Why alkoxide can function as a good LG?

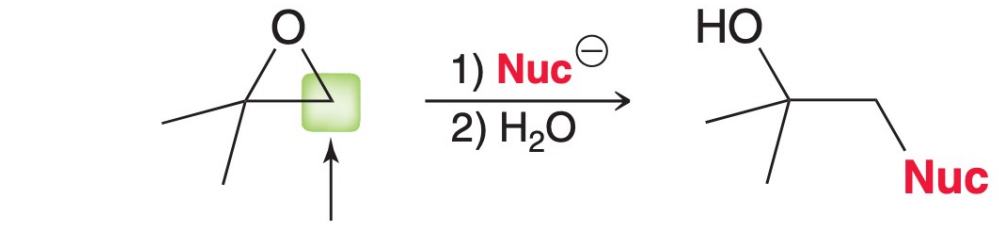


ring strain causes an extremely high energy

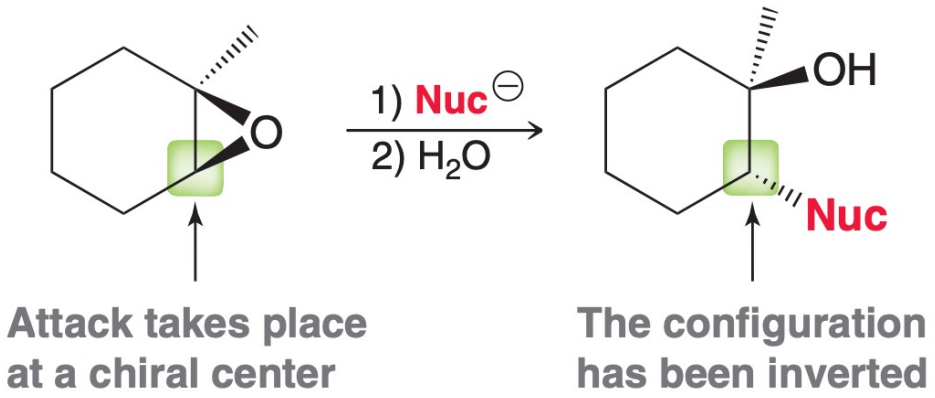
- Typical reagents



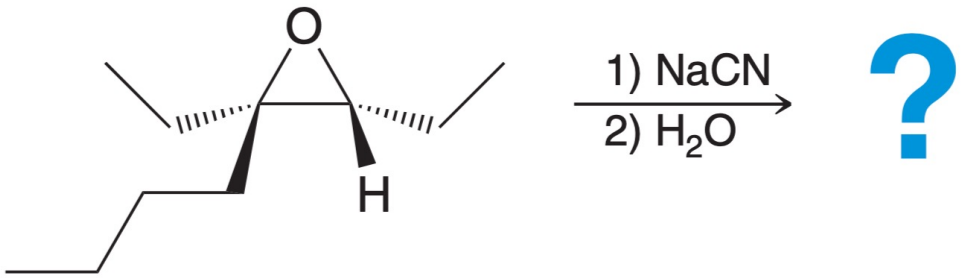
- Regiochemical outcome: attacks at the less substituted (less hindered) position

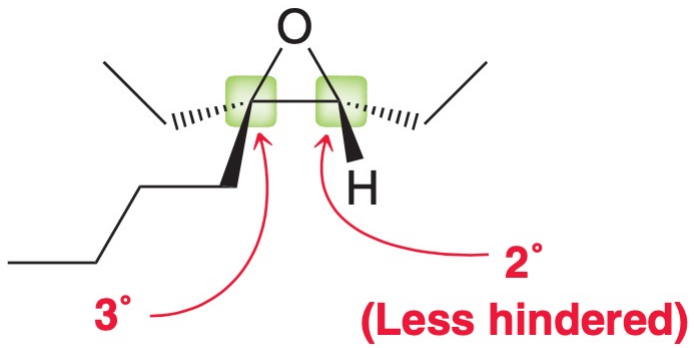


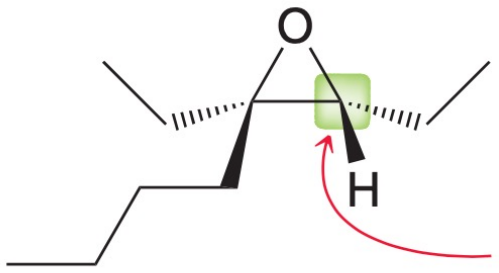
- Stereochemical outcome: inversion of configuration (S_N2)



- Practice: predict the product of the following reaction and draw a mechanism for its formation:

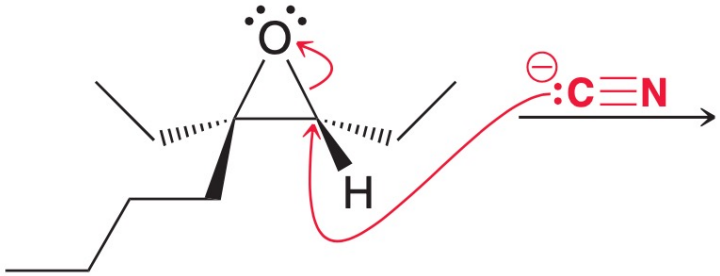




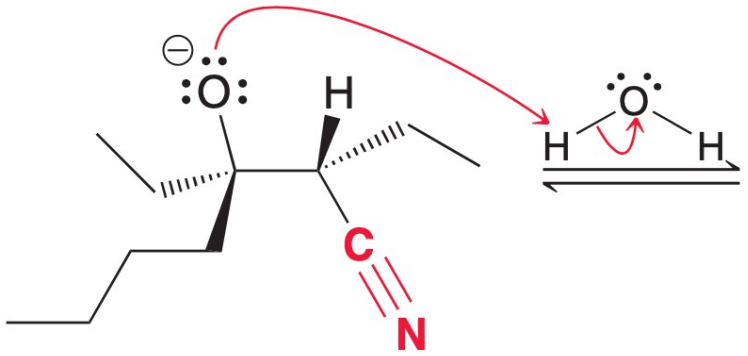


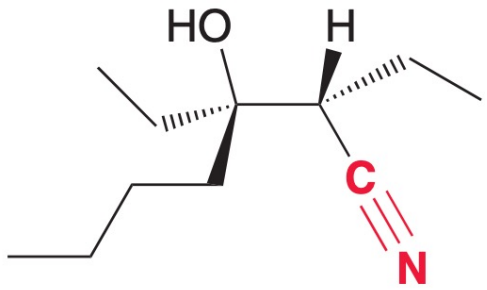
This chiral center will be inverted

Nucleophilic attack

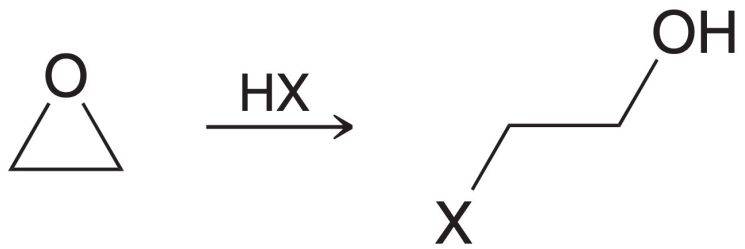


Proton transfer

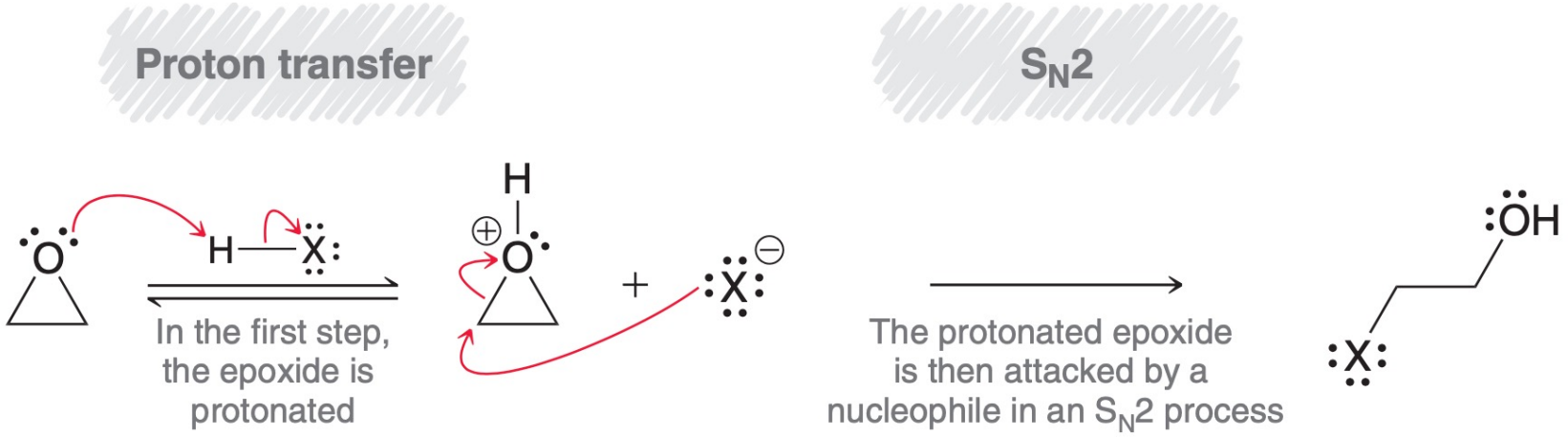




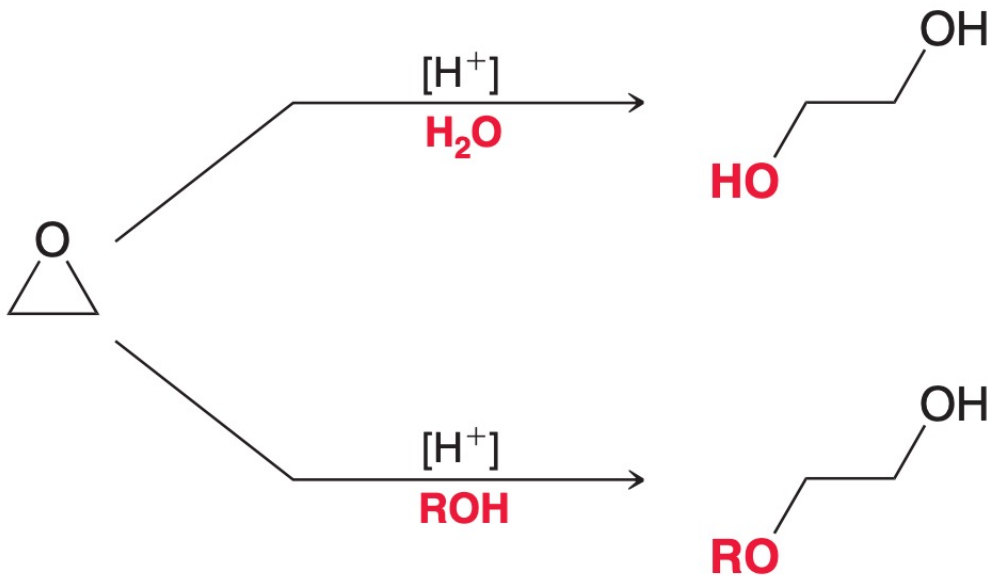
- Acid-catalyzed ring opening



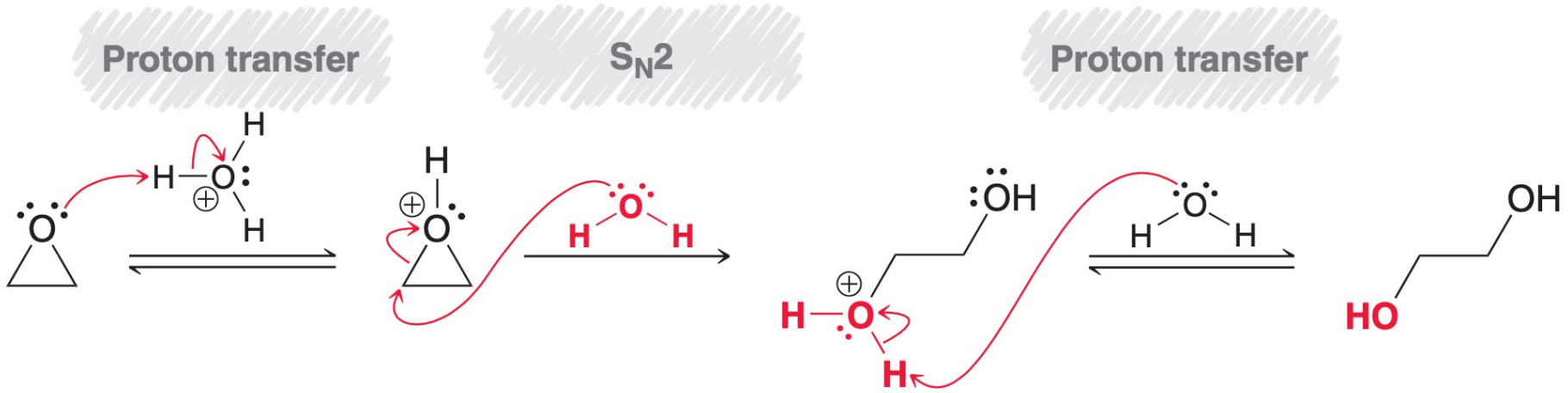
- **Mechanism: Acid-Catalyzed Ring Opening of an Epoxide**



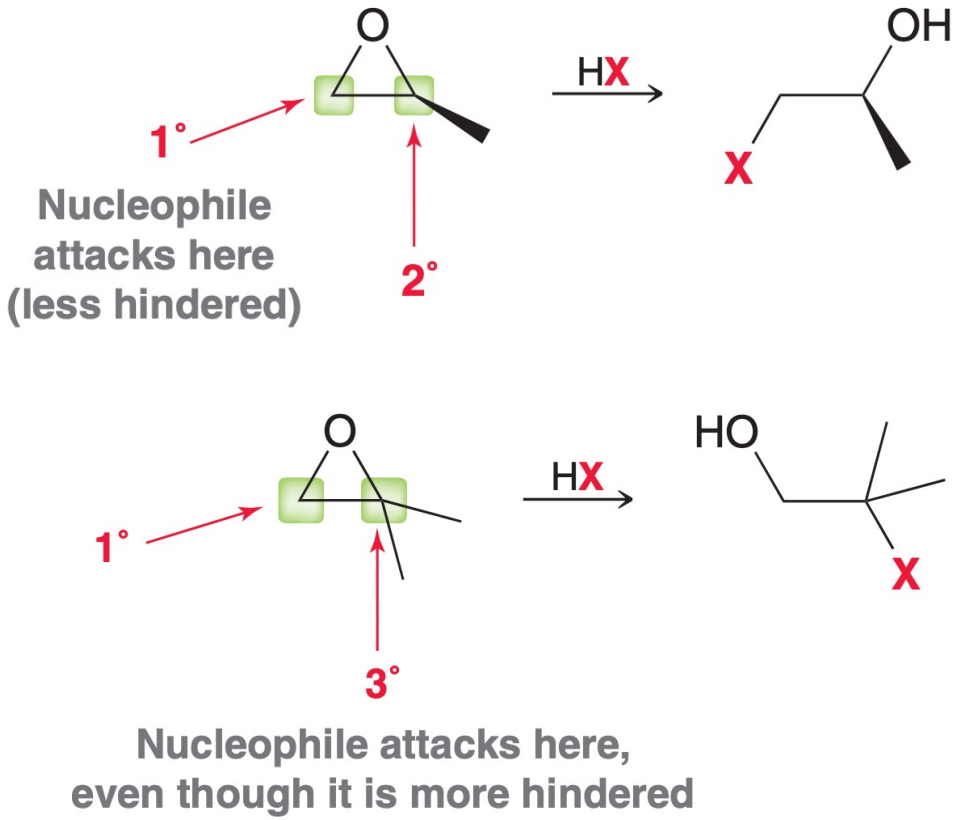
- Using water or alcohol as nucleophiles



- Proton transfer is needed when a neutral nucleophile is used



- Regiochemical outcome



that looks all right…

…but why this???

- Tertiary carbon: *electronic* effect

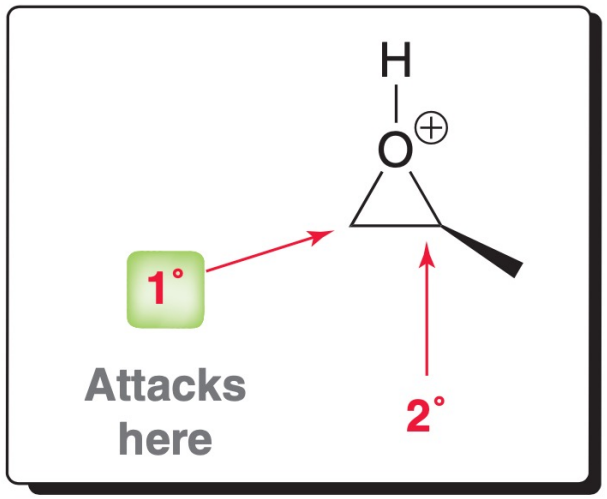
the more substituted carbon has significant carbocationic character

sp^2-hybridized-likely, geometry somewhere between tetrahedral & trigonal planar

also, a more stable transition state

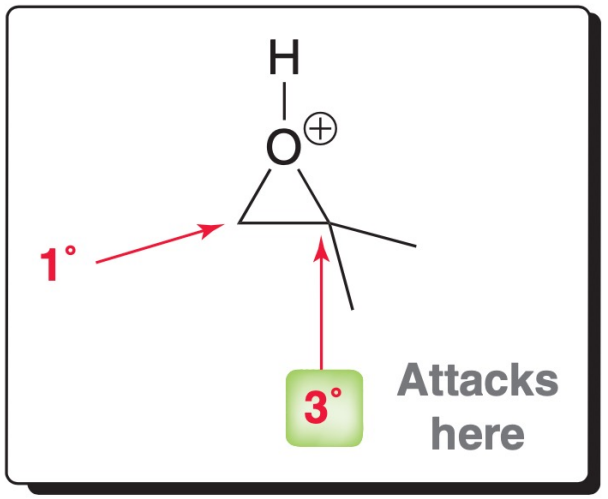
- Summary of regiochemistry

Primary vs. secondary



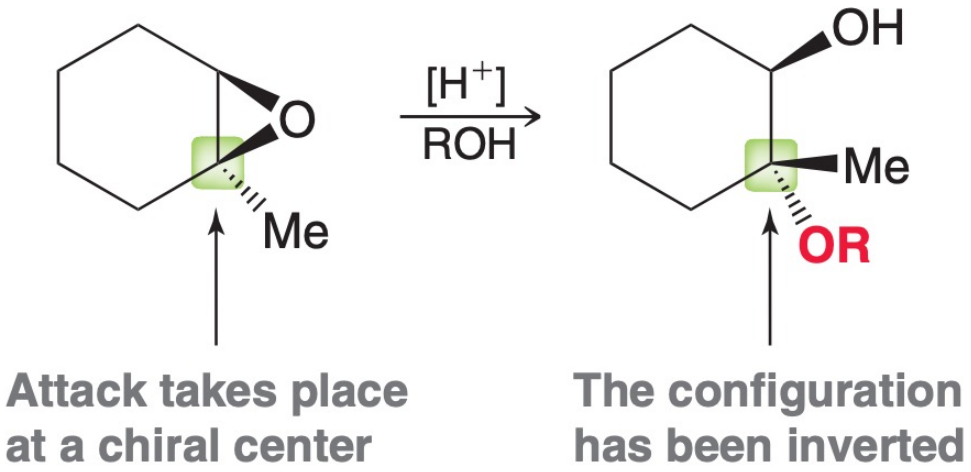
Dominant factor = steric effect

Primary vs. tertiary

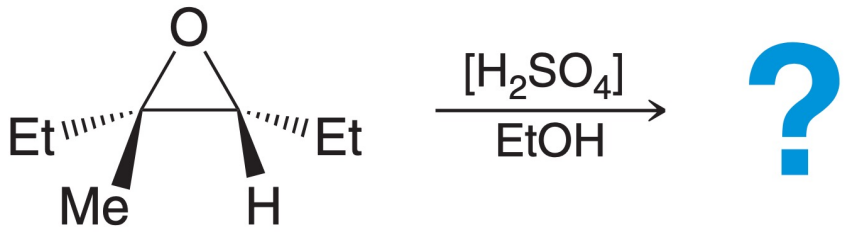


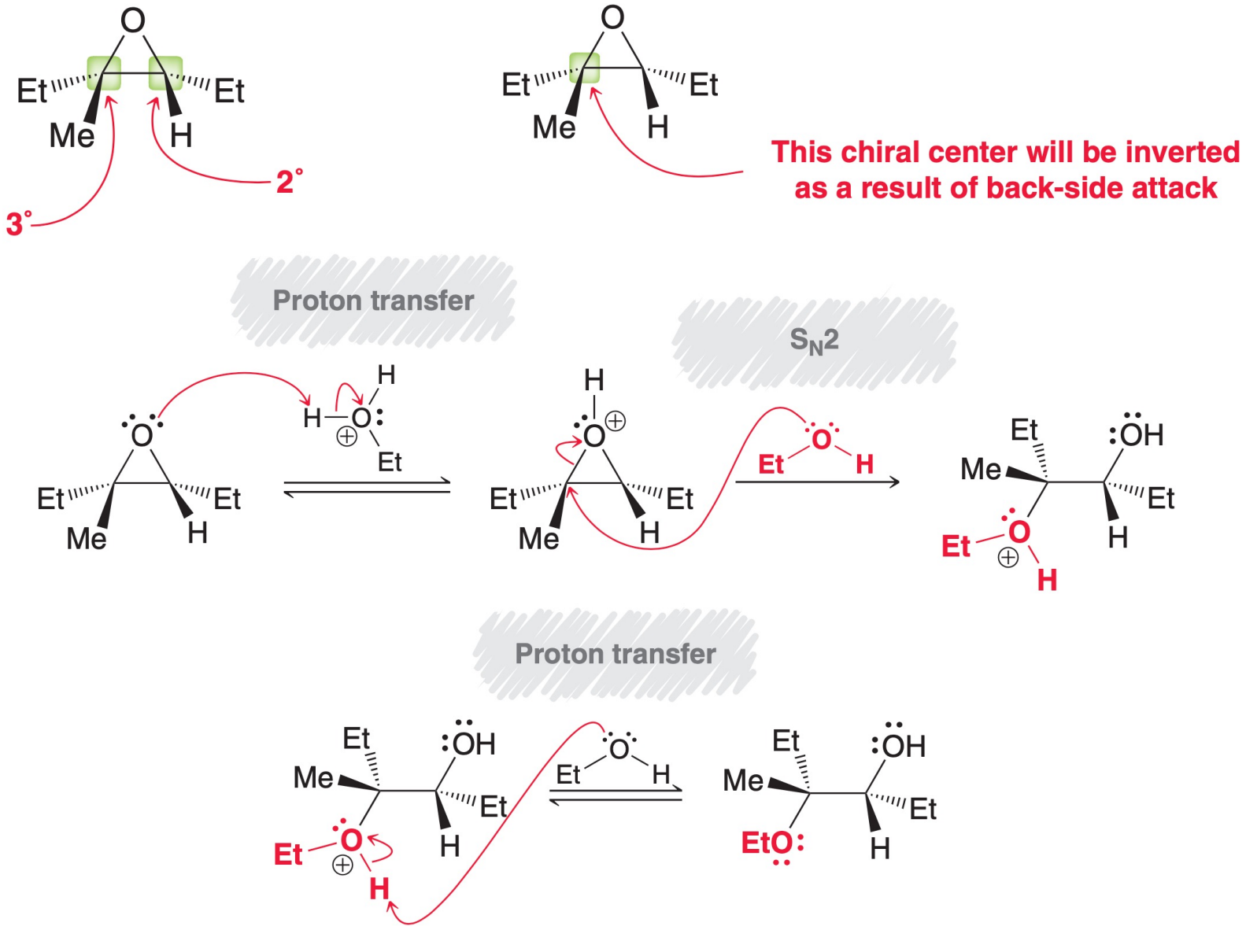
Dominant factor = electronic effect

- Stereochemical outcome: inversion of configuration (S_N2)



- Practice: predict the product of the reaction below and draw a likely mechanism for its formation:

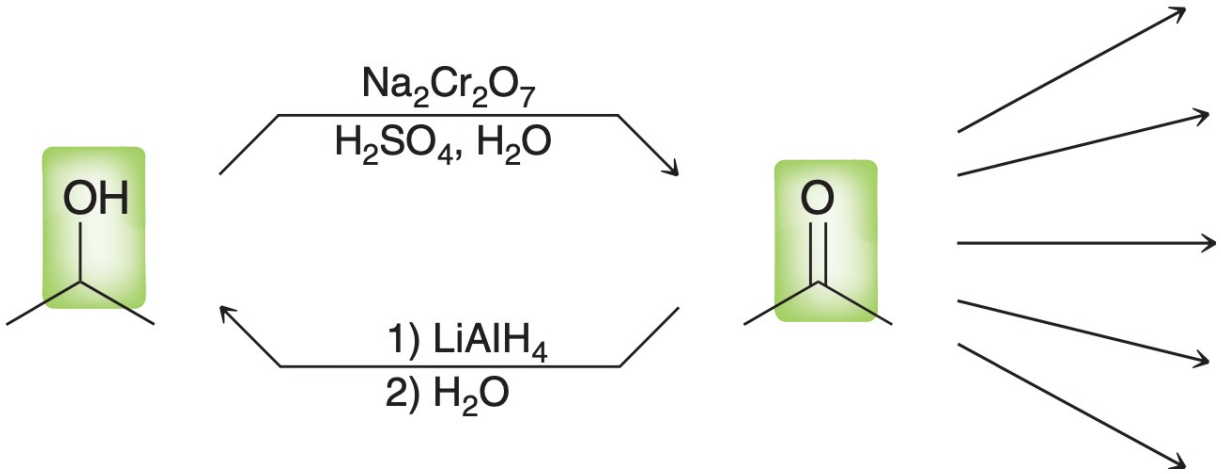



Et
Et
Me
H
2°
3°
This chiral center will be inverted
as a result of back-side attack
Proton transfer
SN2
Et
Et
Me
H
Et
Et
Me
H
Et
H
Et
Et
Me
H
Et
H
Et
Me
Et
:OH
Et
H
Proton transfer
Et
:OH
Me
Et
Et
H
Et
H
Et
:OH
Me
Et
EtO:
H

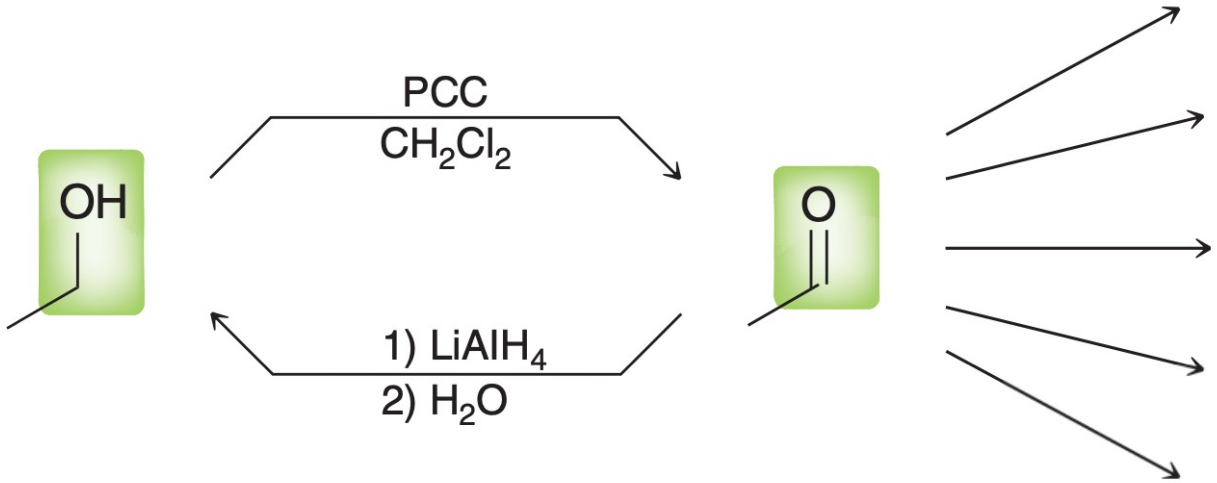
Synthesis Strategies

Functional Group Interconversion, Grignard Reagents: C-C Bond Formation

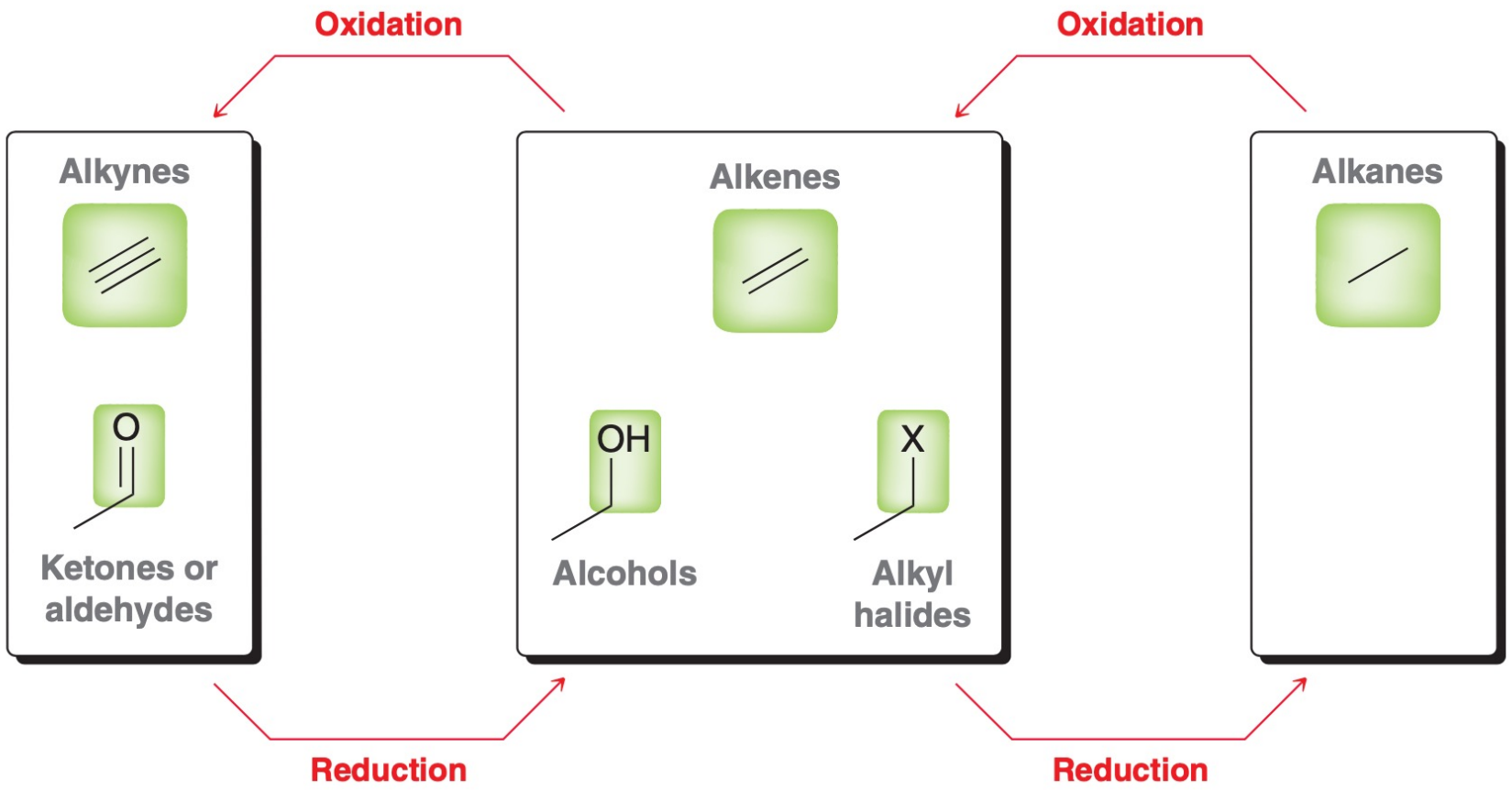
- Secondary alcohol-ketone interconversions

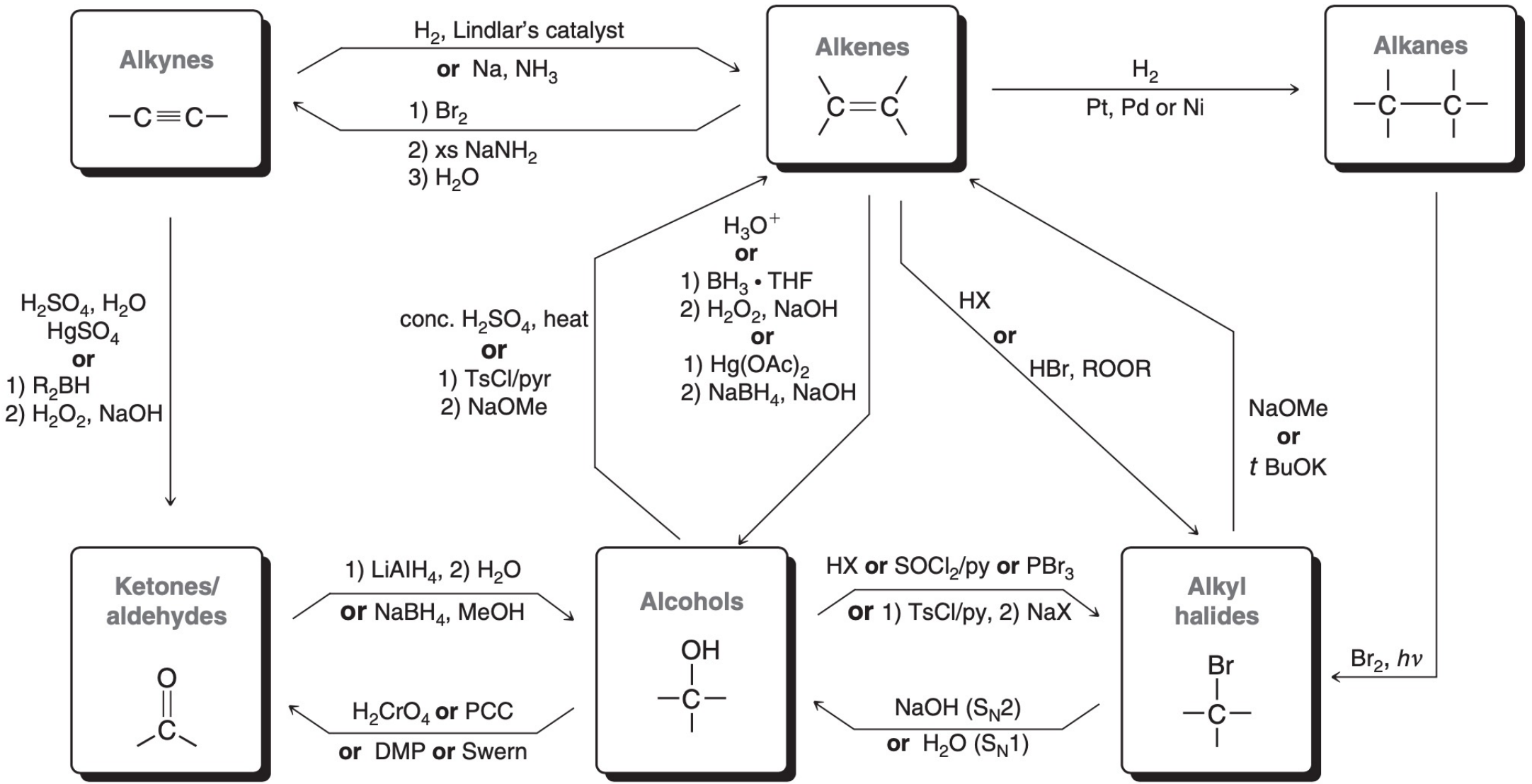


- Primary alcohol-ketone interconversions



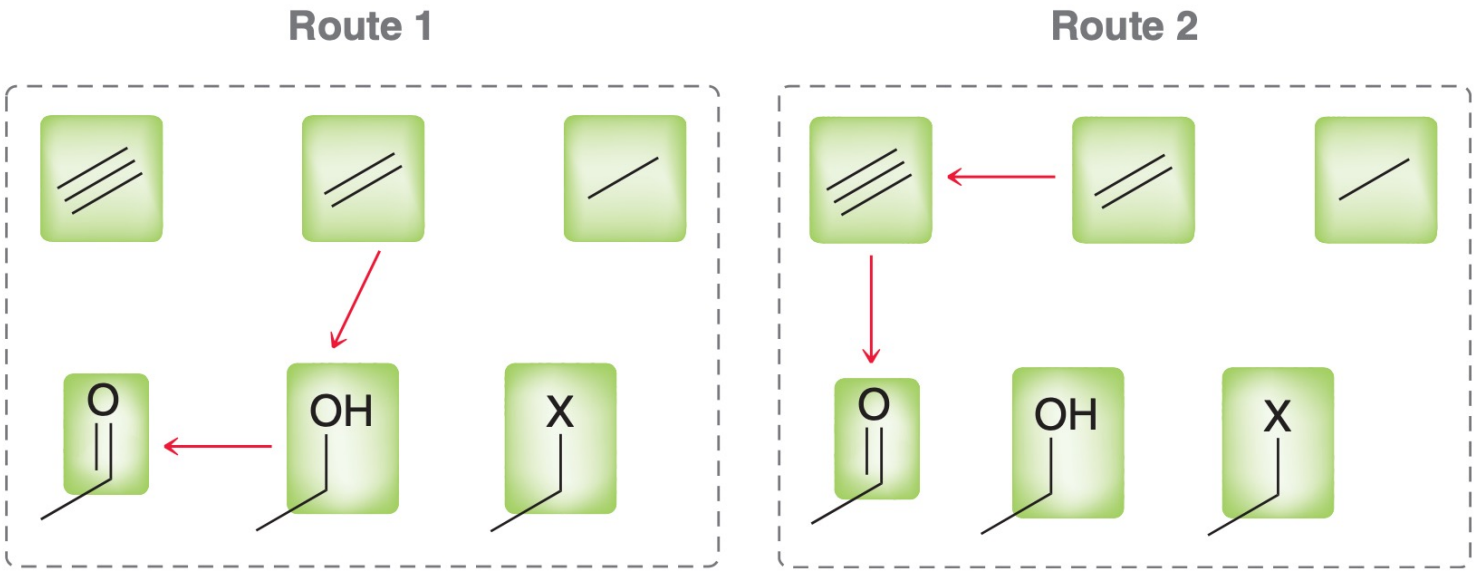
- Organic redox reactions

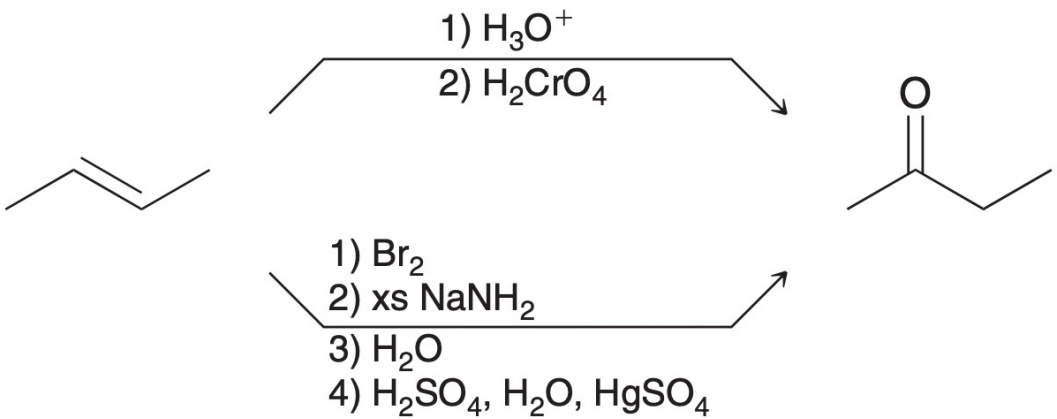



Alkynes
—C≡C—
H2, Lindlar's catalyst
or Na, NH3
1) Br2
2) xs NaNH2
3) H2O
Alkenes
C=C
H2
Pt, Pd or Ni
Alkanes
—C—C—
H2SO4, H2O
HgSO4
or
1) R2BH
2) H2O2, NaOH
conc. H2SO4, heat
or
1) TsCl/pyr
2) NaOMe
H3O+
or
1) BH3 • THF
2) H2O2, NaOH
or
1) Hg(OAc)2
2) NaBH4, NaOH
HX
or
HBr, ROOR
NaOMe
or
t BuOK
Ketones/
aldehydes
O
C
1) LiAlH4, 2) H2O
or NaBH4, MeOH
H2CrO4 or PCC
or DMP or Swern
Alcohols
OH
—C—
HX or SOCl2/py or PBr3
or 1) TsCl/py, 2) NaX
NaOH (SN2)
or H2O (SN1)
Alkyl
halides
Br
—C—
Br2, hν

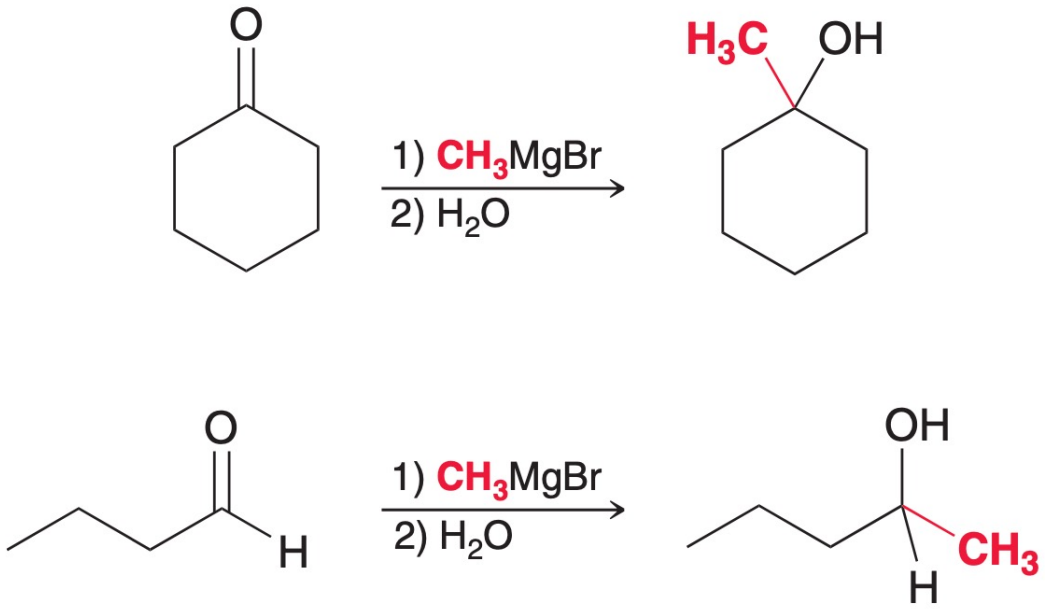
- Practice: propose an efficient synthesis for the following transformation:


O

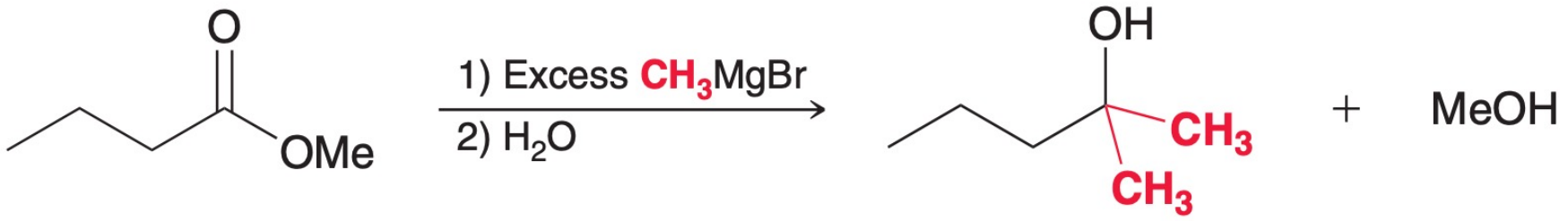

Route 1
Route 2
O
OH
X
O
OH
X


1) H_3O^+
2) H_2CrO_4
O
1) Br_2
2) xs $NaNH_2$
3) H_2O
4) H_2SO_4, H_2O, $HgSO_4$

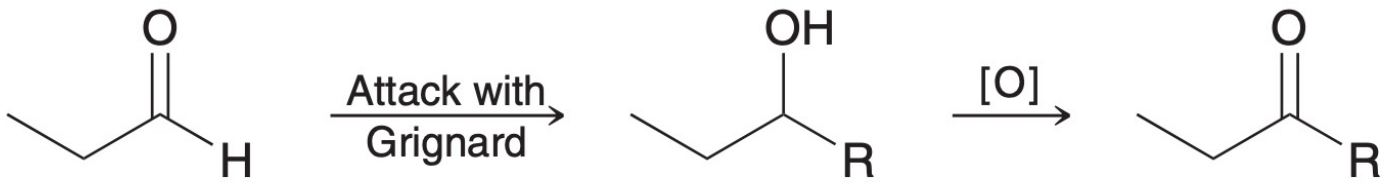
- Grignard reagents: C-C bond formation

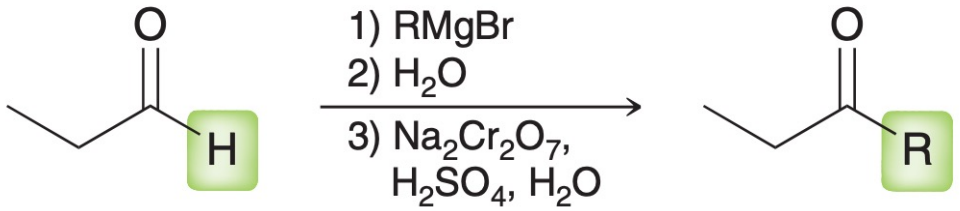


- Grignard reagents with esters

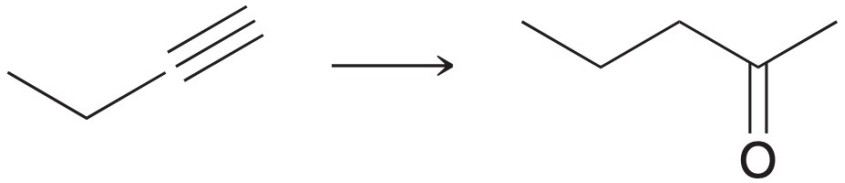


- Grignard reagents: convert aldehydes into ketones





- Practice: propose an efficient synthesis for the following transformation:

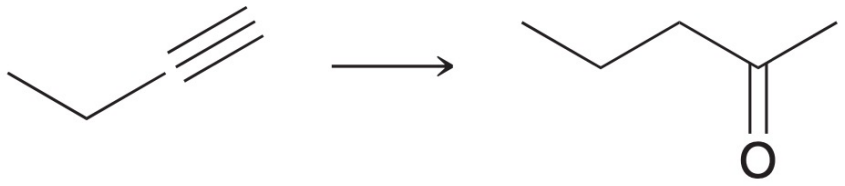


- Always approach a synthesis problem by initially asking two questions:
  - *Is there a change in the carbon skeleton?*

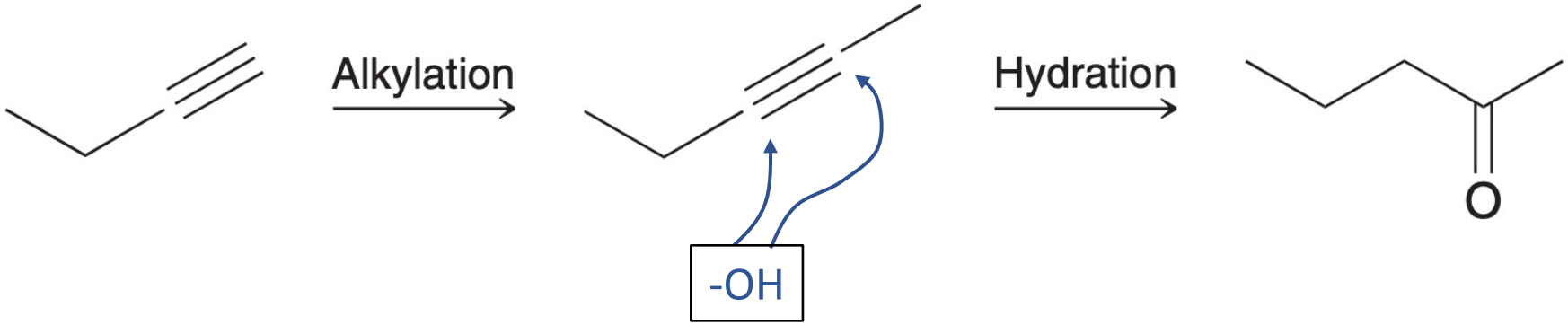
  ——*Yes, the carbon skeleton is increasing in size by one carbon atom.*

  - *Is there a change in the functional groups?*

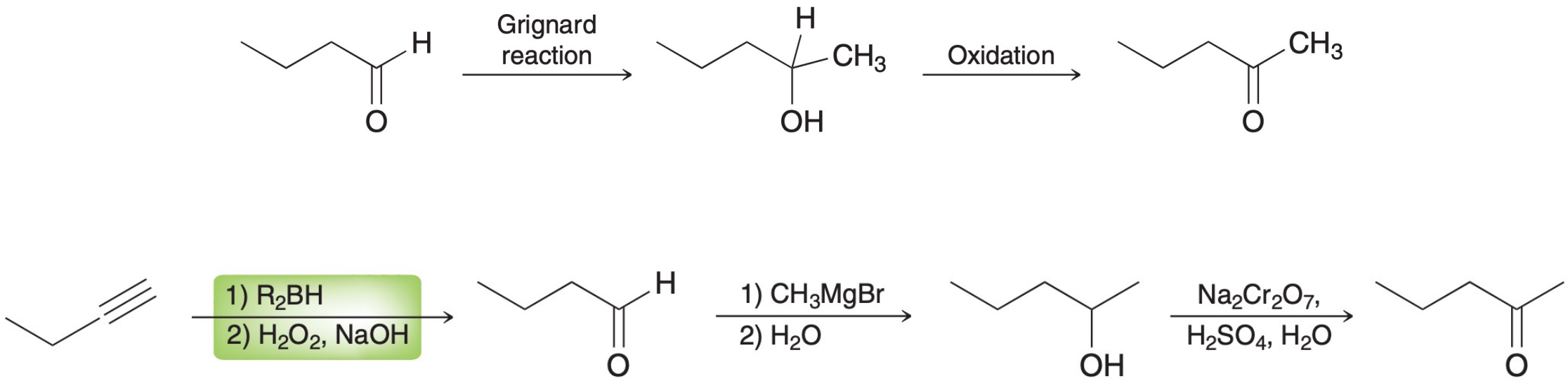
  ——*Yes, the starting material has a triple bond, and the product has a carbonyl group.*



- Alkylation, followed by hydration…?



problematic regiochemical outcome: -OH can be installed at both side!


H
O
Grignard
reaction
H
CH3
OH
Oxidation
CH3
O
1) R2BH
2) H2O2, NaOH
H
O
1) CH3MgBr
2) H2O
OH
Na2Cr2O7,
H2SO4, H2O
O

- The complete route