

$R-X + Nu^- \rightarrow R-Nu + X^-$ This is example (1)
 $X =$ leaving group
 $Nu \Rightarrow$ Attacking nucleophile.

$\Rightarrow S_N2$ (Bimolecular; 2nd order kinetics) [common]

$\Rightarrow S_N1$ (Unimolecular; 1st order kinetics) [common]

$\Rightarrow S_{N}i$ ($i =$ intramolecular; 2nd order kinetics) [rare].

: S_N2 :

$\Rightarrow Cl_3^- - X > 1^\circ R-X > 2^\circ R-X > 3^\circ R-X$

Less sterically hindered carbon, more reactivity.

$\Rightarrow 2\text{chlorohexane} > 3\text{chlorohexane}$

$\Rightarrow (CH_3)_3C-Cl > CH_3-CH_2-CH_2-Cl > (CH_3)_2CH-CH_2-Cl > CH_3CH_2CH_2CH_2Cl$.

$\Rightarrow (CH_3)_3C-Cl > CH_3-CH_2-CH_2-Cl > (CH_3)_2CH-CH_2-Cl > CH_3CH_2CH_2CH_2Cl$.

\Rightarrow Aprotic solvent (DMF; DMSO; Acetonitrile), Acetone

\Rightarrow Inversion of configuration (baileside attack by nucleophile w.r.t L.G.).

\Rightarrow  More is the δ+ charge on carbon attacked by X, faster is the reaction.

: S_N1 :

$3^\circ R-X > 2^\circ R-X > 1^\circ R-X > Cl^- - X$.

\Rightarrow More stable carbocation, faster is the S_N1 reaction.

$\Rightarrow (CH_3)_3C-Cl > (CH_3)_2CH-Cl > CH_3CH_2CH_2-Cl > CH_3-Cl$.

\Rightarrow 

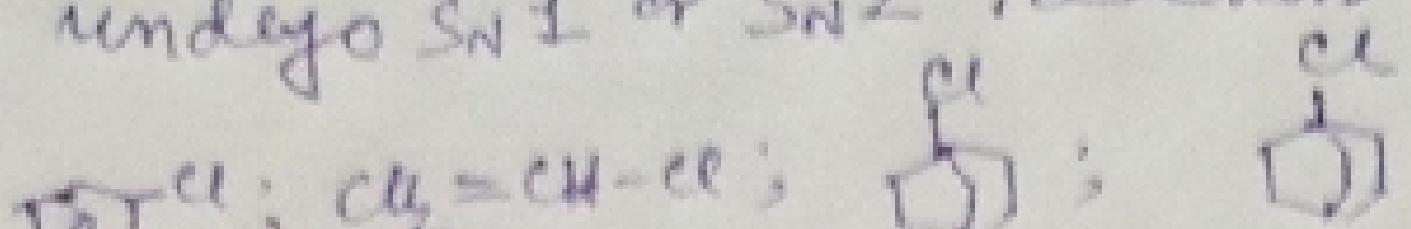
More is the δ+ charge on carbon attacked by X, faster is the reaction.

$\Rightarrow Ph_3C-Cl > Ph_2CH-Cl > PhCH_2Cl$.

exception: $(Me_3C)_3C-Cl > Me_3-Cl$.

$(CH_3)_2CH-CH_2-Cl > CH_3CH_2CH_2CH_2-Cl$.

→ The following alkyl halide does not either (2) undergo S_N1 or S_N2 reaction.



Because $\text{CH}_2=\text{CH}-\text{Cl}$; Backside attack very less / not possible.

Carbocation very unstable.

→ PhCH_2Cl ; $\text{CH}_2=\text{CH}-\text{CH}_2-\text{Cl}$; $\text{MeO}-\text{CH}_2-\text{Cl}$ undergo S_N1 & S_N2 reaction very fast; Because all are example of 1°R-X & they give very stable carbocation.

In protic solvent they give S_N1 mechanism.

In aprotic solvent they give S_N2 mechanism

⇒ 3°R-X irrespective of solvent, S_N1 always.

⇒ 1°R-X irrespective of solvent; S_N2 always.

⇒ 2°R-X $\xrightarrow{S_N1}$ Protic solvent (H_2O ; MeOH ; CH_3CO_2^-).

$\xrightarrow{S_N2}$ Aprotic solvent (DMF ; CH_2O ; DMSO ; HMPT ; Acetone)

: Nucleophile: (lone pair donating tendency)

S_N2 rate is dependent on nucleophile but

S_N1 rate is independent on nucleophile.

Nucleophilicity order

f) $\text{RNH}_2 > \text{PhNH}_2$

a) $\text{Cl}^- > \text{NH}_3^- > \text{OH}^- > \text{F}^-$

g) $\text{RO}^- > \text{PhO}^-$

b) $\text{CH}_3-\text{CH}_2 > \text{CH}_2=\text{CH} > \text{HC}\equiv\text{C}^-$

h) $\text{NH}_2-\text{NH}_2 > \text{NH}_3$

c) $\text{SH}^- > \text{Cl}^-$

i) $\text{H}-\text{O}-\text{O}^- > \text{OH}^-$

d) $\text{I}^- > \text{Br}^- > \text{Cl}^- > \text{F}^-$

[Protic solvent]

e) $\text{TeH}^- > \text{SeH}^- > \text{Sii}^- > \text{O}^-$ [In aprotic].

Solvent it is reverse.

j) $\text{C}_6\text{H}_5 > \text{NHe}_3$

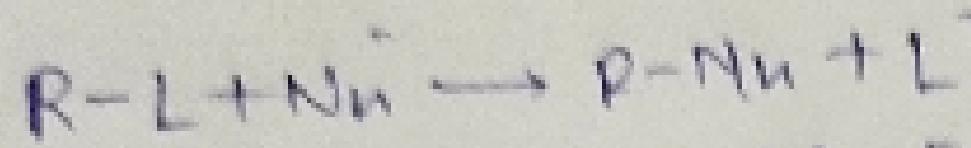
k) $\text{tBNO}^- > \text{MeO}^-$

l) $\text{R}_3\text{N} < \text{NH}_3$.

! Leaving group:

(3)

Better is the leaving group, faster is the S_N1 & S_N2 reactivity. Because C-L_g bond breakage is involved in S_N1 as well as S_N2 mechanism.

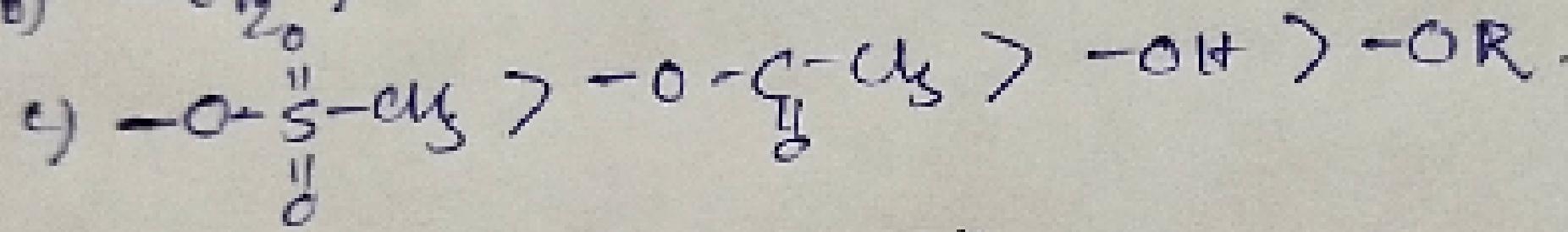
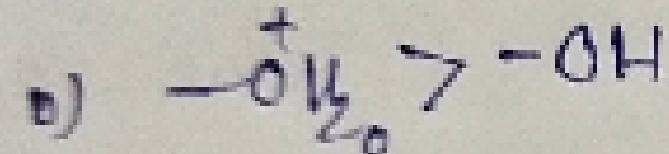


If L^- is stable then it is example of good L.G.

$\Rightarrow L^-$ stable base; weak base

\Rightarrow conjugate acid should be strong acid.

a) $I^- > Br^- > Cl^- > F^- \Rightarrow H^- & R^-$ cannot act as leaving group.



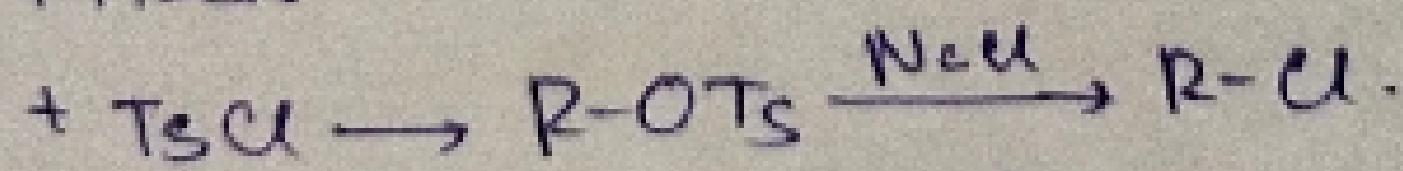
[diazonium ion one of the best L.G.]

Triflate ion $-O-\overset{\text{O}}{\underset{\text{S}}{\text{||}}}-(CF_3)_2$ is one of the best L.G.



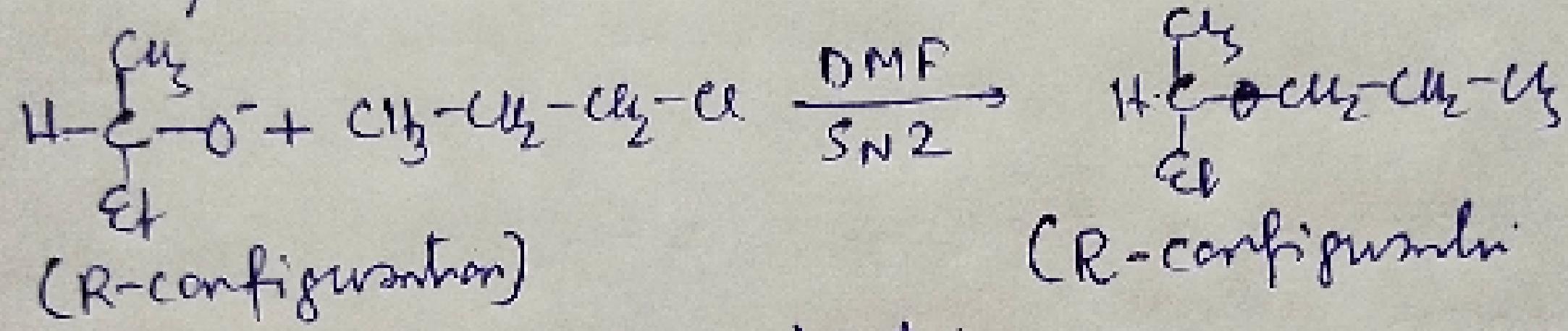
Tosylate ($-OTs$) bromate ($-OBs$) are

example of very good leaving group.

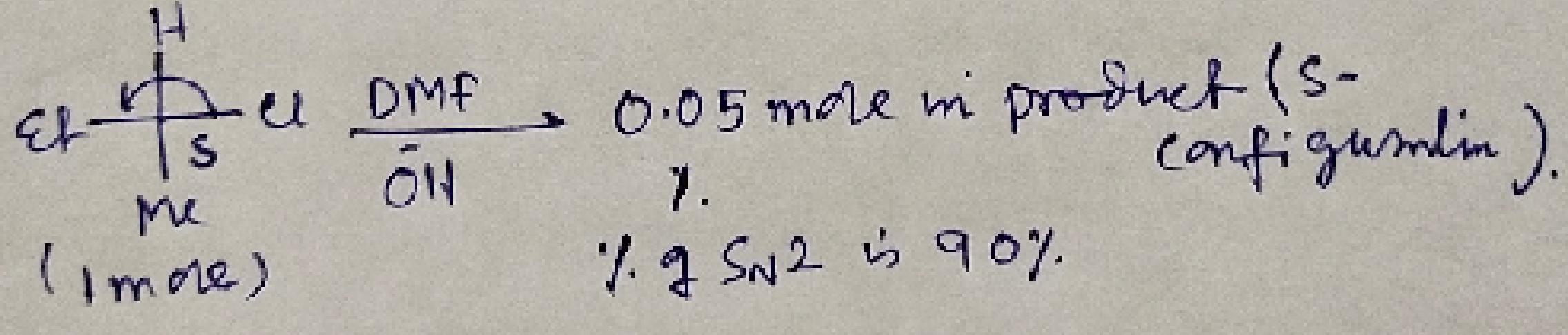
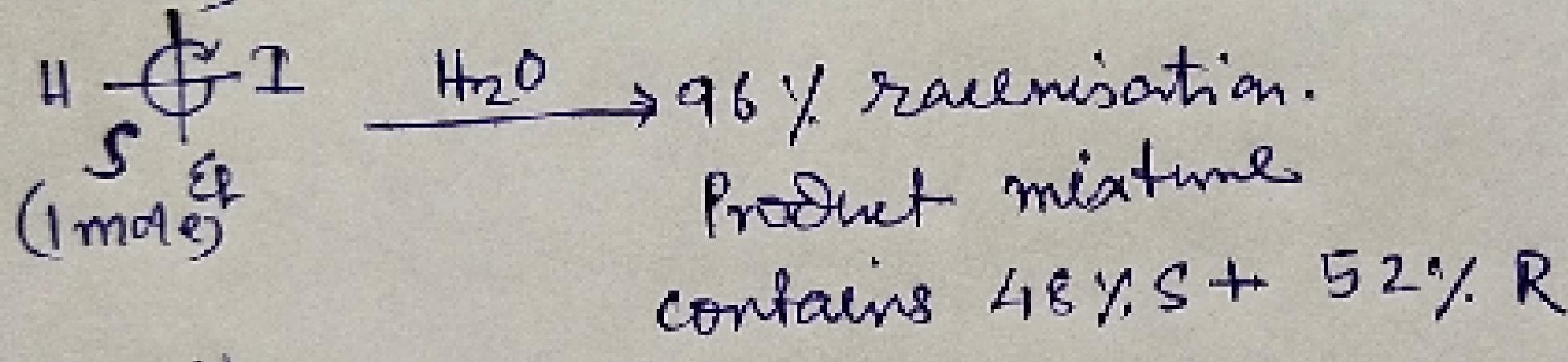


* Stereochemistry of Sn^+ : $\text{[C-X} \xrightarrow{\text{* Nu}} \text{C-Nu} + \text{X}^-$
 * chiral]

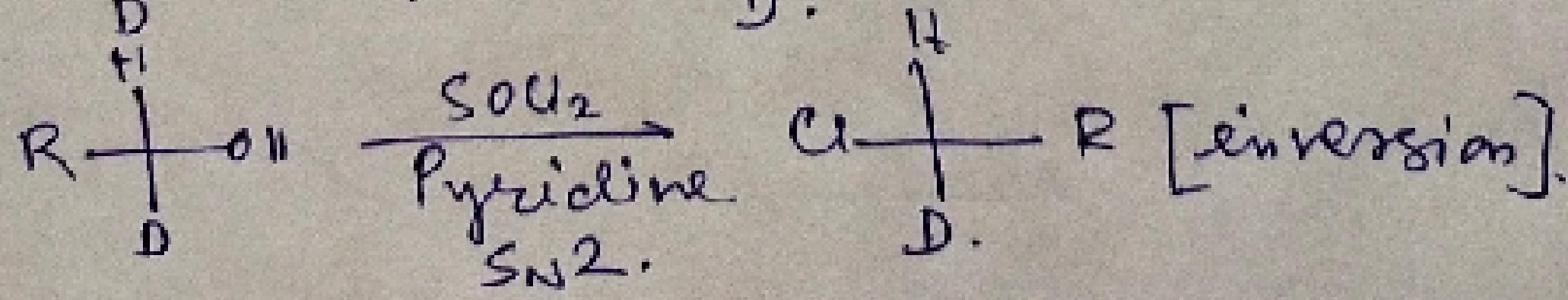
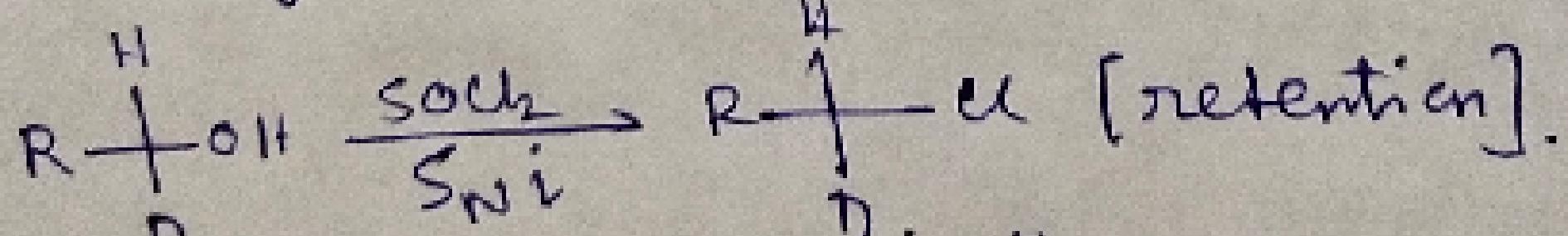
- $\Rightarrow \text{S}_{\text{N}}2$ reaction gives inversion mainly. carbon
- $\Rightarrow \text{S}_{\text{N}}2$ gives single stereoisomer. (A)
- $\Rightarrow \text{S}_{\text{N}}1$ gives racemication as mainly.
- \Rightarrow More stable carbocation; more is the racemication.
- \Rightarrow 100% racemication never takes place.



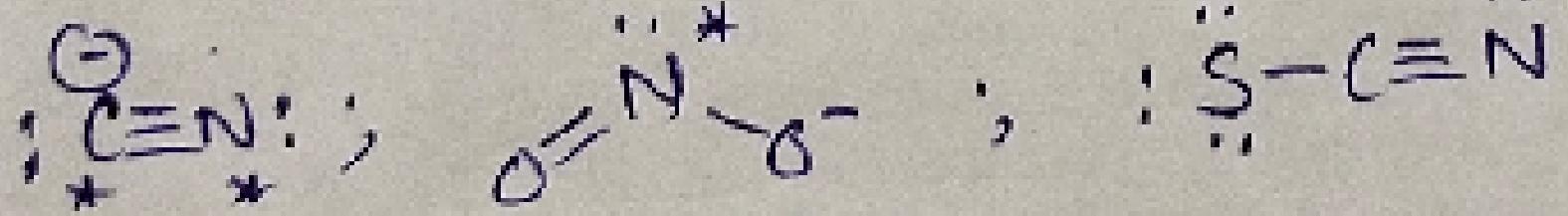
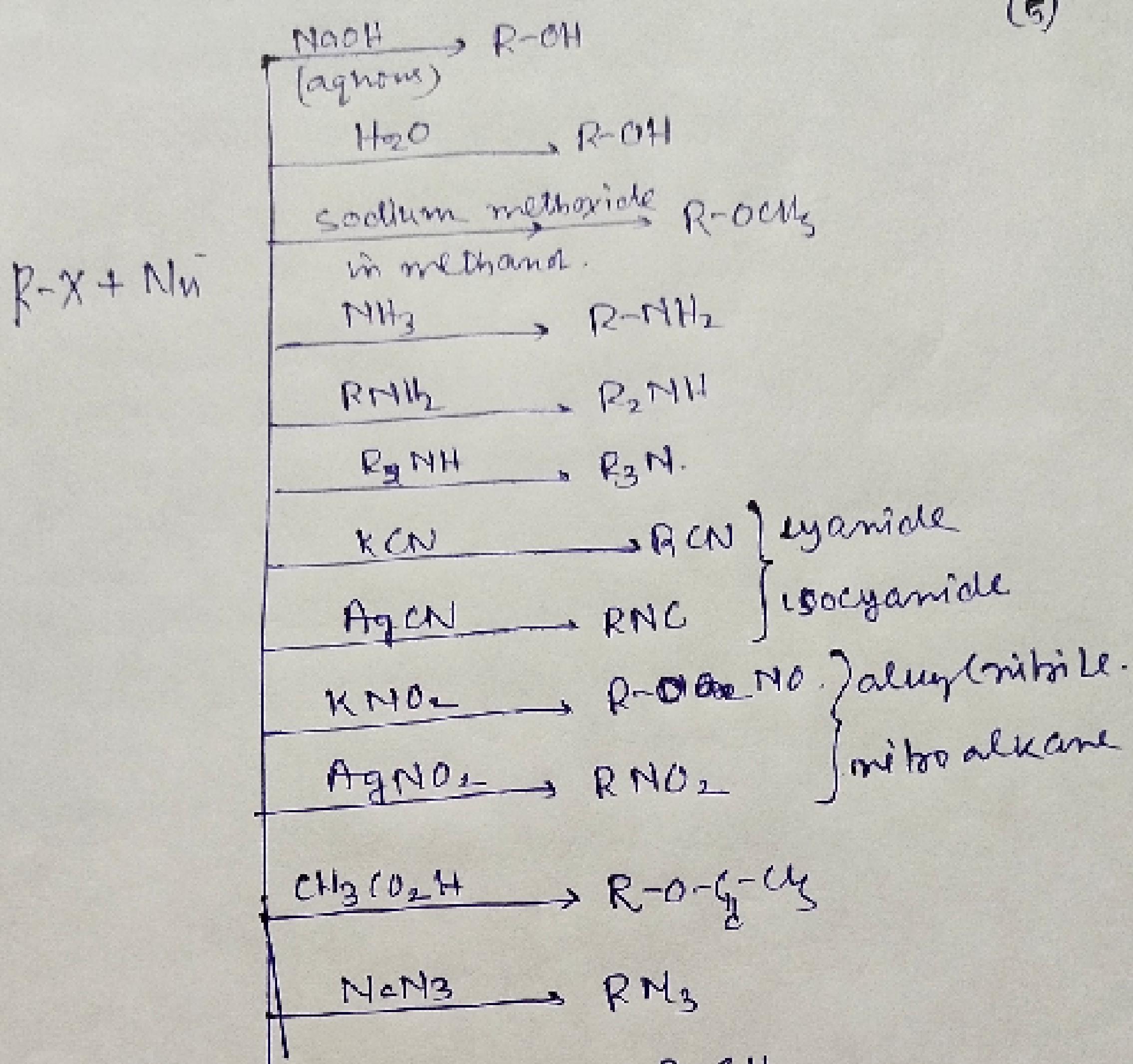
(exception S_N2 \Rightarrow retention
of configuration)
ex.



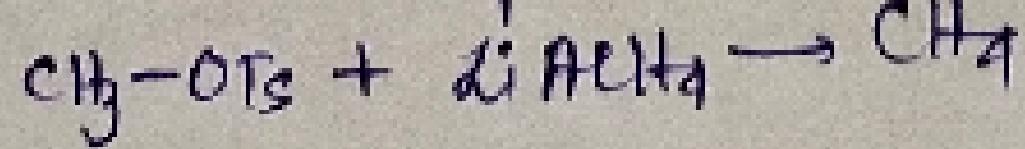
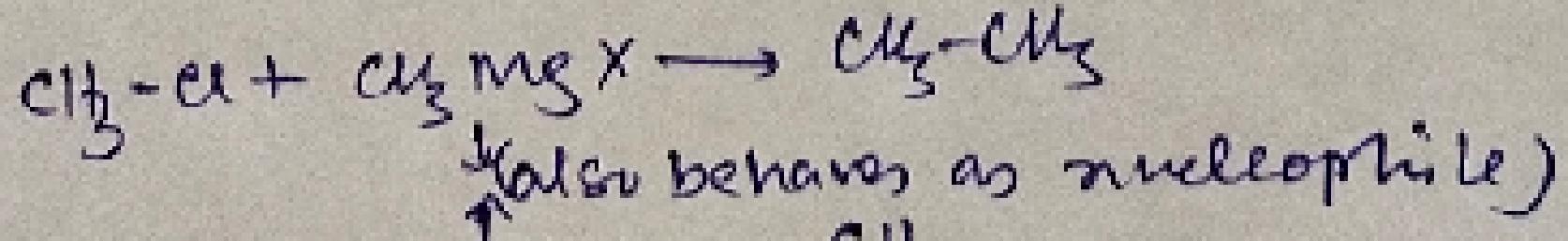
⇒ Sniffer gives retention of configuration.



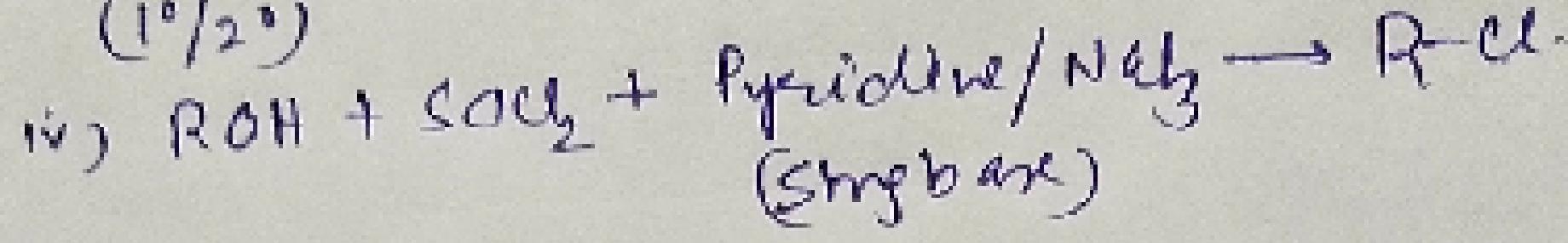
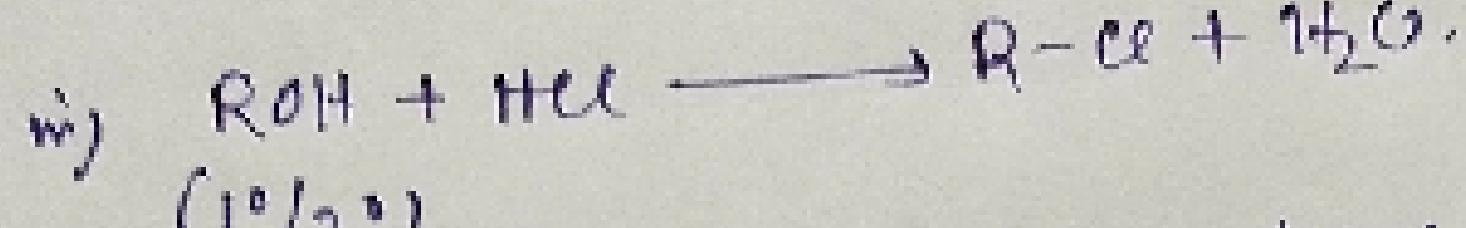
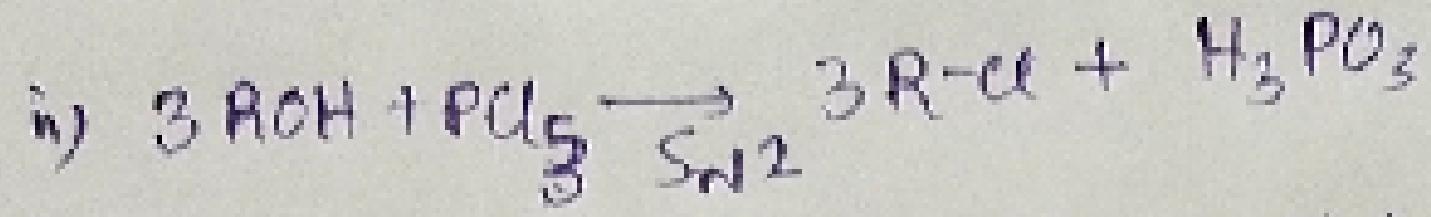
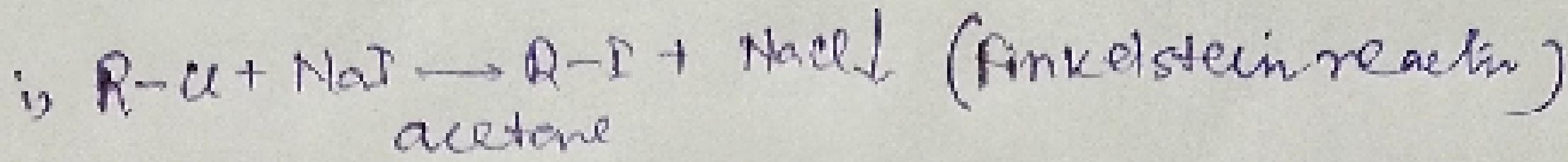
(5)



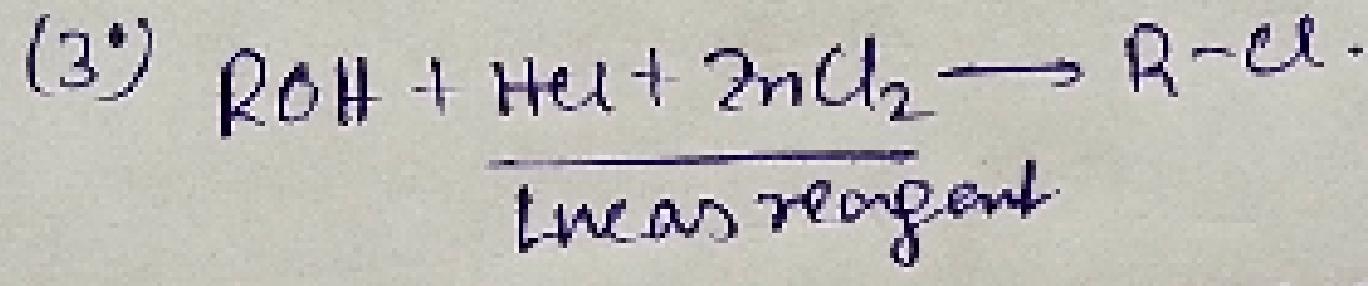
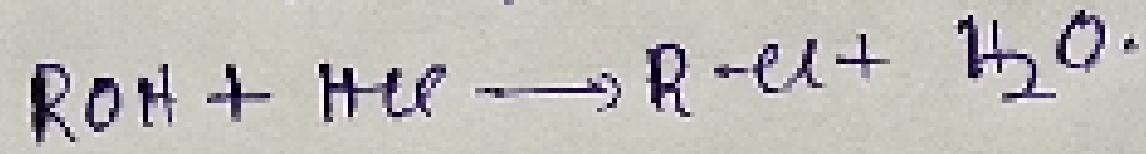
are example of ambidentate nucleophile.



: Different types of S_N2 reaction: (6)



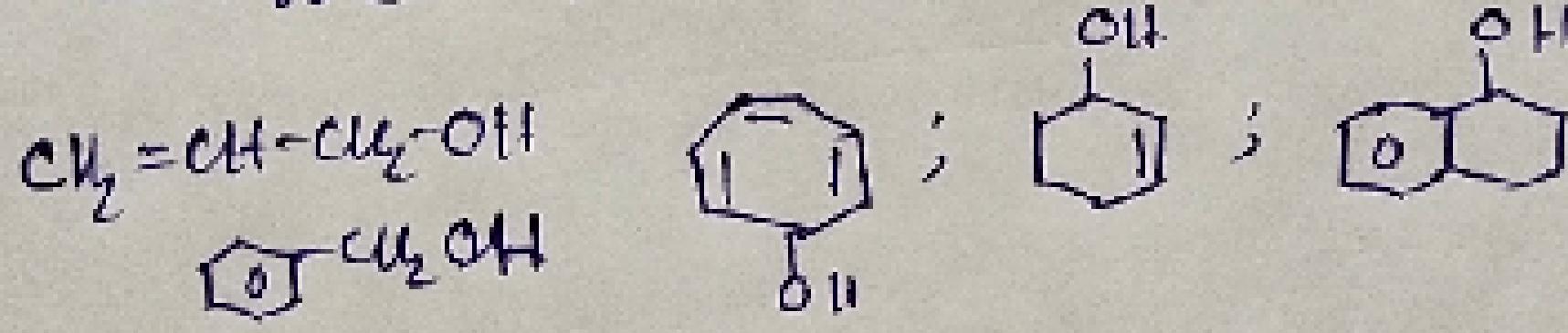
: Different types of S_N1 reaction:



for 3° alcohol, immediate turbidity.

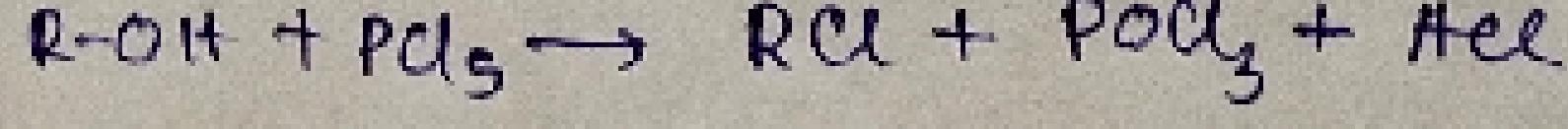
for 2° alcohol; turbidity forms within 5-10 min.

for 1° alcohol; no turbidity at room temperature.



Δ^{OII} (They all give turbidity instant)

Example of S_N1 mechanism.



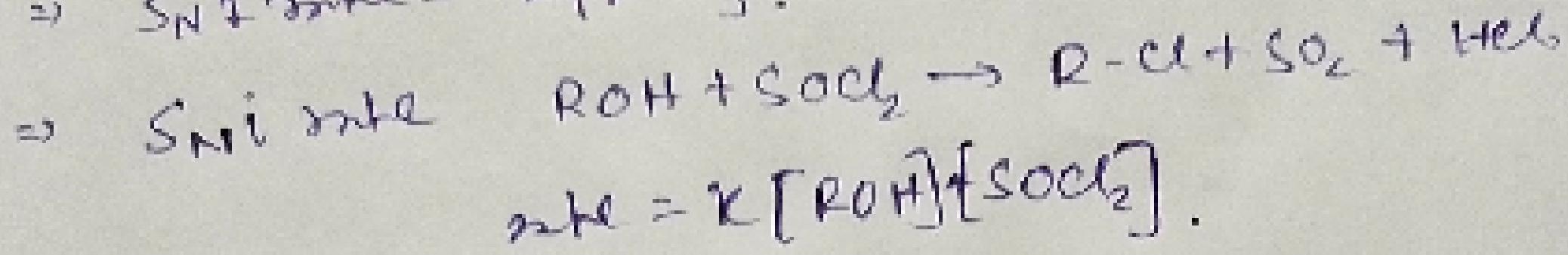
$SO_2 \uparrow$ & $HCl \uparrow$ gas removes, equilibrium forward.

∴ yield of product will be very high.

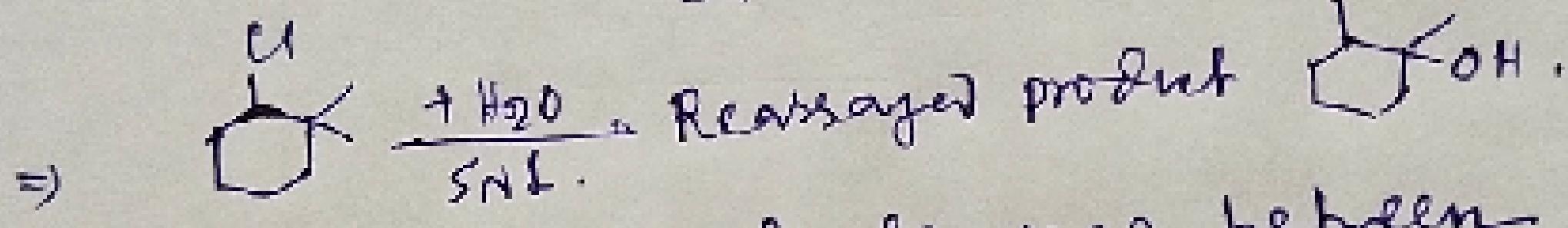
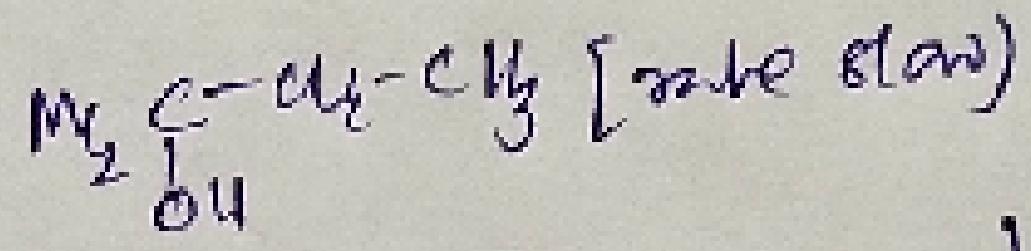
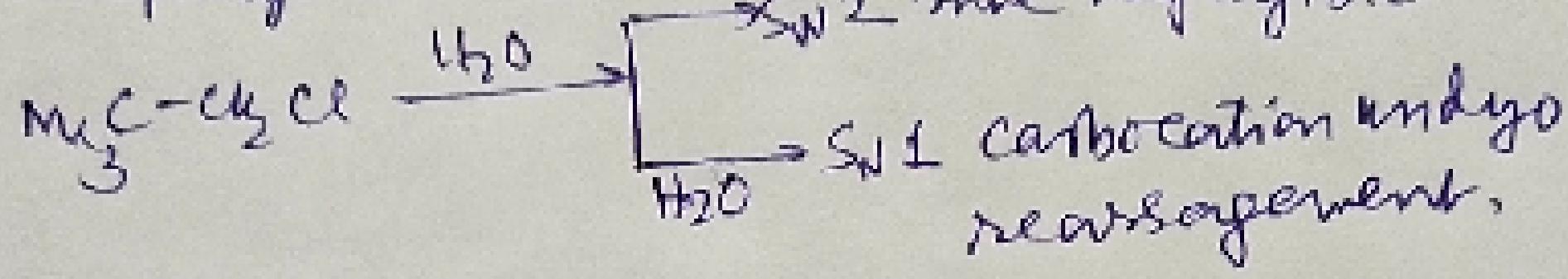


$\Rightarrow S_N2 \text{ rate} = k[R-X][Nn]$.

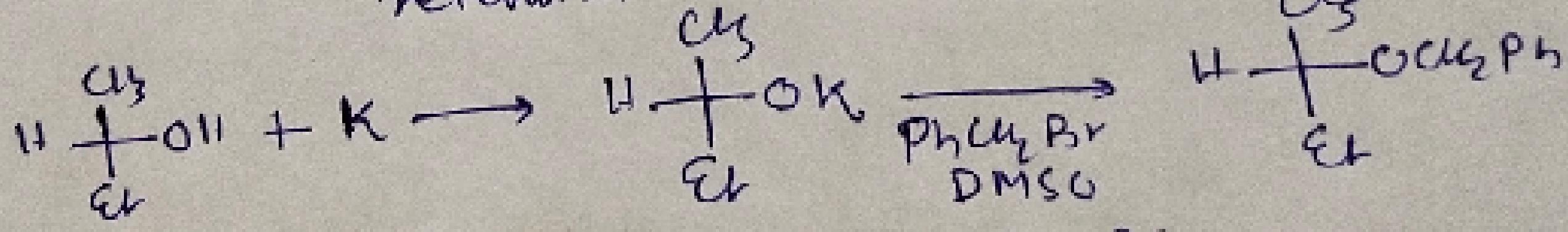
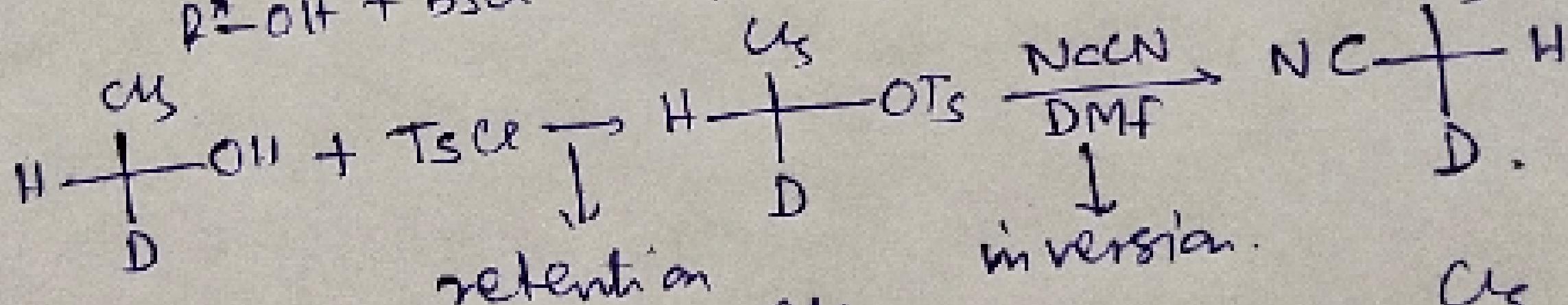
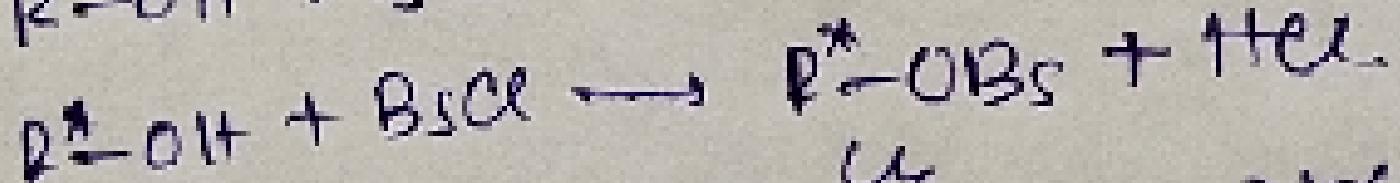
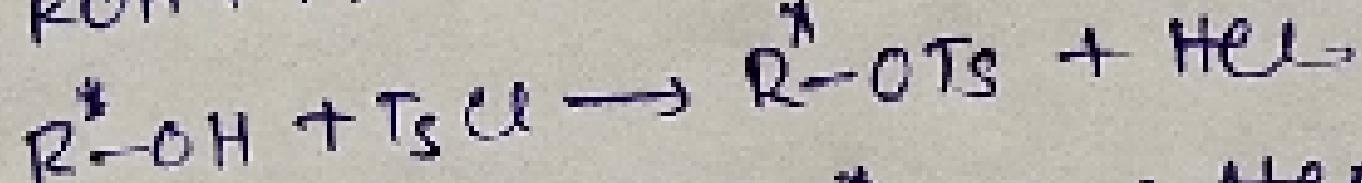
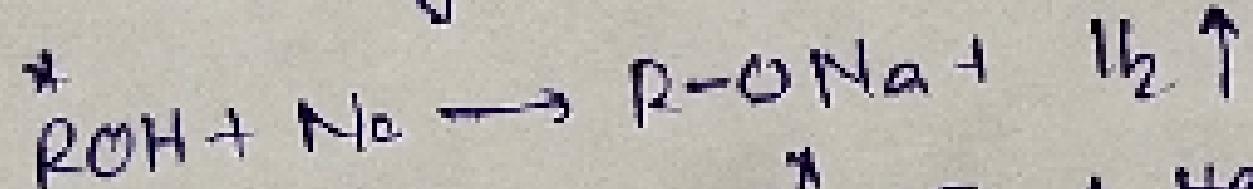
$\Rightarrow S_N1 \text{ rate} = k[R-X]$.



\Rightarrow Neopentyl Chloride



\Rightarrow If there is no bond cleavage between chiral carbon & leaving group then retention of configuration takes place.



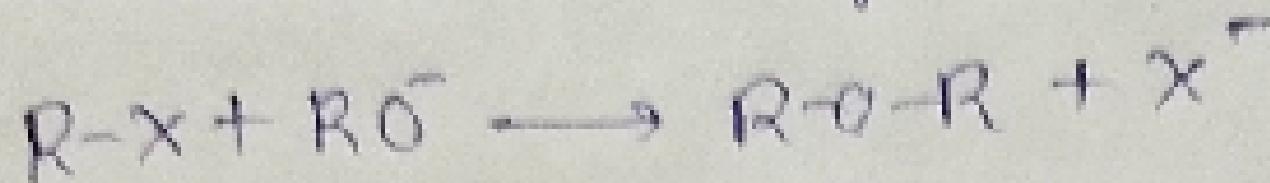
Both steps are example of retention of configuration.

Ether formation by S_N2

mechanism:

(8)

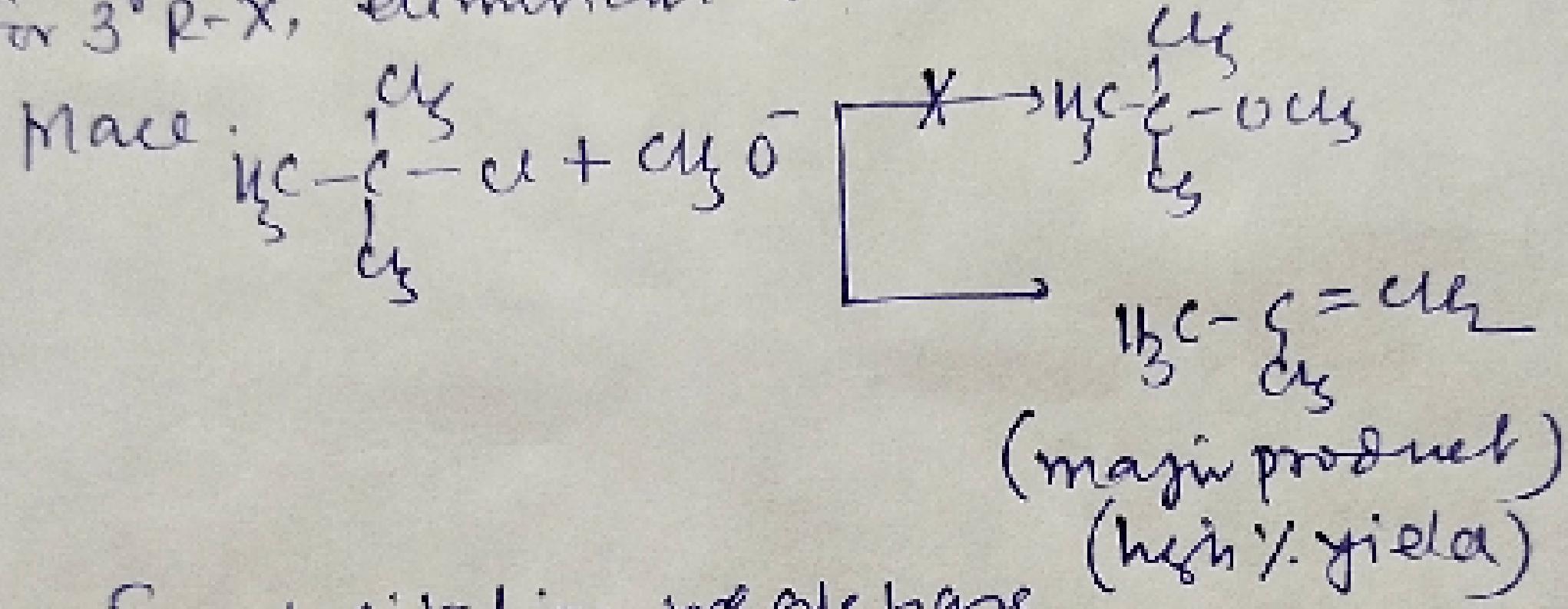
Williamson Ether synthesis:



alkyl alkoxide
nucleophile ion.

In this example of S_N2 , the yield will be very good when $R-X$ is 1° & 2° $R-X$.

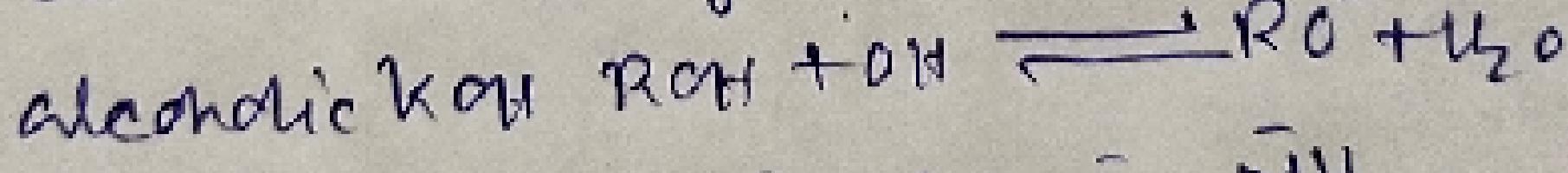
for $3^\circ R-X$, elimination reaction takes,



For substitution we take base

is required SH , SPh , OPh , $\text{CH}_3\text{S}^{\ominus}\text{O}^-$
aqueous KOH/NaOH ; H_2O ; EtOH; $\text{CH}_3-\overset{\text{O}}{\underset{\text{S}^{\ominus}}{\text{C}}}-\text{O}^-$,
 $\text{N}_3^-, \text{SPh}, \text{CN}^-$.

for elimination strong base



RO^- ; MeO^- ; EtO^- ; $t\text{BnO}^-$, NH_2^- ,

KNH_2 , NaNH_2 ; $t\text{BnOK}$. is required.

$\text{PhCl} + \text{PhO}^- \xrightarrow{\text{X}} \text{Ph-O-Ph}$ (can't be prepared).

 $\text{Ph}-\overset{\text{O-CMe}_3}{\text{C}_6\text{H}_4}-\text{Ph}$: Ph-O-CMe_3

$\text{Et}_2\text{O-CEt}$ $\text{CH}_2=\text{CH}-\text{O-CH}_2=\text{CH}_2$ can't be prepared.

Ether formation by S_N2

mechanism:

(8)

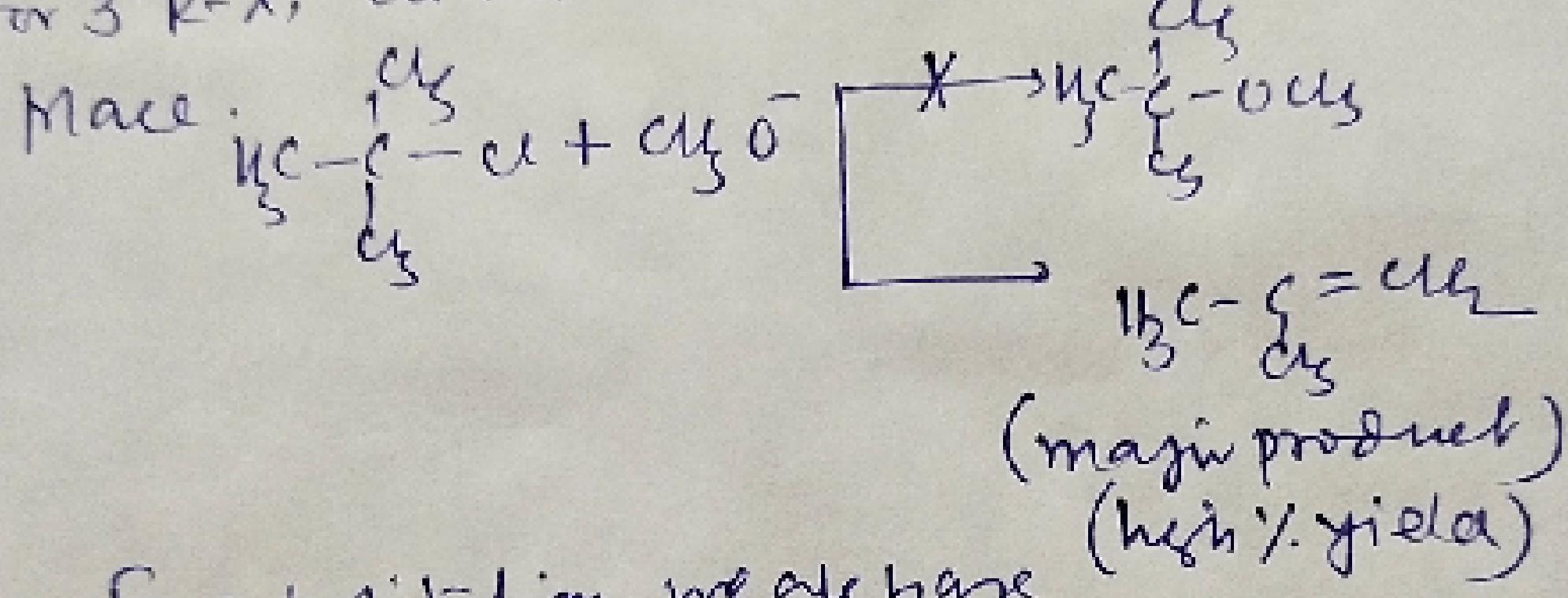
Williamson Ether synthesis:



alkyl alkoxide
halide ion.

It is example of S_N2 . So the yield will be very good when $R-X$ is 1° & $2^\circ R-X$.

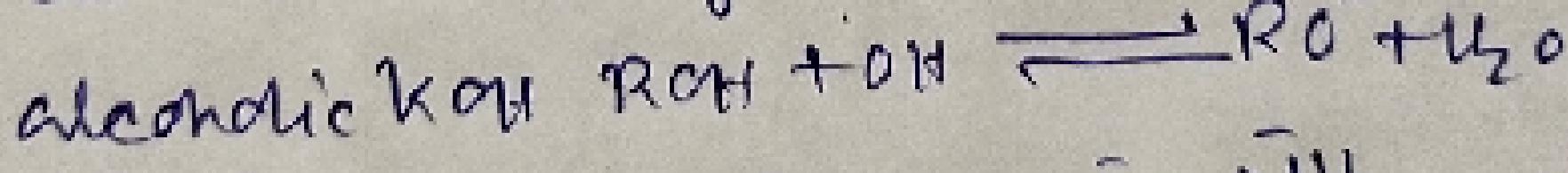
for $3^\circ R-X$, elimination reaction takes



For substitution we take base

is required SH_2 , SiF_3 , $\text{O}^{\oplus}\text{Ph}$, $\text{CH}_3\text{S}^{\ominus}\text{O}^{\oplus}$,
aqueous KOH/NaOH ; H_2O ; strong; $\text{CH}_3\text{S}^{\ominus}\text{O}^{\oplus}$,
 $\text{N}_3^{\ominus}, \text{SPPh}_2, \text{CN}^{\ominus}$.

for elimination strong base



RO^- ; MeO^- ; EtO^- ; $t\text{BnO}^-$, NH_2^- ,

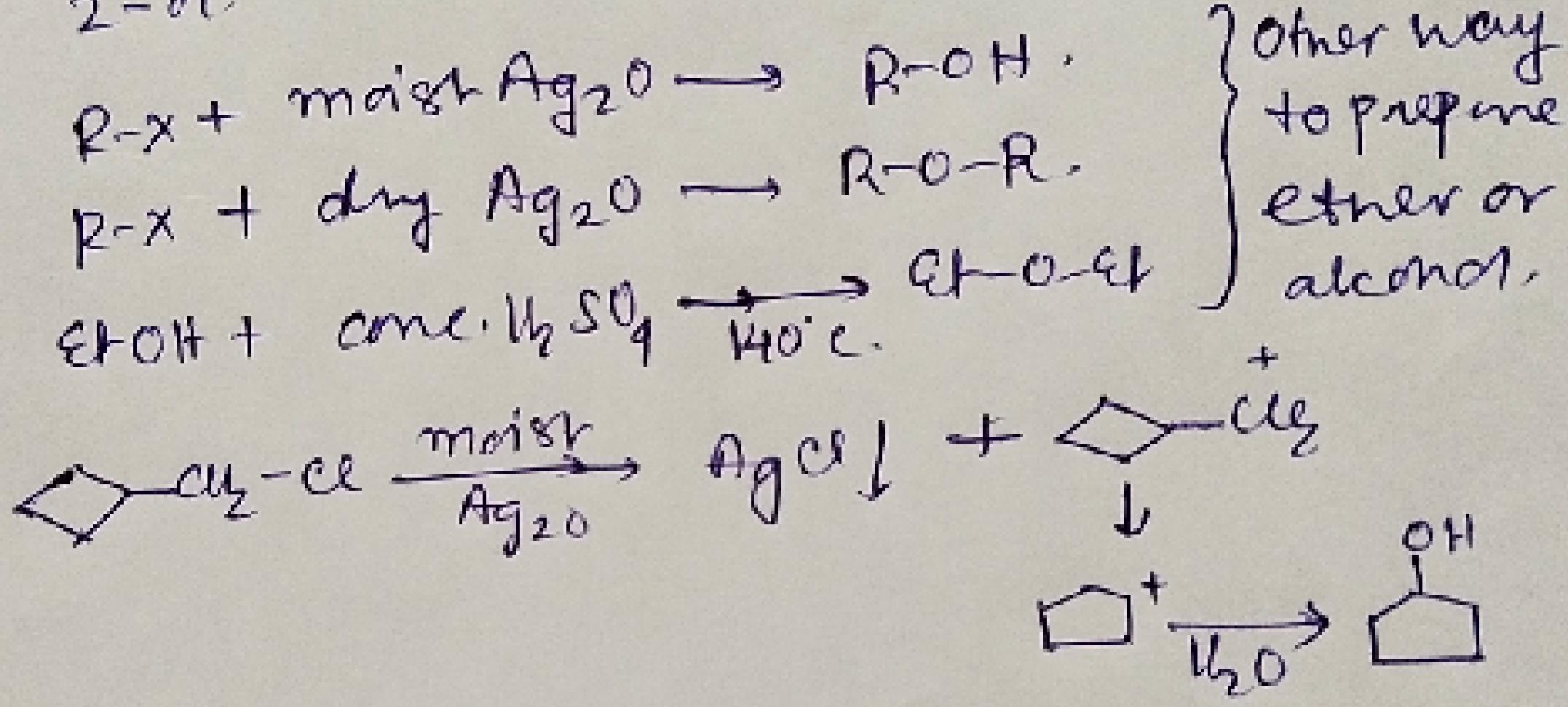
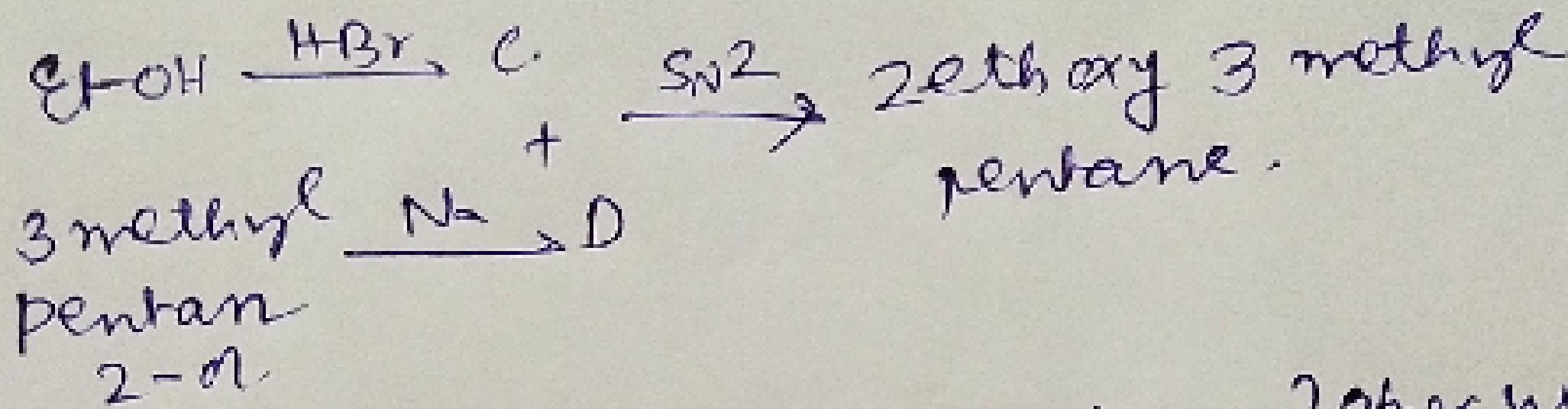
KNH_2 , NaNH_2 ; $t\text{BnOK}$. is required.

$\text{PhCl} + \text{PhO}^- \rightarrow \text{Ph-O-Ph}$ can't be prepared.

; $\text{Ph}-\text{O}-\text{CMe}_3$; $\text{Ph}-\text{O}-\text{CMes}$,
 $\text{Et}_2\text{O}-\text{O}-\text{Et} \quad \text{CH}_2=\text{CH}-\text{O}-\text{CH}=\text{CH}_2$ can't
be prepared.

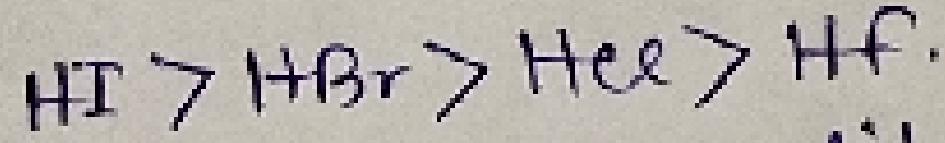
To prepare Et_3COEt , we should use
 $\text{Et}_3\text{C}^- + \text{EtX}$ but not $\text{Et}^- + \text{Et}_3\text{C}^- \text{X}$. (9)

To prepare $\text{Me}_3\text{C-O-Me}$, we should use.
 $\text{Me}_3\text{C}^- + \text{MeX}$ but not $\text{MeO}^- + \text{Me}_3\text{C}^- \text{X}$

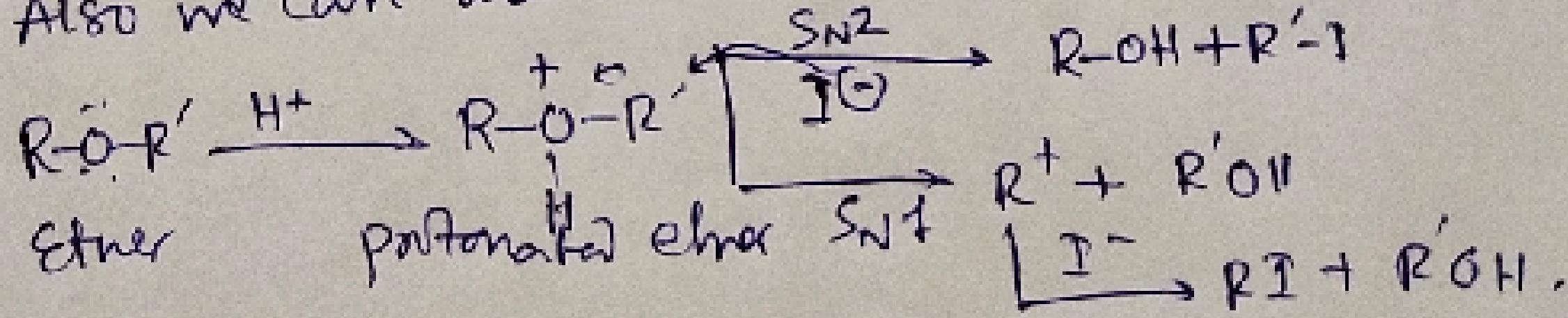


Ether cleavage:

for ether cleavage acidic medium is required.

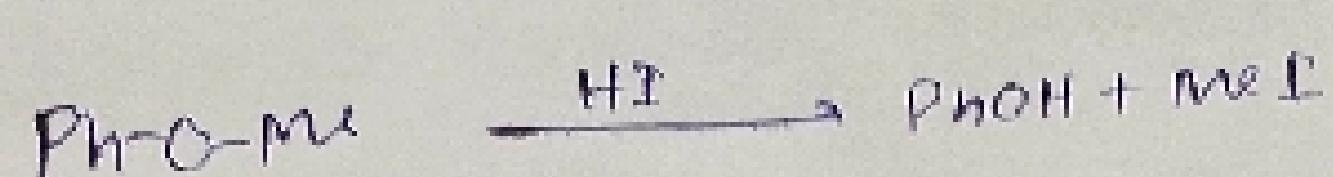


Also we can use dilute HCl or H_3O^+ .

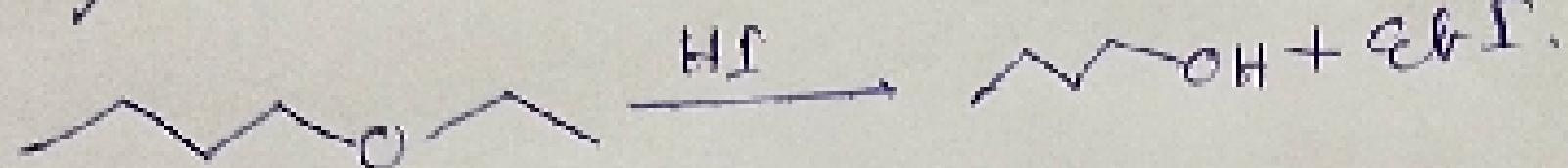
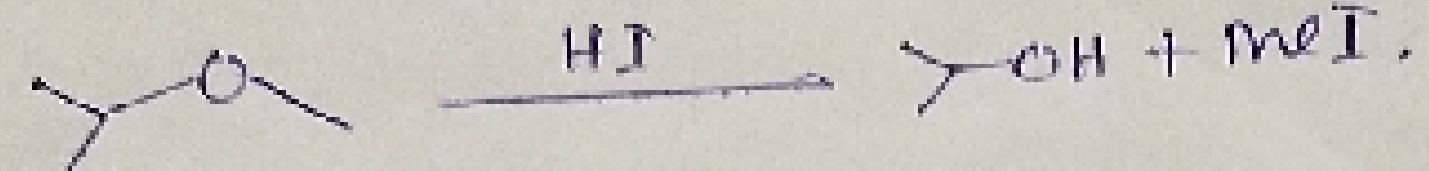
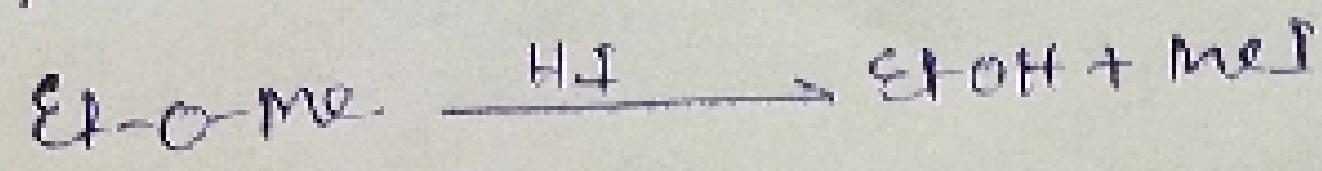


May be $\text{S}_{\text{N}}1$ or $\text{S}_{\text{N}}2$ depending on nature of R & R'

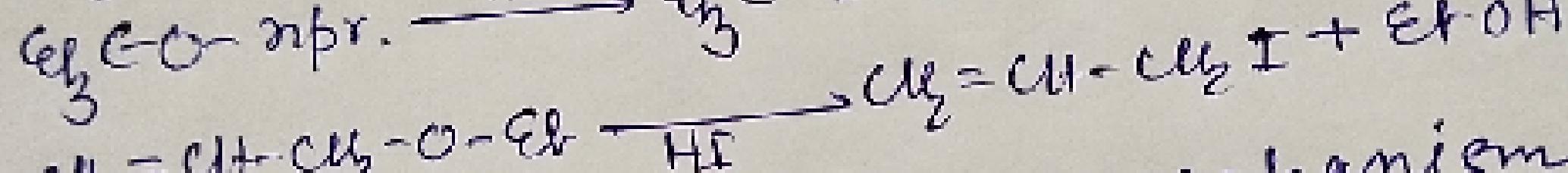
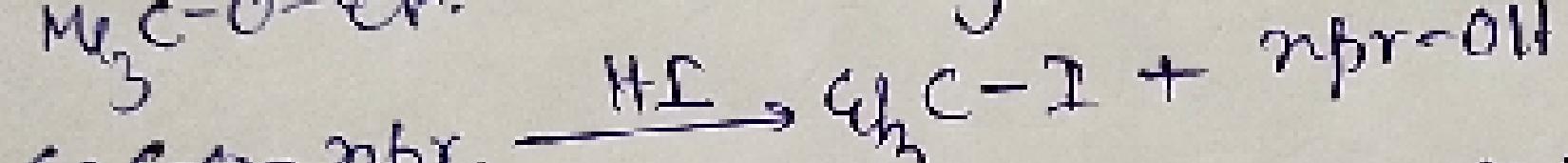
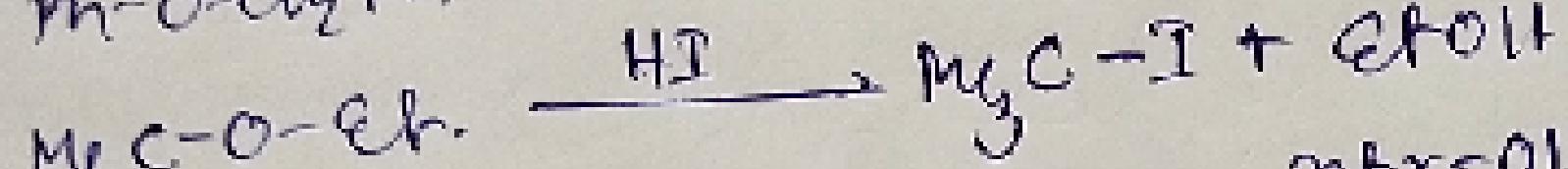
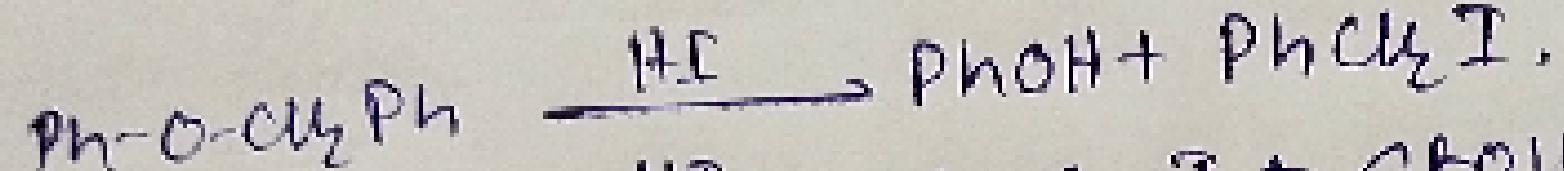
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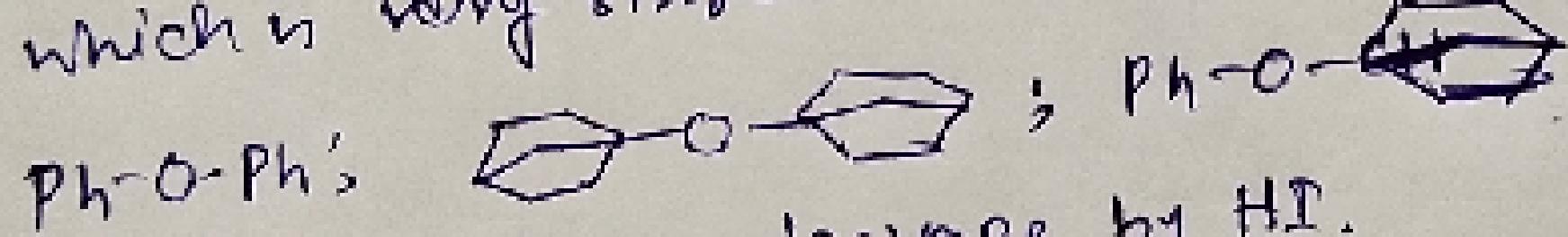
If neither R' nor R'' is stable then mechanism is S_N2 .



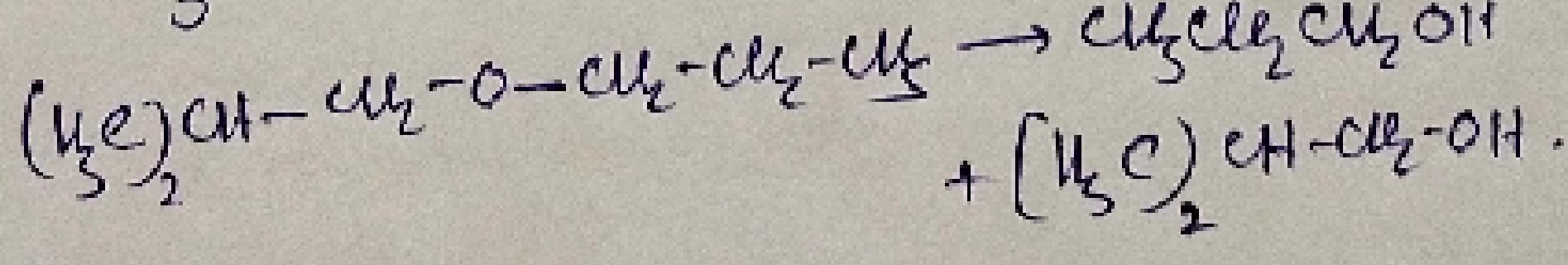
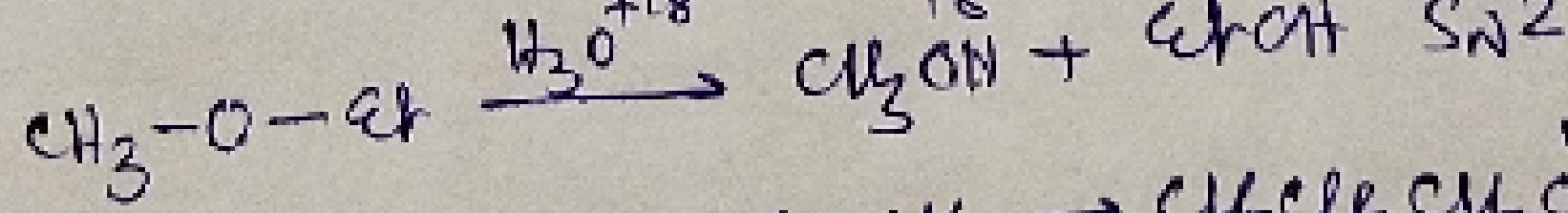
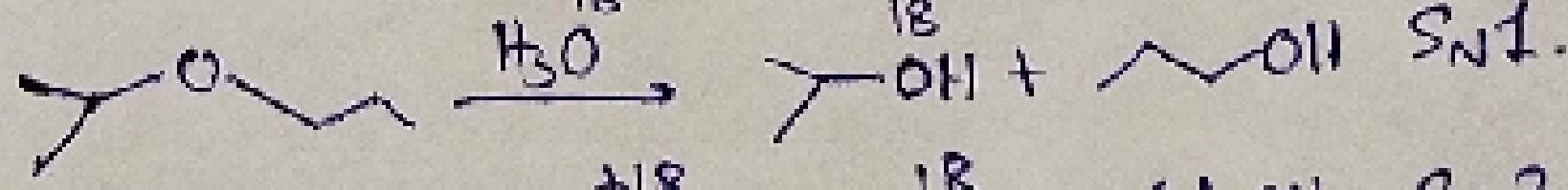
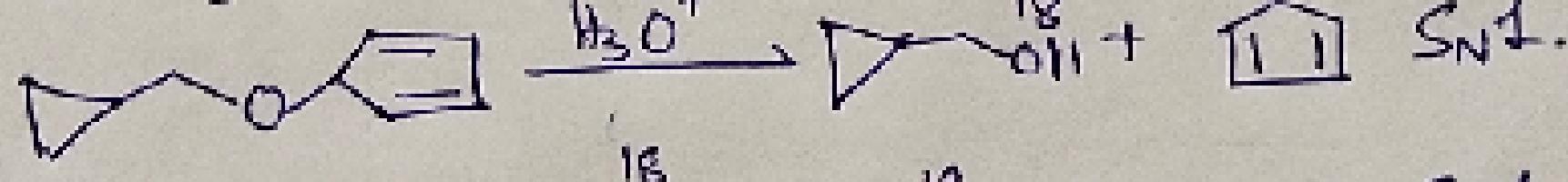
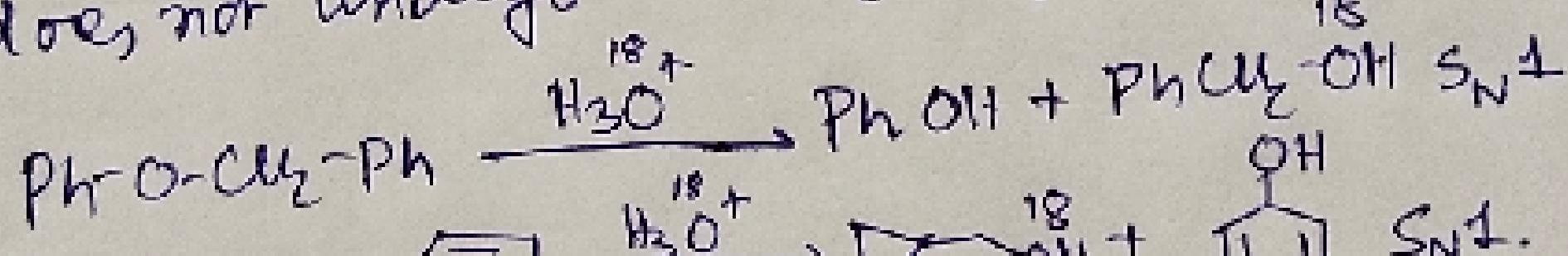
Here I^- attacks less sterically hindered carbon



If either R' or R'' is stable then mechanism is S_N1 , here I^- attacks the carbocation which is very stable.

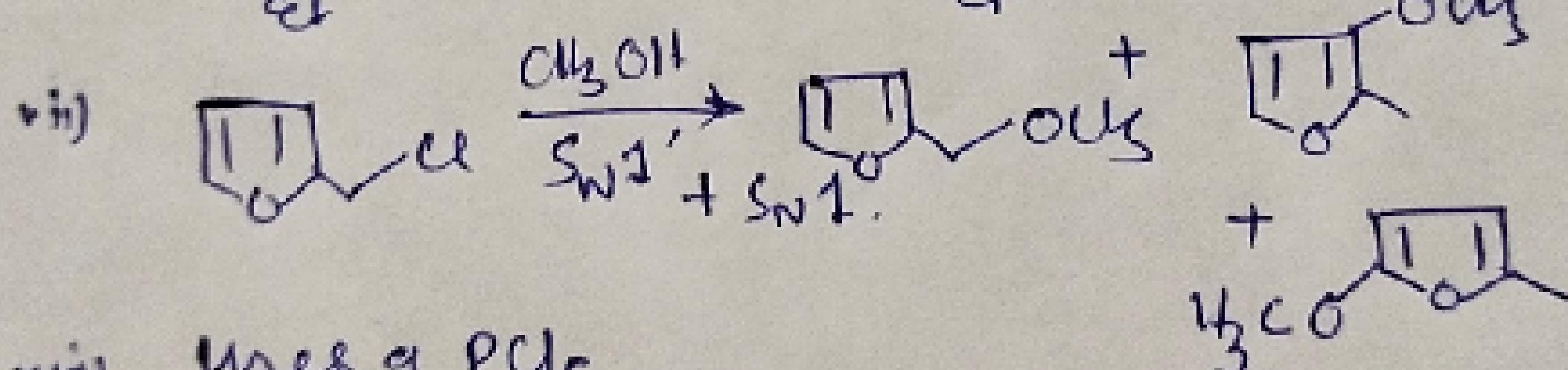
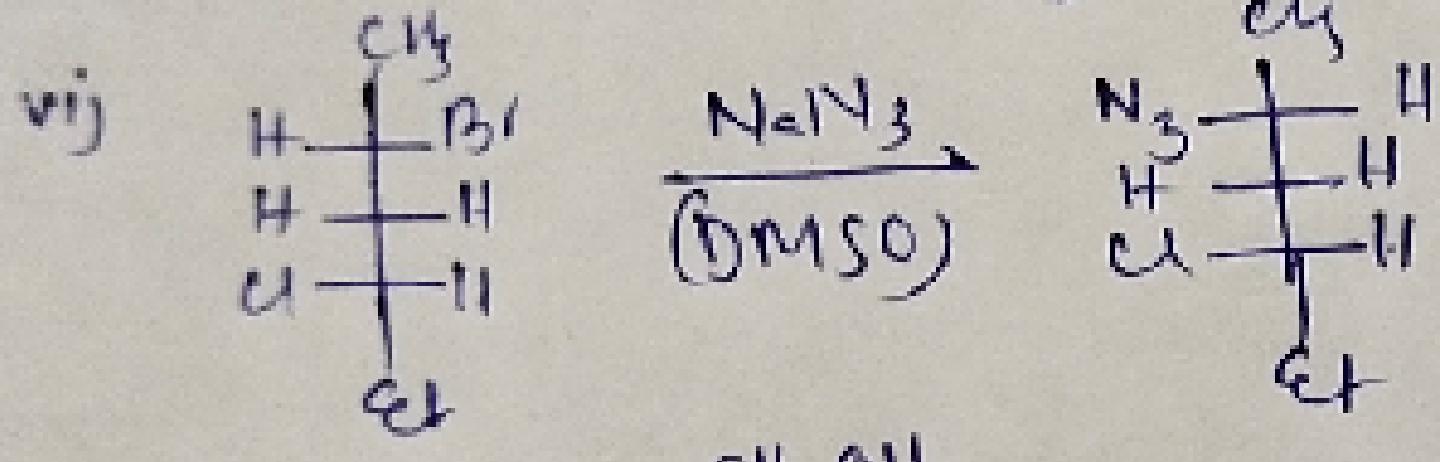
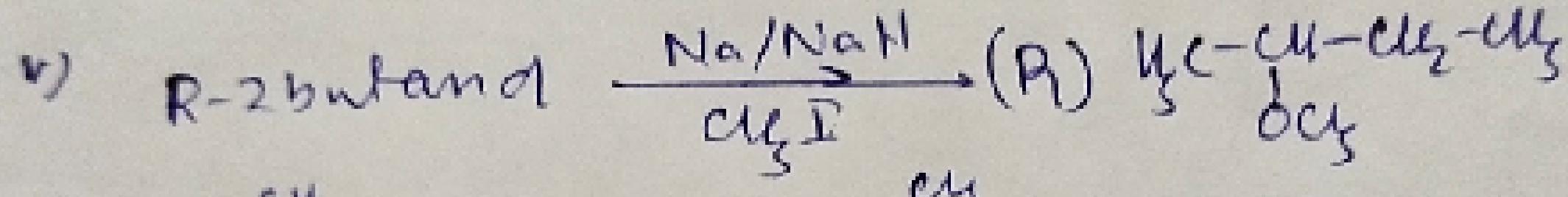
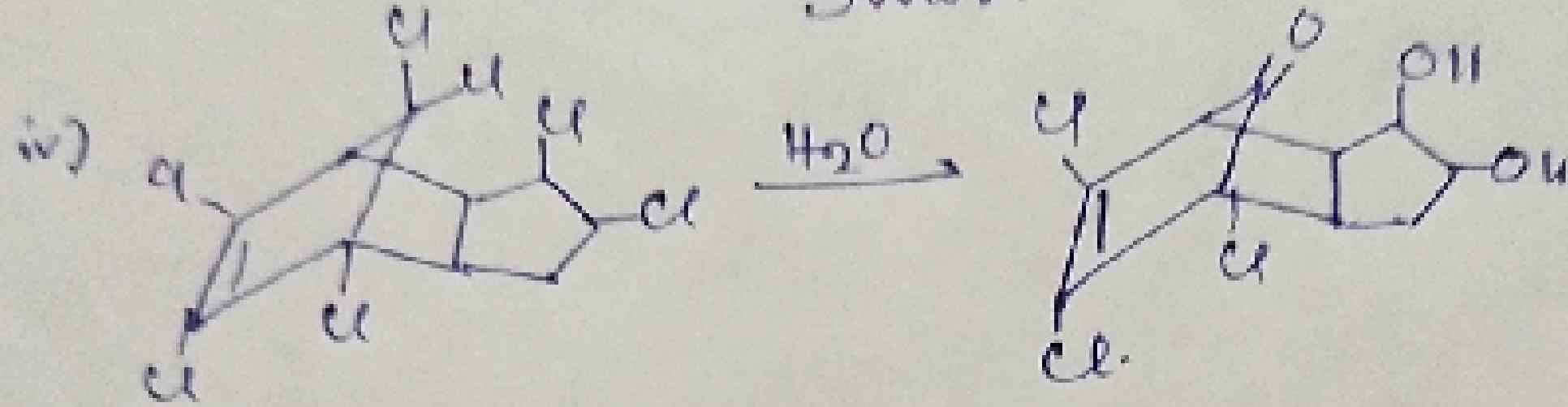
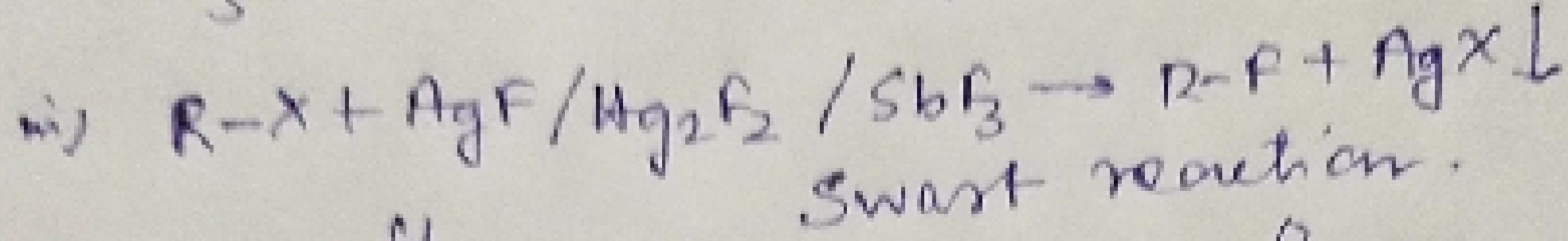
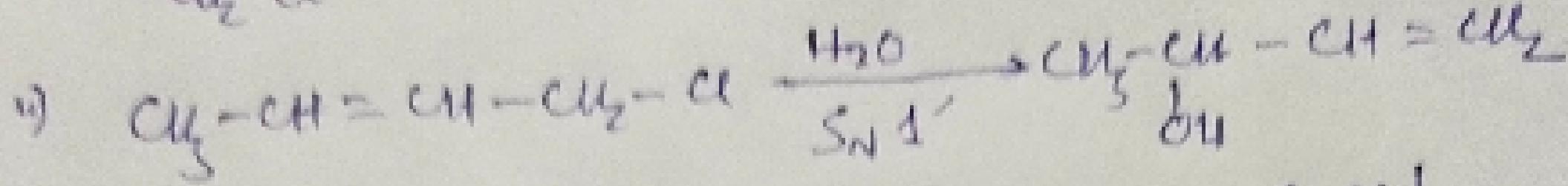
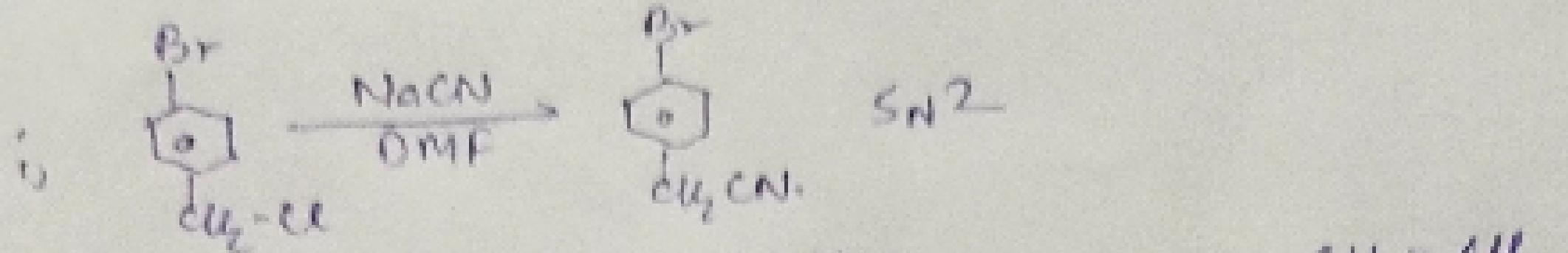


$\text{Ph-O-Ph}'$ does not undergo cleavage by HI .



(11)

Some questions/examples:



viii) Uses of PCl_5

