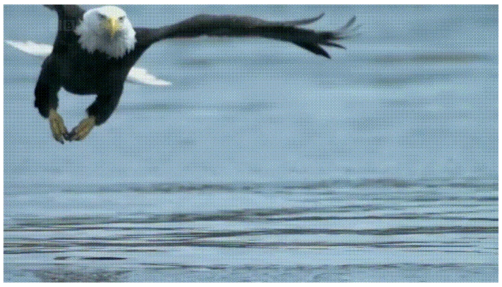


"The Claw"

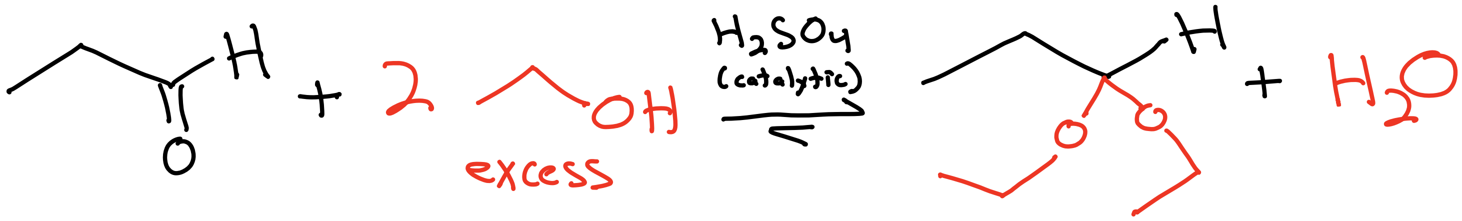
Cyclic acetals are more stable than "normal" acetals because of the chelate effect.

⇓

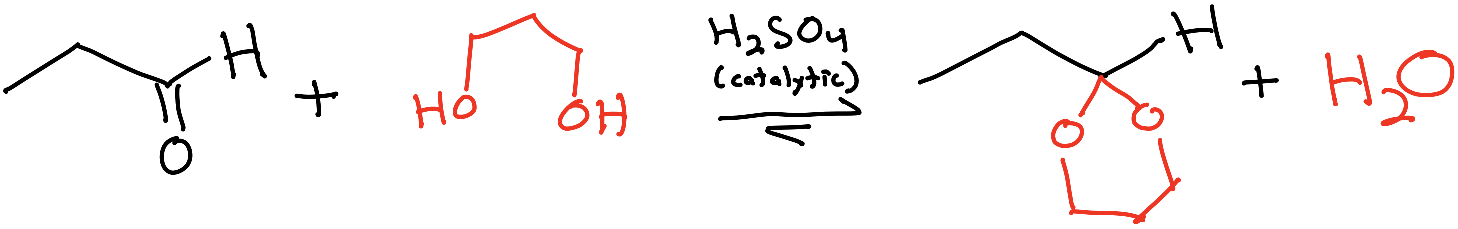
"claw" in Latin

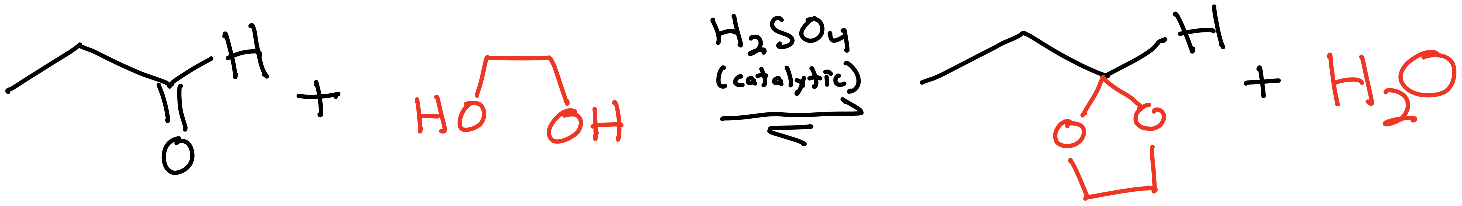
"Two OH groups already attached to each other 'go on' easier and 'come off' harder"

"Normal" acetal



Cyclic acetals → $\underbrace{\text{5 and 6-membered rings!}}_{\text{Stable→Strain free}}$



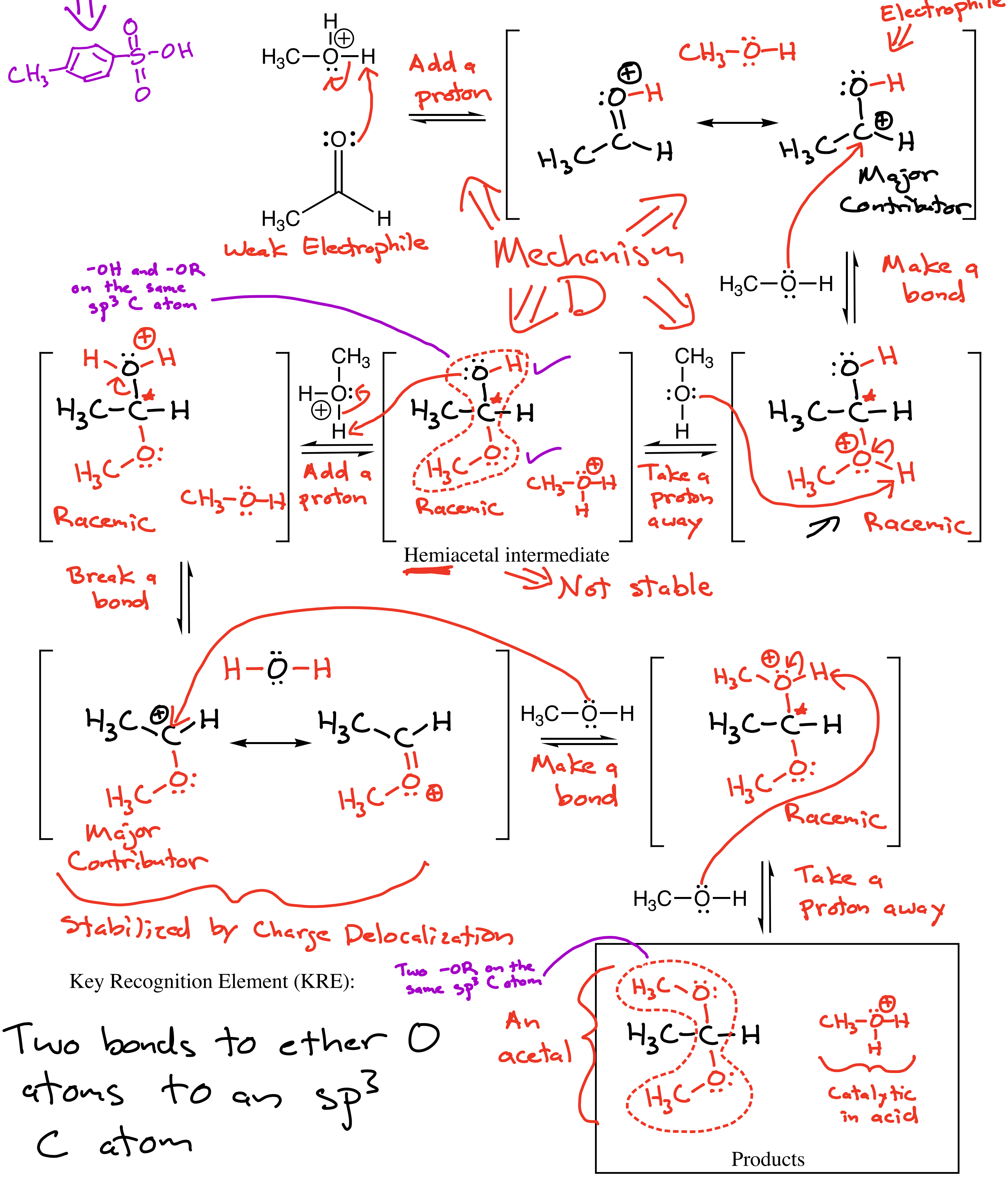


TsOH or H_2SO_4

Tosylic Acid

"Hey, does that thing have a hemi in it?" "SWEET!" !

Acid Catalyzed Hemiacetal and Acetal Formation From an Aldehyde or Ketone

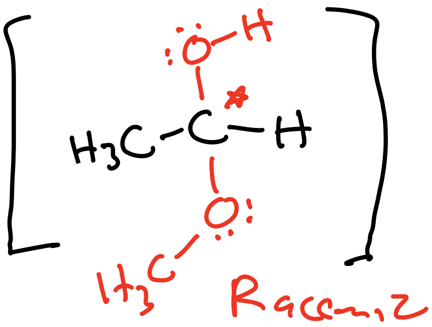


Key Recognition Element (KRE):

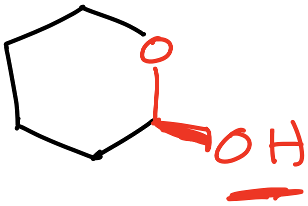
Two bonds to ether O atoms to an sp^3 C atom

Recap

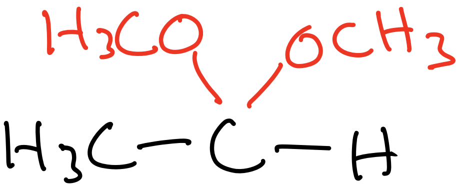
Hemiacetal → One alcohol and one ether on the same C atom.

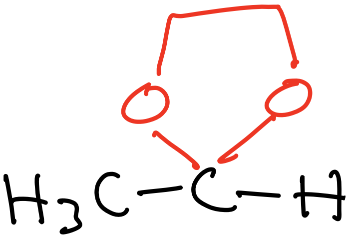


Not Stable

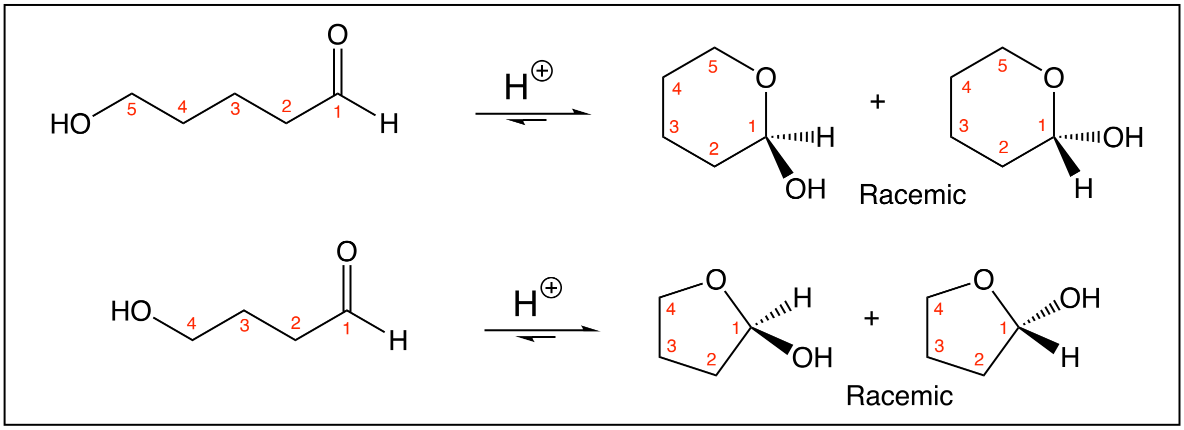


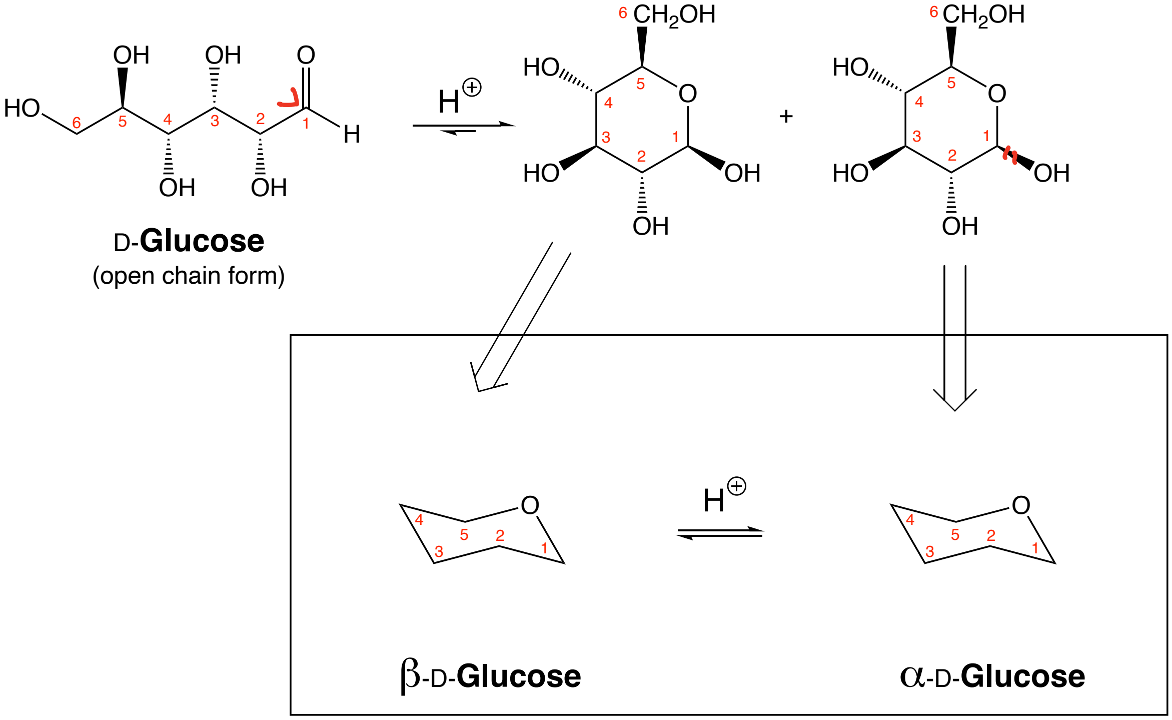
Stable (Chelate effect)

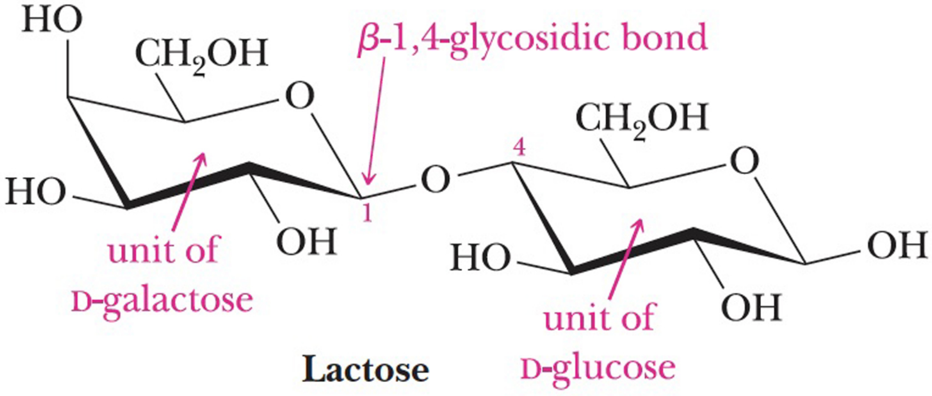




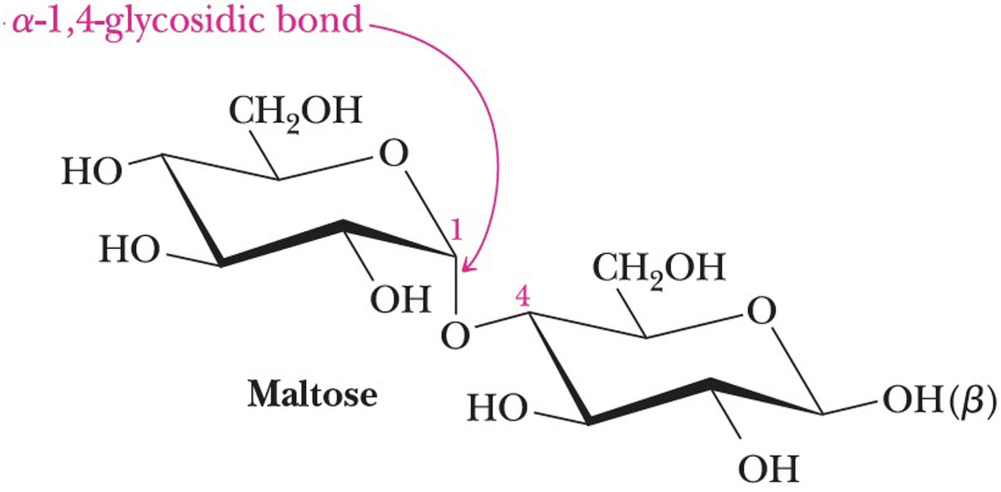
Cyclic Hemiacetals and Carbohydrates



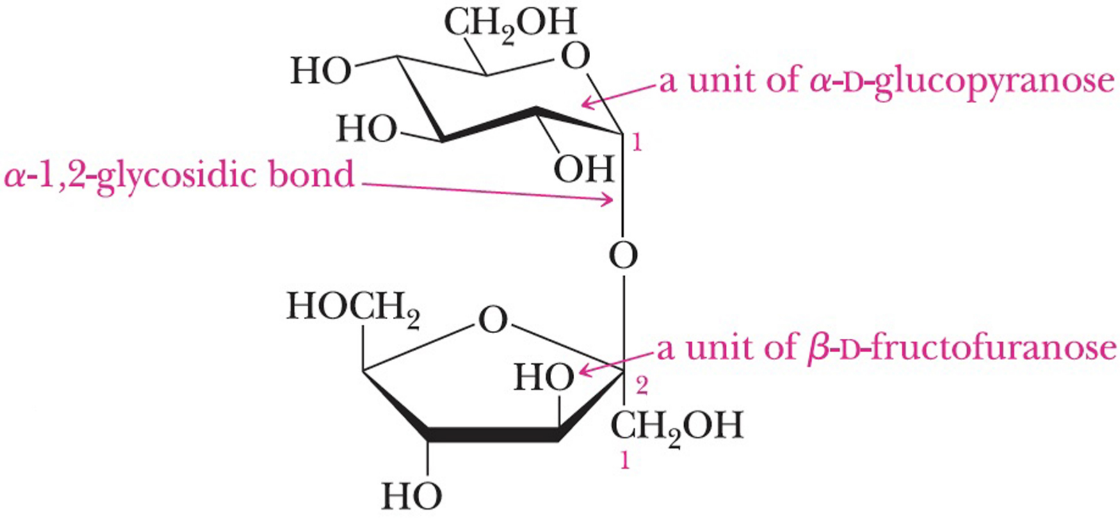




Lactose



Maltose



Sucrose

Organic Chemistry is the study of carbon-containing molecules. This class has two points.

The first point of the class is to understand the organic chemistry of living systems. We will teach you how to think about and understand the most amazing molecules on the planet!!

You will learn how MRI scans work. 1/14/26

You will learn the basic principles of pharmaceutical science and how many drugs work. 1/21/26

You will learn about the special bond that holds carbohydrates such as glucose in six-membered rings, connects carbohydrate monomers together to make complex carbohydrate structures and is critical to DNA and RNA structure.

You will learn how soap is made from animal fat and how it works to keep us clean.

You will learn the important structural reason proteins, the most important molecular machines in our bodies, can support the chemistry of life.

You will learn how important antibiotics like penicillins work, including ones that make stable covalent bonds as part of their mode of action.

You will learn why carrots are orange and tomatoes are red.

You will learn the very cool reason that the DNA and RNA bases are entirely flat so they can stack in the double helix structure.

You will learn how energy drinks work.

You will learn even more about why fentanyl is such a devastating part of the opioid problem and how Naloxone is an antidote for a fentanyl overdose.

You will learn even more details about why Magic Johnson is still alive, decades after contracting HIV, and how the same strategy is being used to fight COVID.

You will learn about the surprising chemical reason the Pfizer and Moderna mRNA vaccines elicit strong immune responses.

The second point of organic chemistry is the synthesis of complex molecules from simpler ones by making and breaking specific bonds, especially carbon-carbon bonds.

You will learn how carbon-metal bonds lead to new carbon-carbon bonds. 1/21/26

You will learn how most reactions of carbonyl compounds involve only the four common mechanistic elements operating in only a few common patterns. 1/21/26

You will learn how, by simply adding a catalytic amount of base like HO^- to aldehydes or ketones, you can make new carbon-carbon bonds, giving complicated and useful products.

You will learn a reaction that can convert vinegar and vodka into a common solvent.

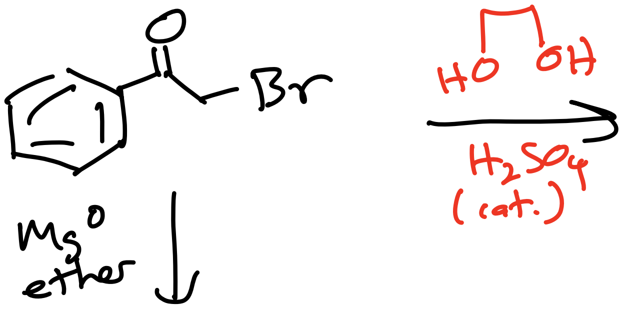
You will learn why molecules with six-membered rings and alternating double bonds are stable.

You will learn a reaction that can turn model airplane glue into a powerful explosive.

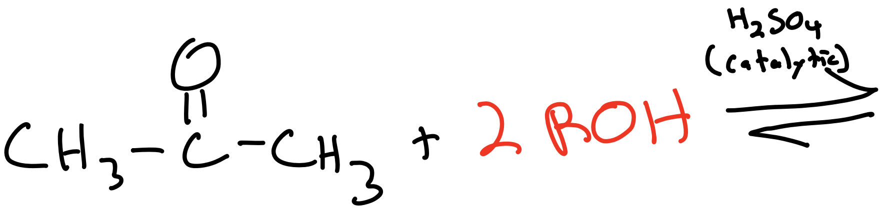
Most important, you will develop powerful critical thinking skills:

1. You will learn how to look at a molecule and accurately predict which atoms will react to make new bonds, and which bonds will break during reactions.
2. You will learn how to analyze a complex molecule's structure so that you can predict ways to make it via multiple reactions starting with less complex starting molecules.

Protecting Group → Reversibly mask the reactivity of a function to prevent unwanted reactions



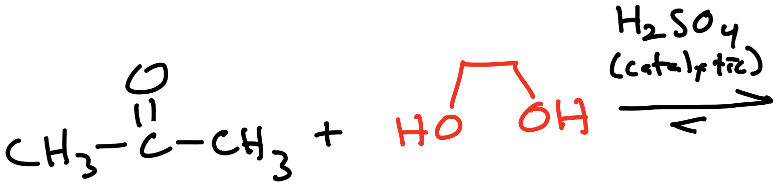
Acetal Formation is Reversible



$$CH_3-\overset{\overset{O}{\|}}{C}-CH_3 + 2\,ROH \xrightleftharpoons[]{H_2SO_4\ (\text{catalytic})}$$

Add more and acetal side
is favored.
Add more and ketone side
is favored.

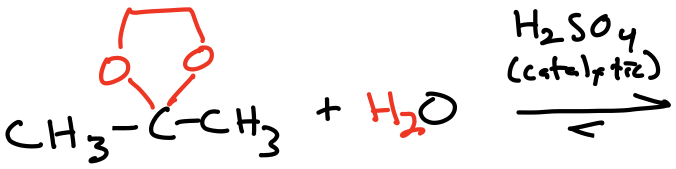
This is how cyclic acetal protecting
groups are to a carbonyl



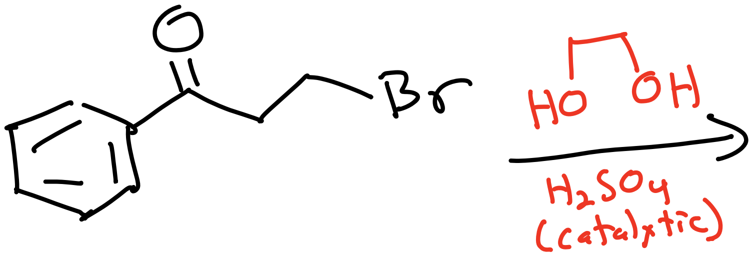
$$CH_3-\overset{\overset{O}{\|}}{C}-CH_3 + HO\!\frown\!OH \xrightleftharpoons[]{H_2SO_4\ (\text{catalytic})}$$

Le Chatlier's Principle

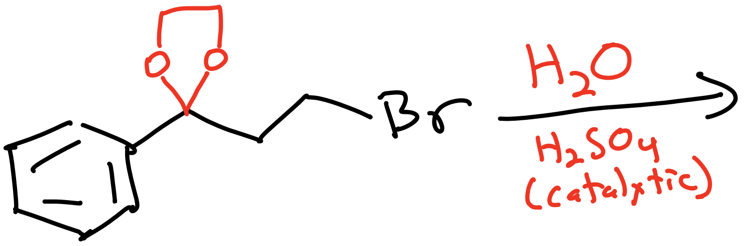
This is how cyclic acetal protecting
groups are to get back a carbonyl



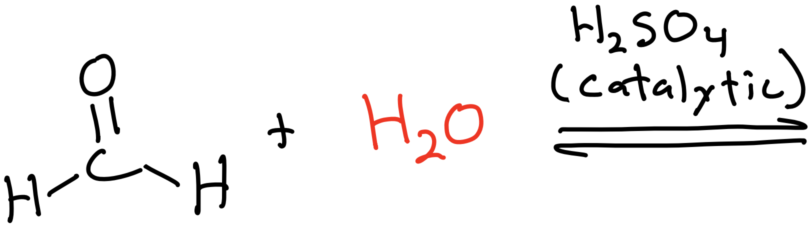
Protecting Group "ON"



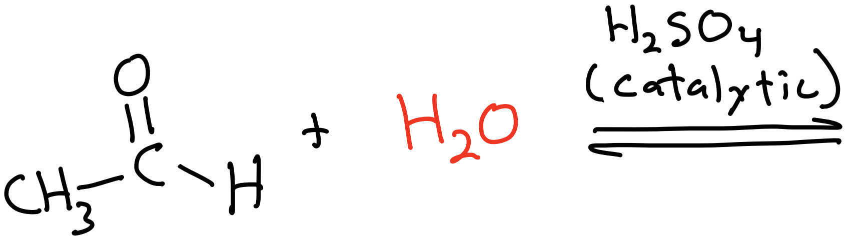
Protecting Group "OFF"



Geminal Diols: H_2O instead of ROH



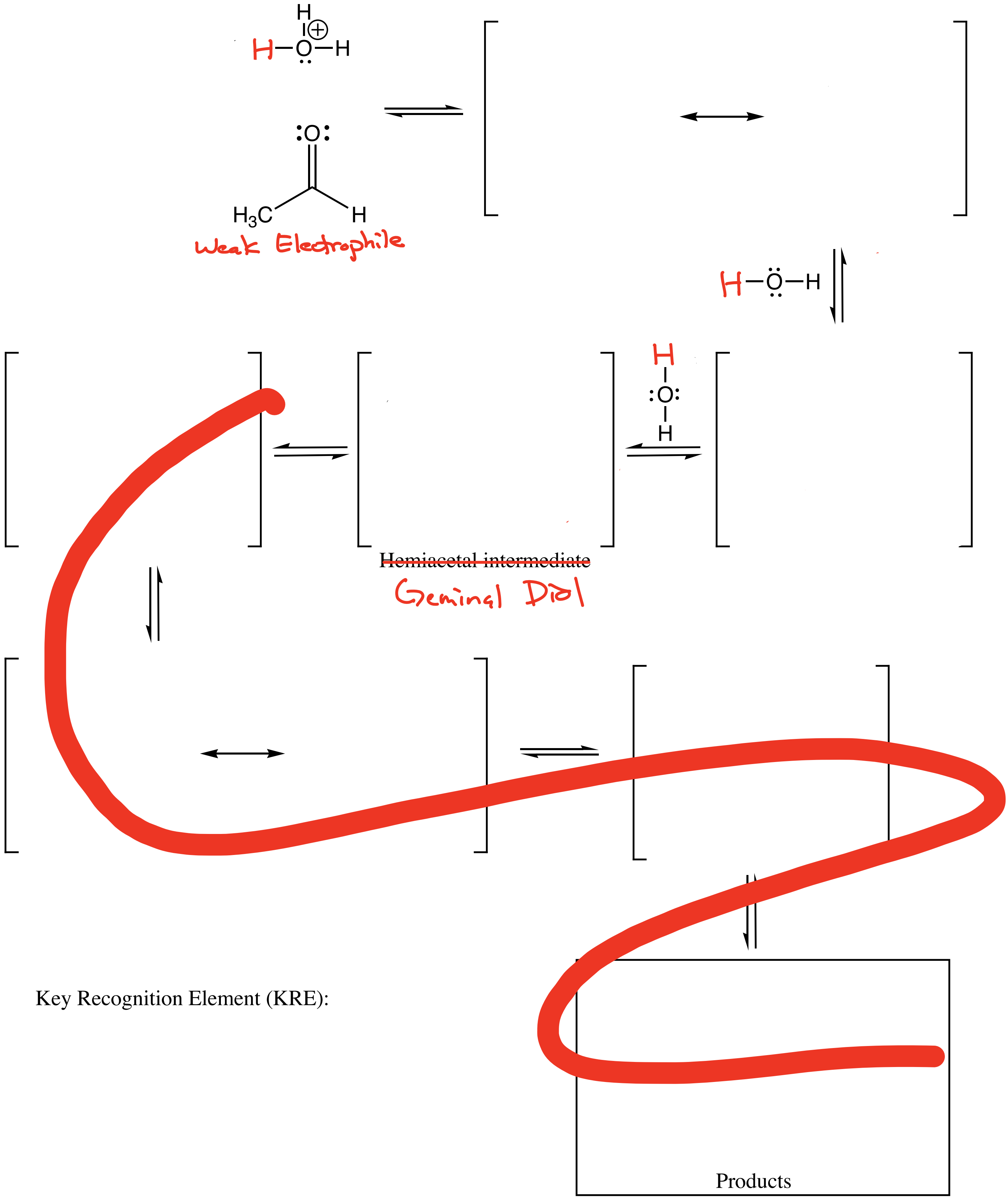
Formaldehyde
(gas)



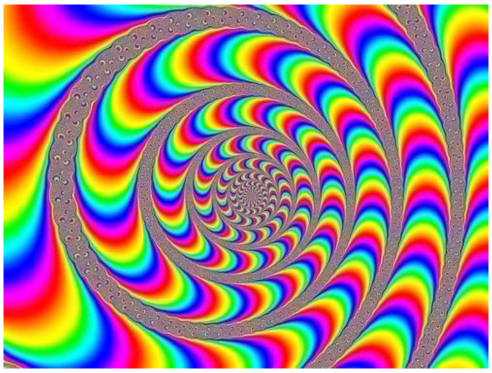
Favored at
equilibrium

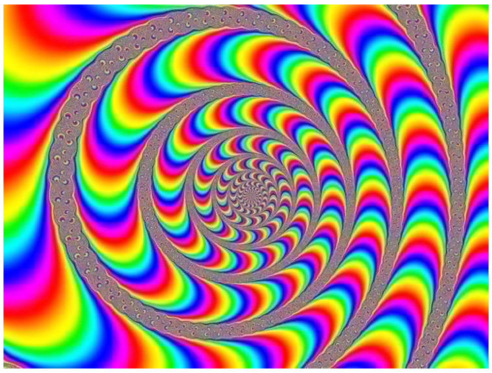
Geminal diol

Acid Catalyzed ~~Hemiacetal and Acetal~~ Formation From an Aldehyde or Ketone

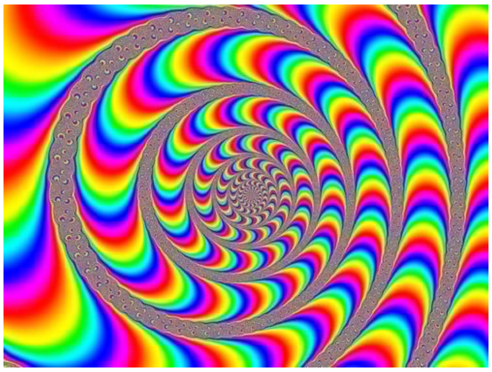


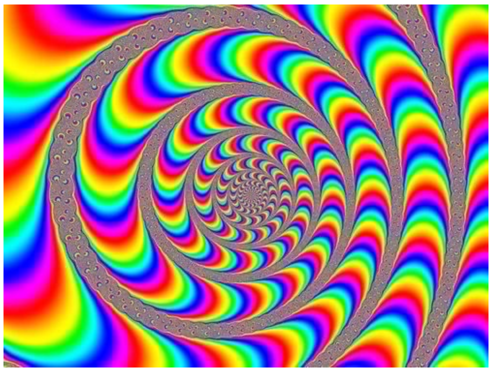
Key Recognition Element (KRE):






WAYNE'S WORLD

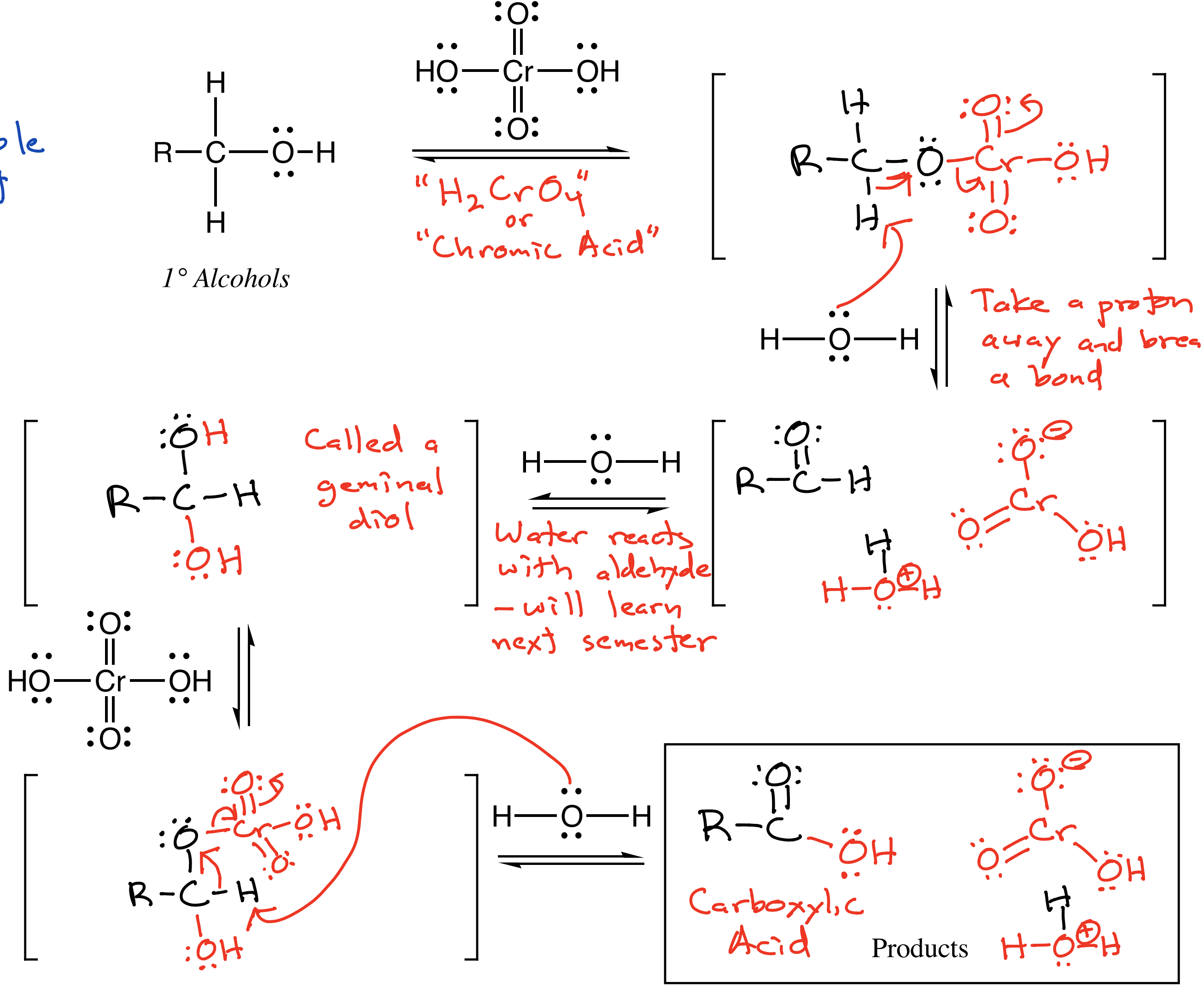




Called "Jones Reagent" ($CrO_3 + H_2O$ or $K_2Cr_2O_7$) + H_2SO_4

Chromic Acid Oxidation of Alcohols

Not responsible for first step



Take a proton away and break a bond

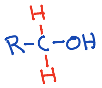
Called a geminal diol

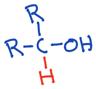
Water reacts with aldehyde - will learn next semester

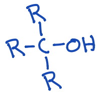
Not responsible for this step

Carboxylic Acid

Summary:


$R-\overset{H}{\underset{H}{C}}-OH$ 1° alcohols ⇒ Carboxylic Acid 
$R-\overset{O}{\overset{\|}{C}}-OH$

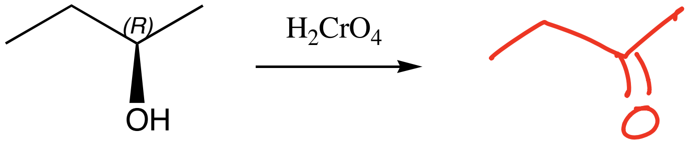

$R-\overset{R}{\underset{H}{C}}-OH$ 2° alcohols ⇒ Ketone 
$R-\overset{O}{\overset{\|}{C}}-R$


$R-\overset{R}{\underset{R}{C}}-OH$ 3° alcohols ⇒ NO REACTION

Regiochemistry: N/A

Stereochemistry: N/A

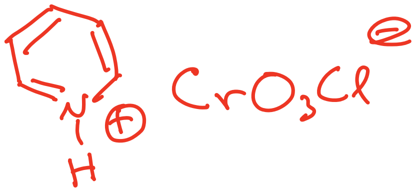
Example:



Ketone

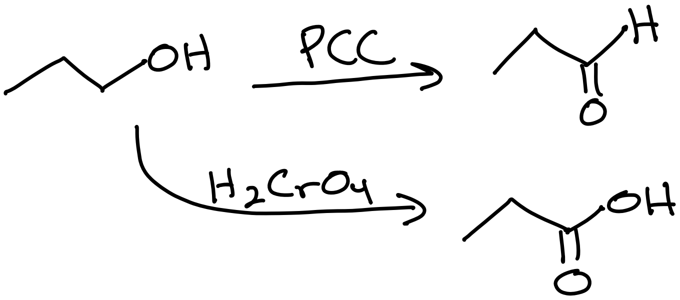
From last semester

A chromic acid-like reagent WITHOUT WATER will stop at the aldehyde when using a primary alcohol as starting material



Pyridinium Chlorochromate

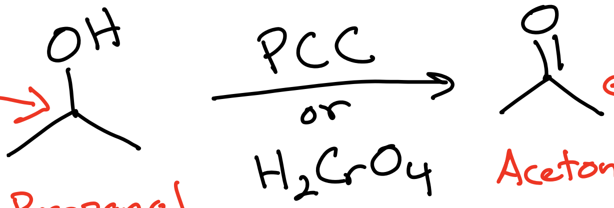
PCC



Aldehyde

Carboxylic Acid

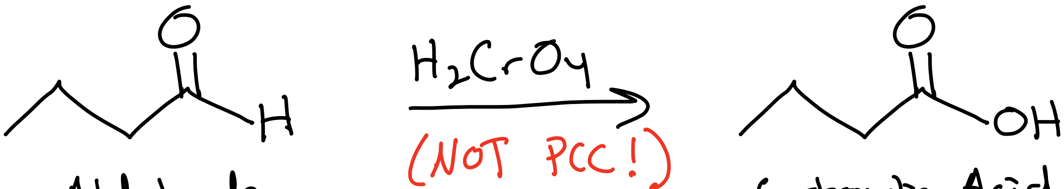
Rubbing Alcohol



Nail Polish Remover

2-Propanol

Acetone



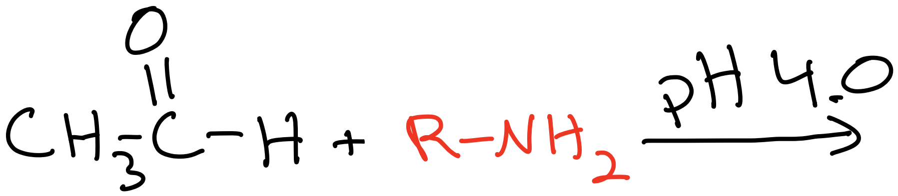
Aldehyde

Carboxylic Acid

$R-\ddot{N}H_2$

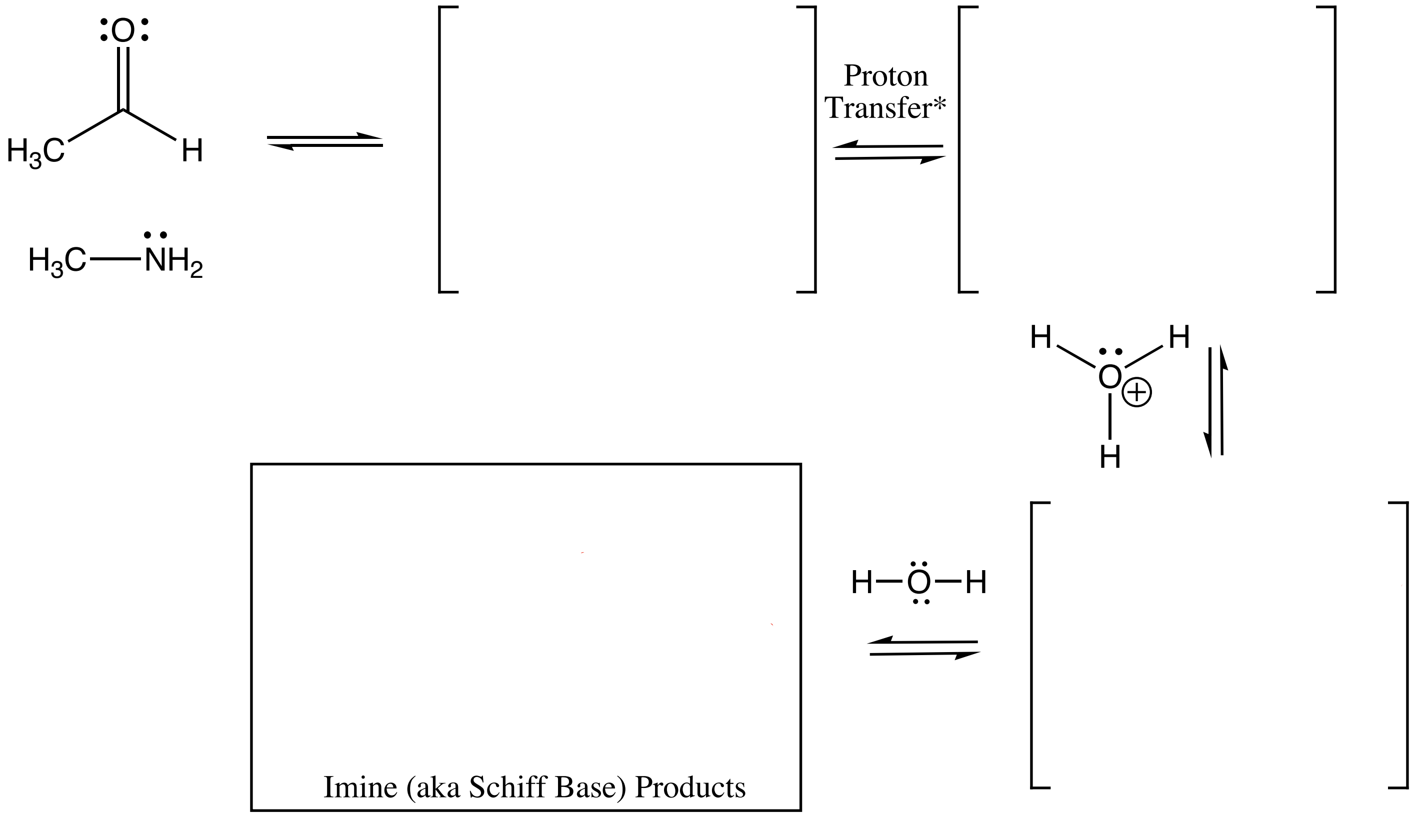
Amine

Overall Process



$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-H + R-NH_2 \xrightarrow{pH\ 4.0}$$

Formation if an Imine (Schiff Base) From an Aldehyde or Ketone Reacting with an Amine

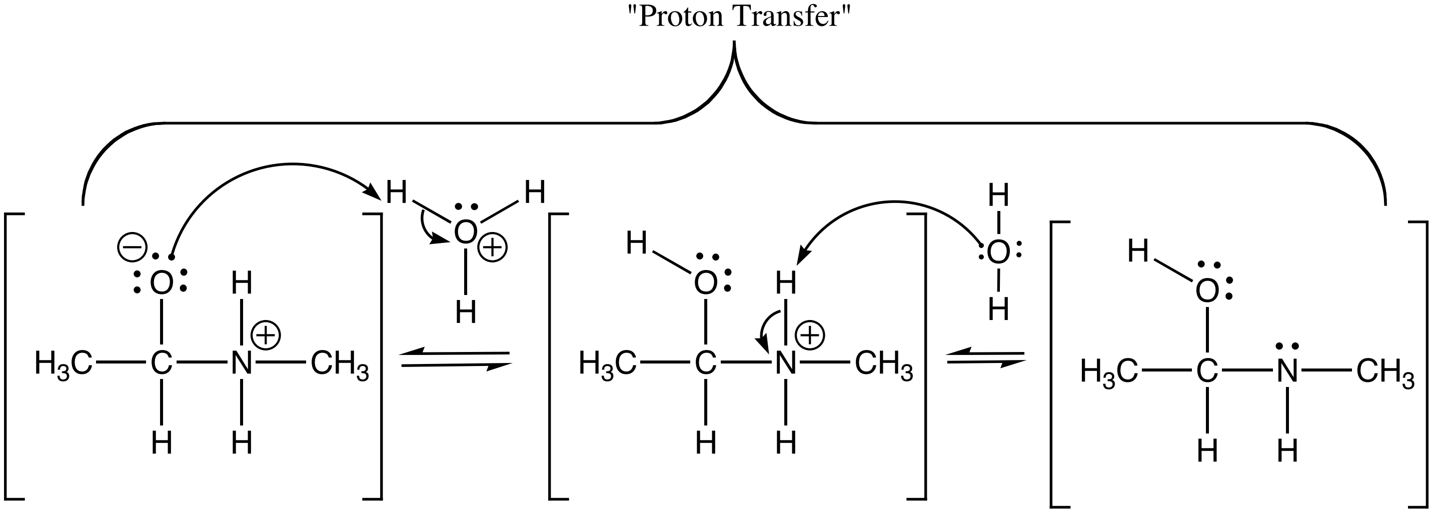


Key Recognition Element (KRE):

Note: this last step might actually occur as two steps in some cases.

---

* "Proton Transfer" refers to a situation in which a proton moves from one part of a molecule to another on the SAME MOLECULE. We do not draw arrows for proton transfer steps because that would be deceptive. In some cases, the same proton may move from one part of the molecule to the other directly, but in other cases, solvent molecules may be involved as indicated in the following scheme. To make things even more interesting, the following two steps might even be reversed in some cases. Becuase of all the ambiguity, we just write "Proton Transfer" and do not bother with arrows.



Here are the keys to understanding mechanisms in 320N!!

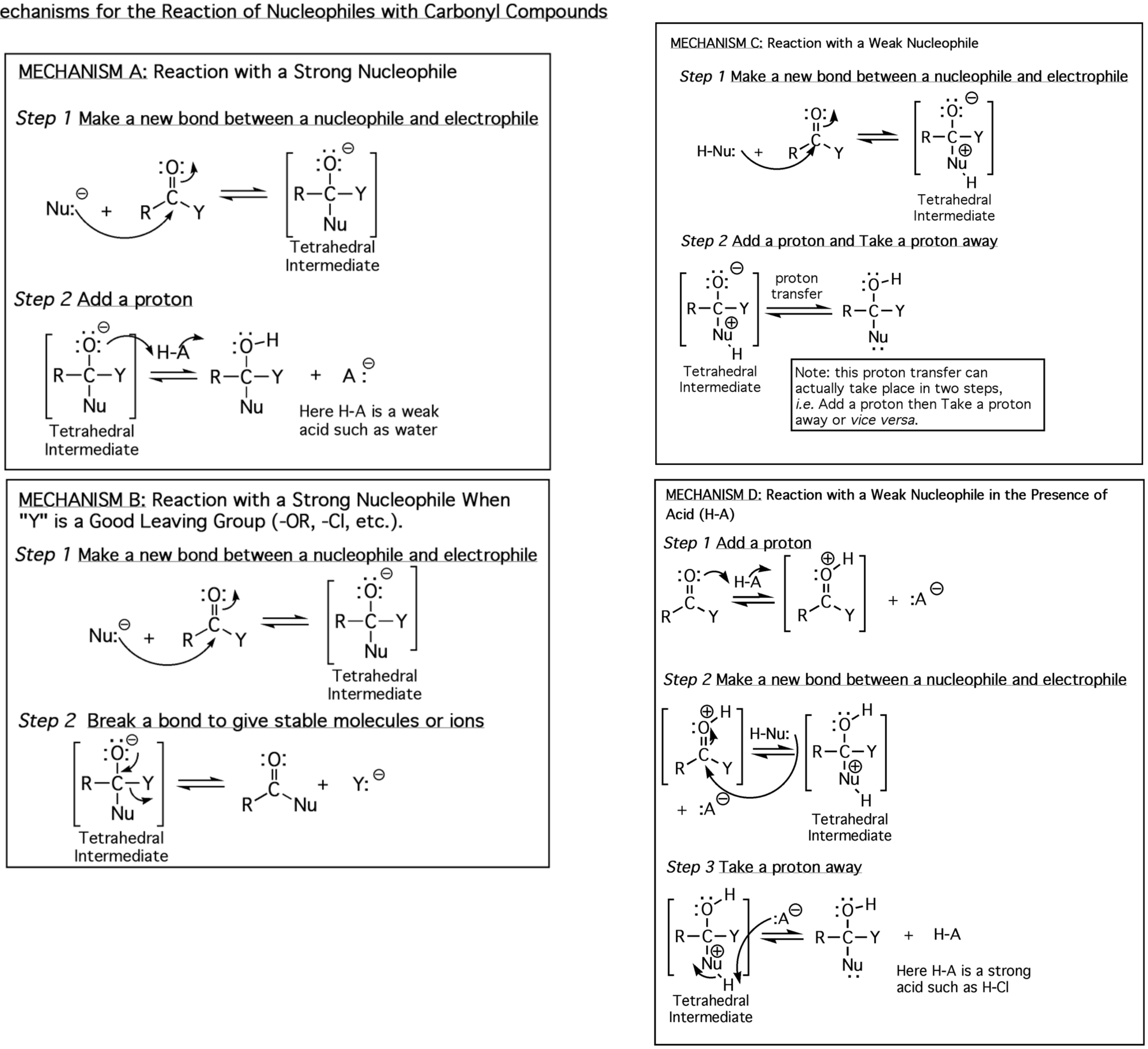
1) There are basically four different mechanisms elements that make up the steps of carbonyl reactions.

- **A) Make a bond between a nucleophile and an electrophile**
- **B) Break a bond to give stable molecules or ions**
- **C) Add a proton**
- **D) Take a proton away**

2) These same four mechanism elements describe most of the other mechanisms you have/will learn!!! (Yes, organic chemistry really is this simple if you look at it this way!!)

There are basically four different mechanisms that describe the vast majority of carbonyl reactions and these mechanisms are different combinations/ordering of the four mechanism elements listed above. In this class, I have termed them "Mechanism A", "Mechanism B", "Mechanism C", and "Mechanism D". They all involve a nucleophile attacking the partially positively charged carbon atom of the carbonyl to create a tetrahedral intermediate. Different reaction mechanisms are distinguished by the timing of protonation of the oxygen atom as well as the presence or absence of a leaving group attached to the carbonyl.

Four Mechanisms for the Reaction of Nucleophiles with Carbonyl Compounds



MECHANISM A: Reaction with a Strong Nucleophile

Step 1 Make a new bond between a nucleophile and electrophile

Step 2 Add a proton

Here H-A is a weak acid such as water

MECHANISM B: Reaction with a Strong Nucleophile When "Y" is a Good Leaving Group (-OR, -Cl, etc.).

Step 1 Make a new bond between a nucleophile and electrophile

Step 2 Break a bond to give stable molecules or ions

MECHANISM C: Reaction with a Weak Nucleophile

Step 1 Make a new bond between a nucleophile and electrophile

Step 2 Add a proton and Take a proton away

Note: this proton transfer can actually take place in two steps, *i.e.* Add a proton then Take a proton away or *vice versa*.

MECHANISM D: Reaction with a Weak Nucleophile in the Presence of Acid (H-A)

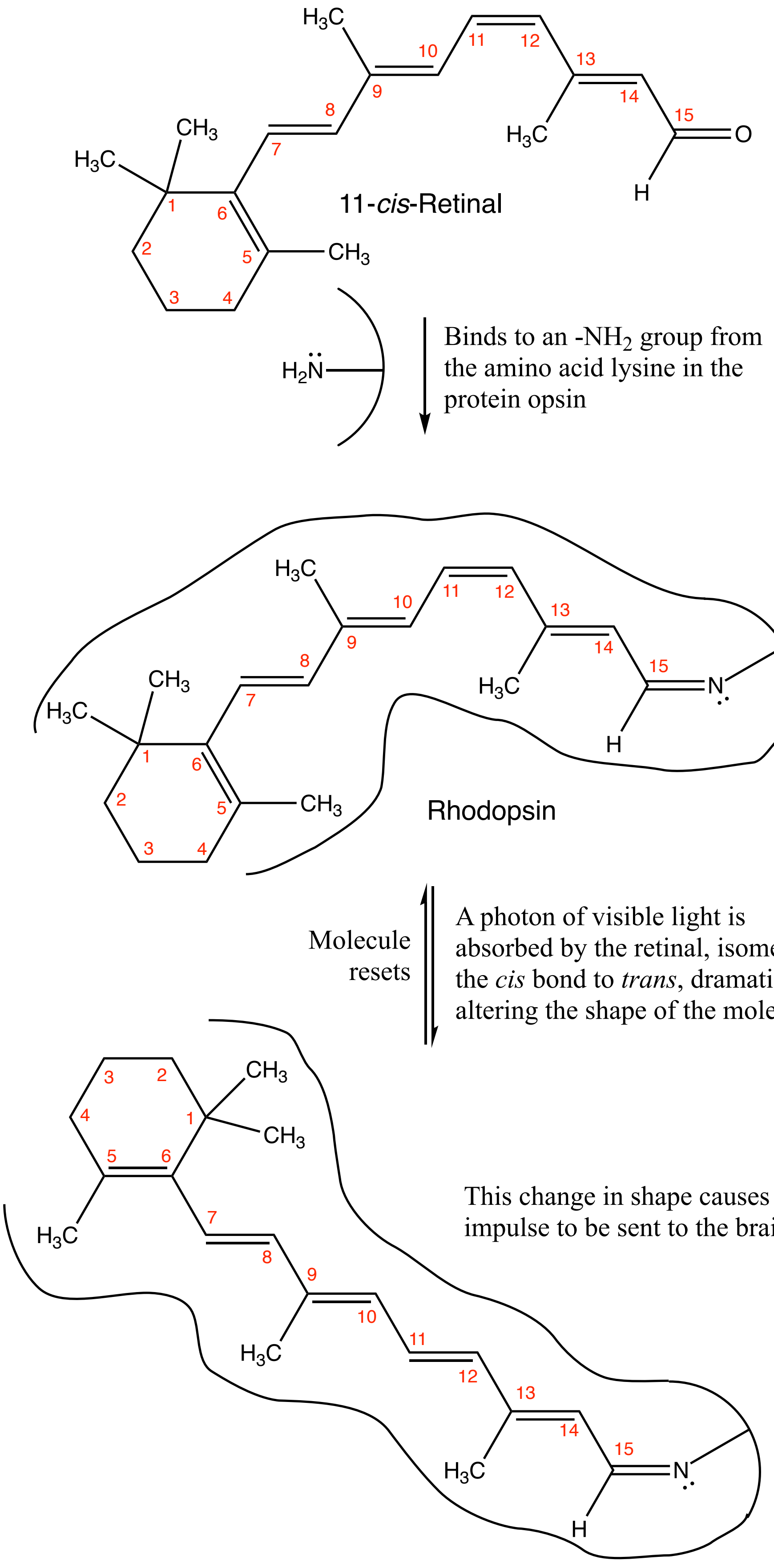
Step 1 Add a proton

Step 2 Make a new bond between a nucleophile and electrophile

Step 3 Take a proton away

Here H-A is a strong acid such as H-Cl

How vision works



11-*cis*-Retinal

Binds to an -NH$_2$ group from the amino acid lysine in the protein opsin

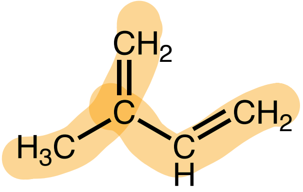
Rhodopsin

Molecule resets

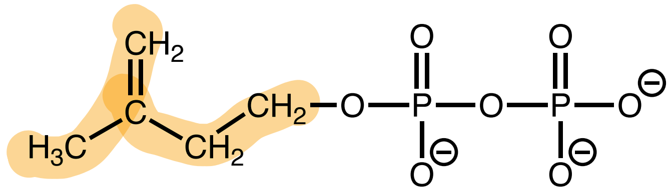
A photon of visible light is absorbed by the retinal, isomerizing the *cis* bond to *trans*, dramatically altering the shape of the molecule

This change in shape causes a nerve impulse to be sent to the brain

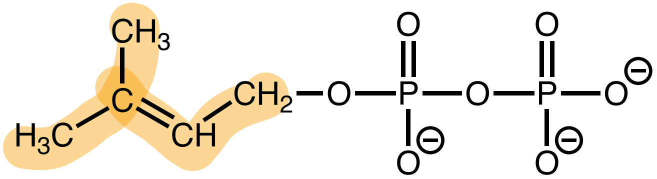
Terpenes



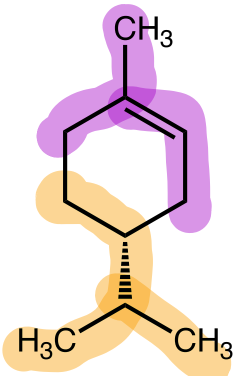
Isoprene



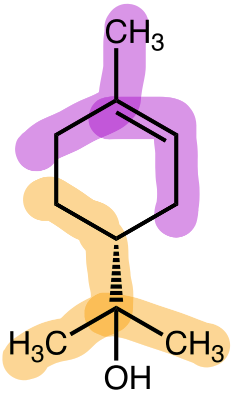
Isopentanyl diphosphate



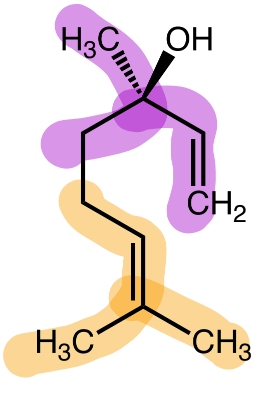
Dimethylallyl diphosphate



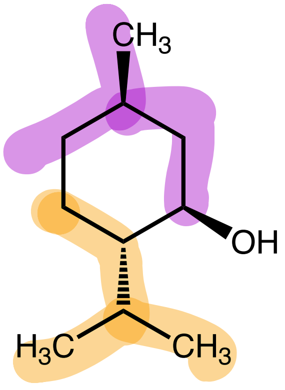
Limonene
(citrus flavor)



α-Terpineol
(from lilacs, used in
perfume)

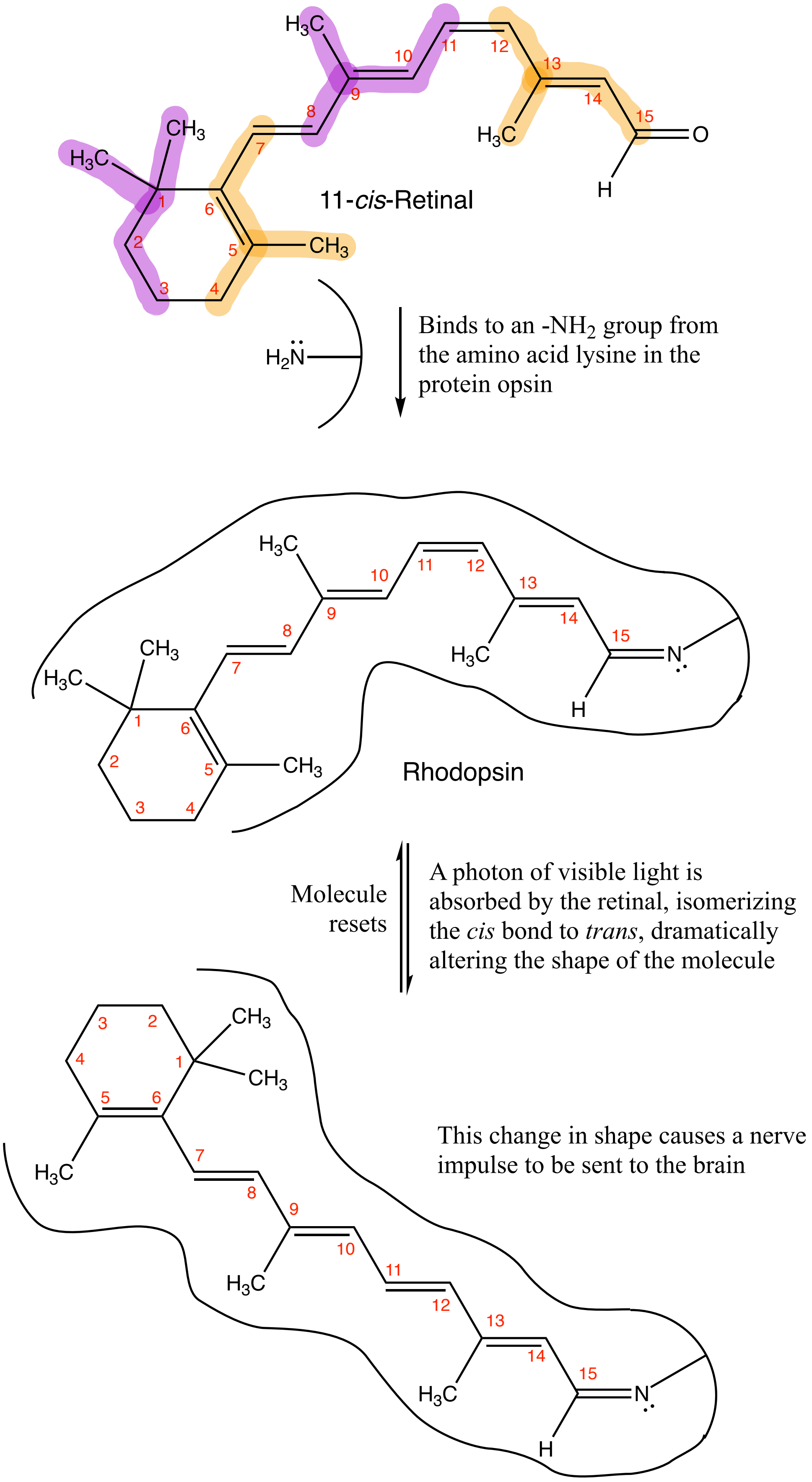


(*R*)-(-)-Linalool
(from lavender, used in
perfume)



(-)-Menthol
(common flavoring from
peppermint)

How vision works

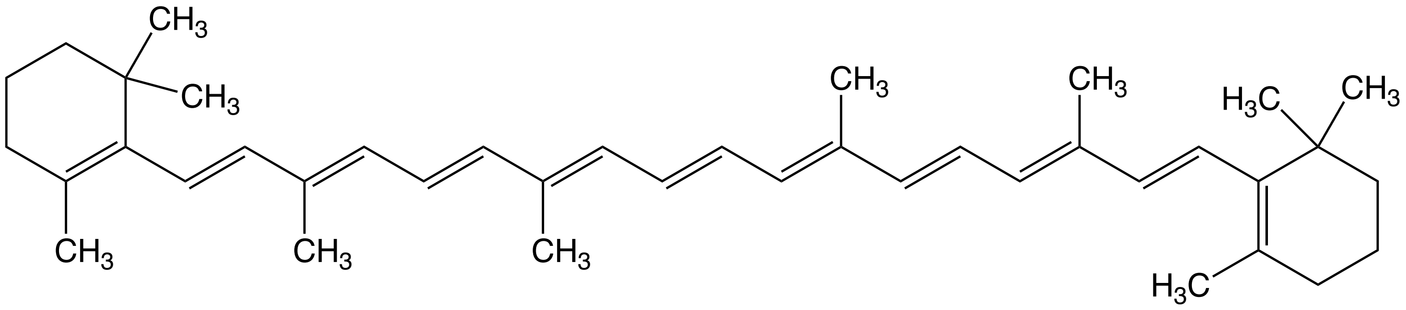


Binds to an -NH_2 group from the amino acid lysine in the protein opsin

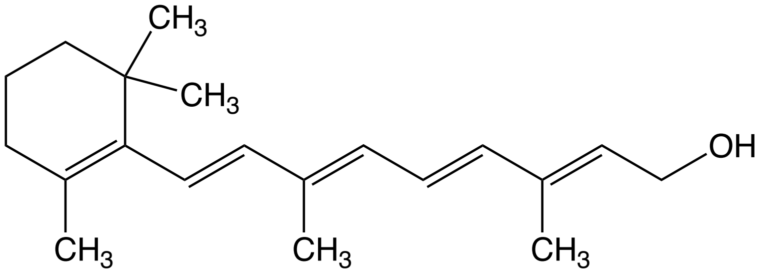
Molecule resets

A photon of visible light is absorbed by the retinal, isomerizing the *cis* bond to *trans*, dramatically altering the shape of the molecule

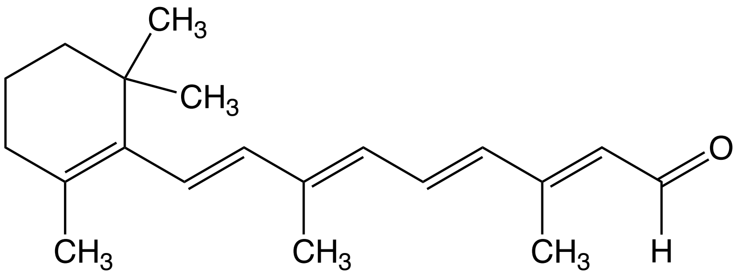
This change in shape causes a nerve impulse to be sent to the brain



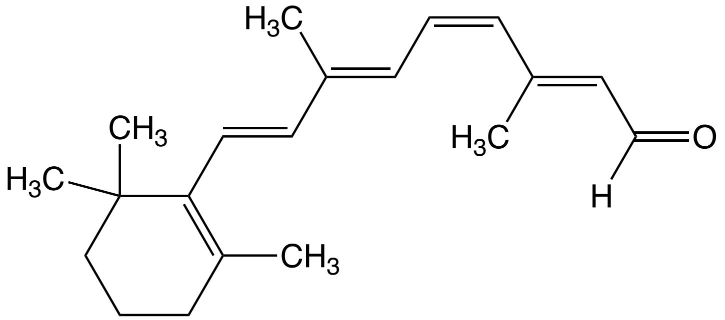
β-Carotene



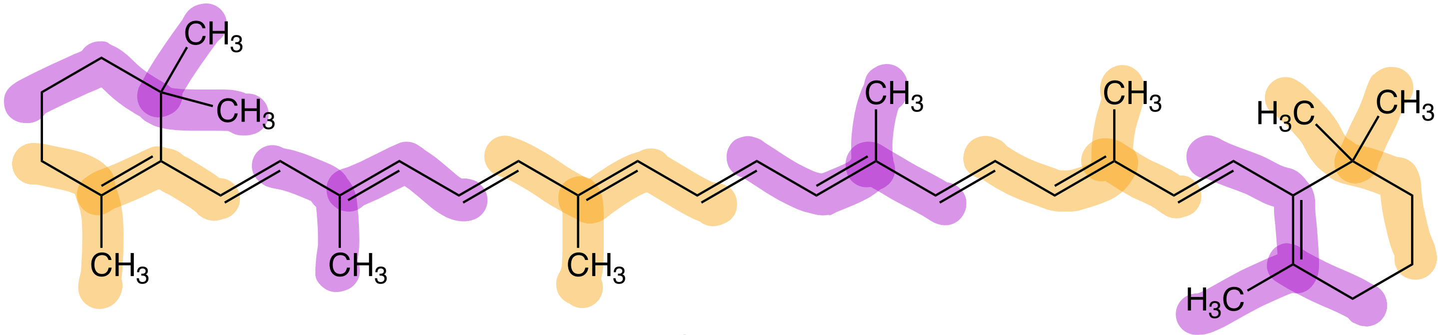
Vitamin A



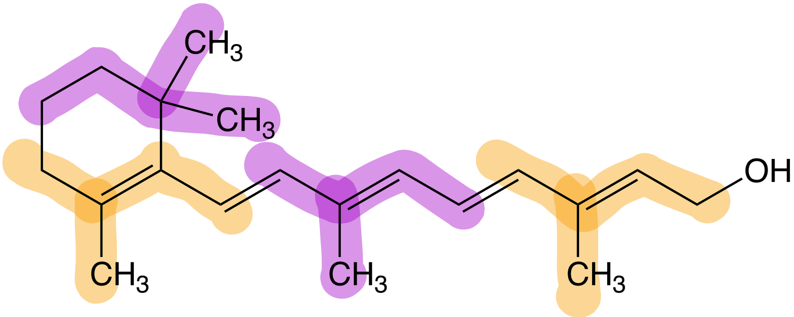
All *trans* Retinal



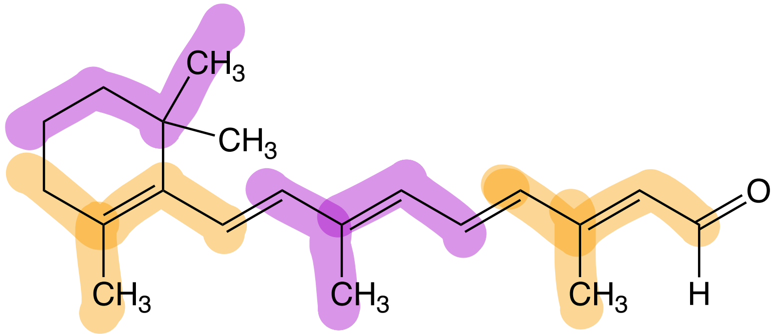
11-*cis*-Retinal



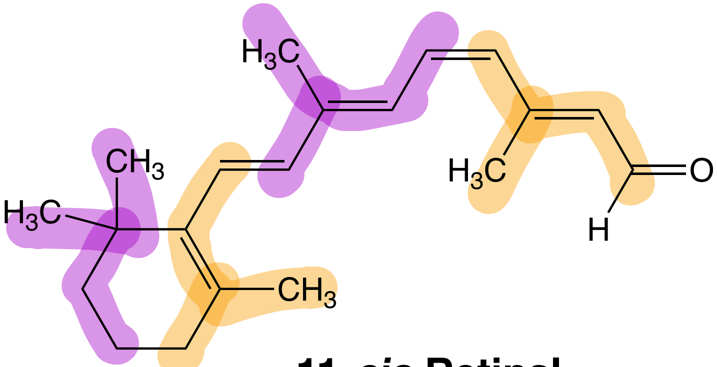
β-Carotene



Vitamin A

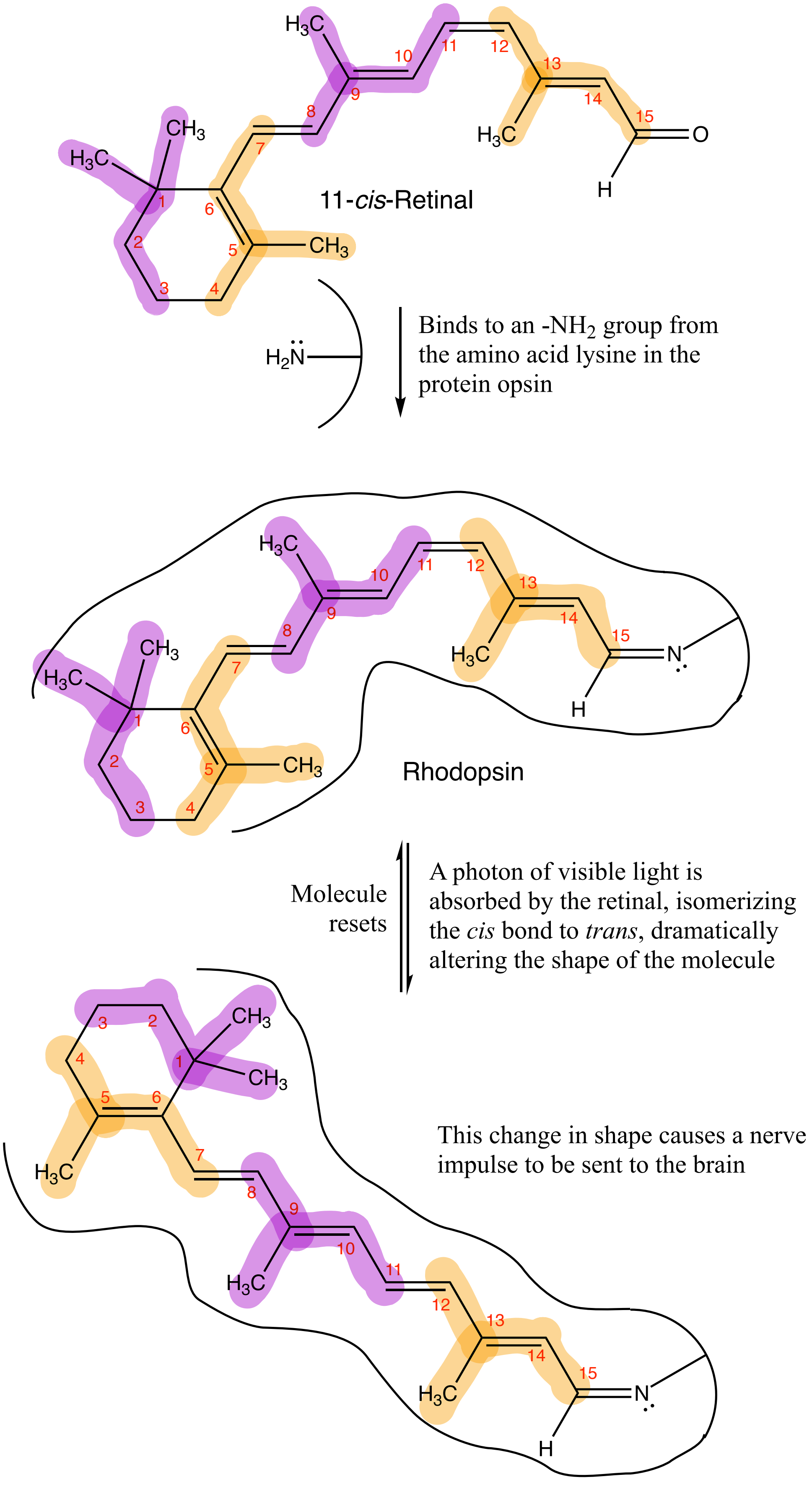


All *trans* Retinal



11-*cis*-Retinal

How vision works



11-*cis*-Retinal

Binds to an -NH_2 group from the amino acid lysine in the protein opsin

Rhodopsin

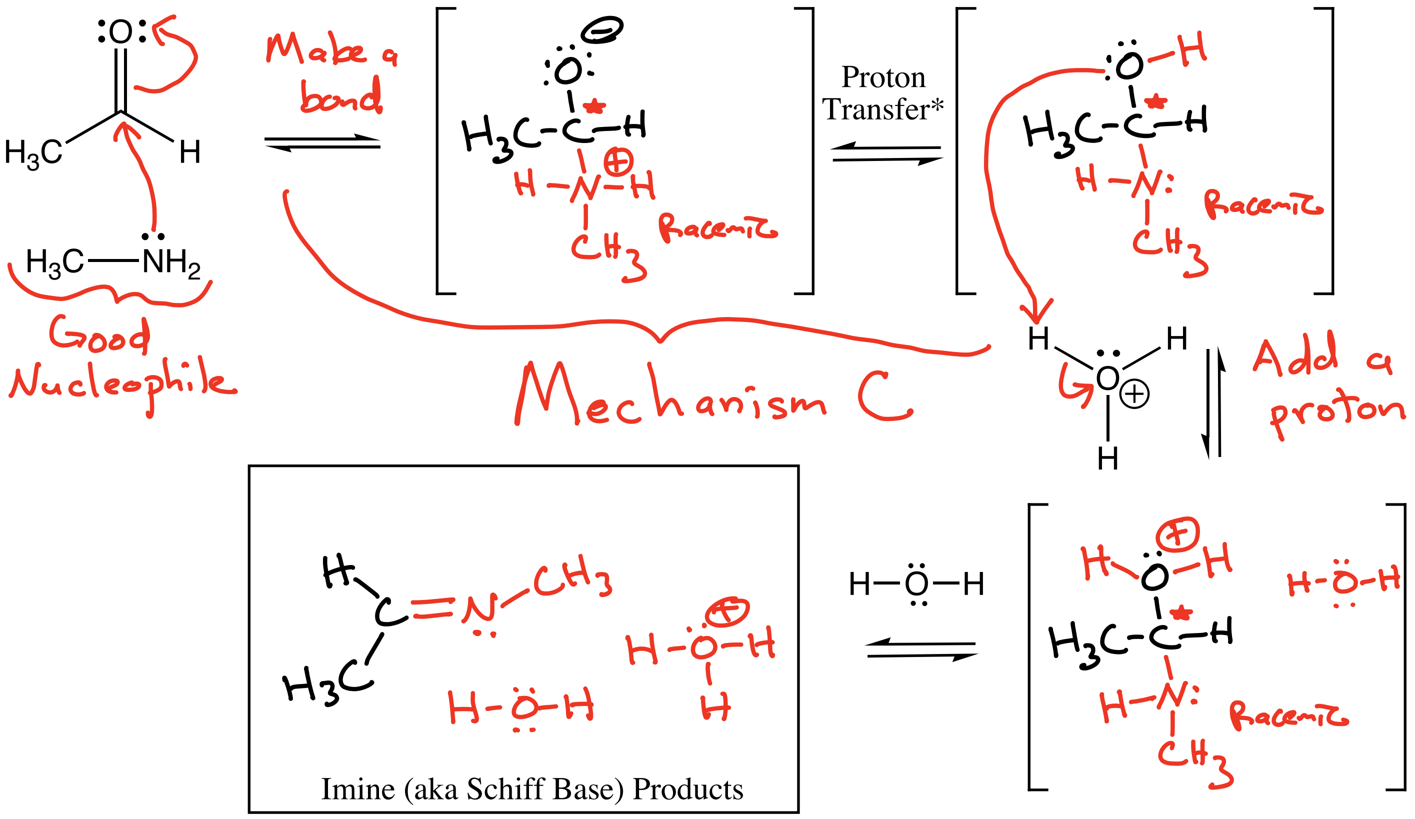
A photon of visible light is absorbed by the retinal, isomerizing the *cis* bond to *trans*, dramatically altering the shape of the molecule

Molecule resets

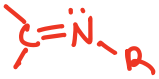
This change in shape causes a nerve impulse to be sent to the brain

Recall:

Formation of an Imine (Schiff Base) From an Aldehyde or Ketone Reacting with an Amine



Key Recognition Element (KRE):

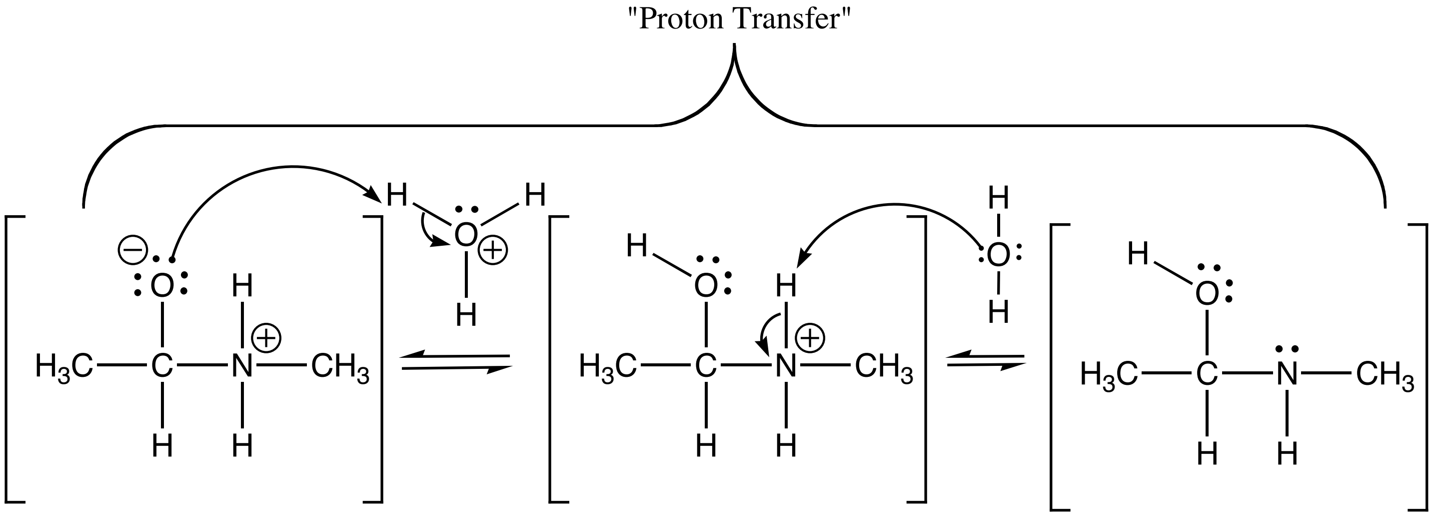


The C=O is converted to C=N

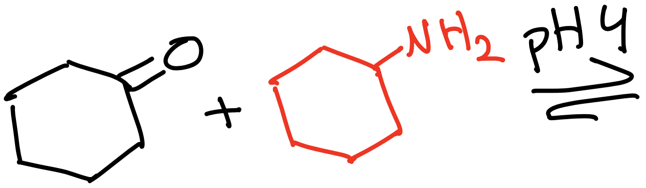
(Note: this last step might actually occur as two steps in some cases.)

---

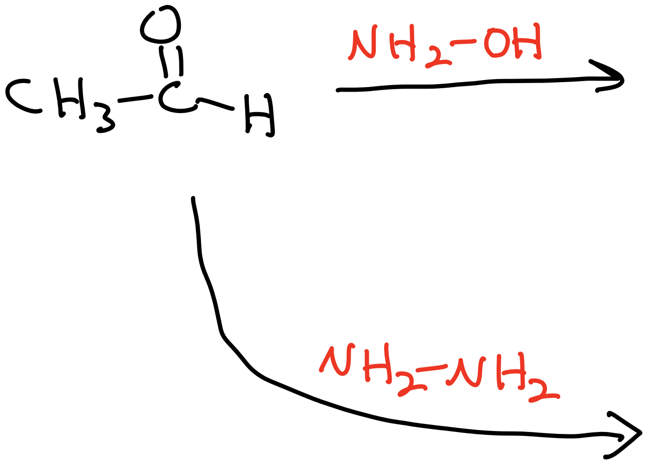
* "Proton Transfer" refers to a situation in which a proton moves from one part of a molecule to another on the SAME MOLECULE. We do not draw arrows for proton transfer steps because that would be deceptive. In some cases, the same proton may move from one part of the molecule to the other directly, but in other cases, solvent molecules may be involved as indicated in the following scheme. To make things even more interesting, the following two steps might even be reversed in some cases. Becuase of all the ambiguity, we just write "Proton Transfer" and do not bother with arrows.



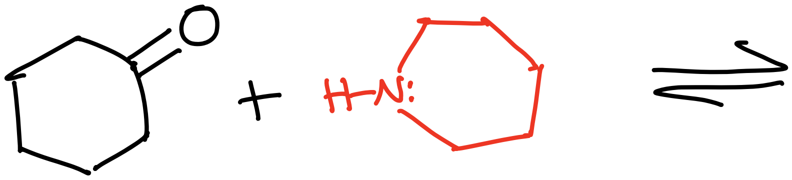
This is reversible:



Other similar reagents react the same way:



2° Amines

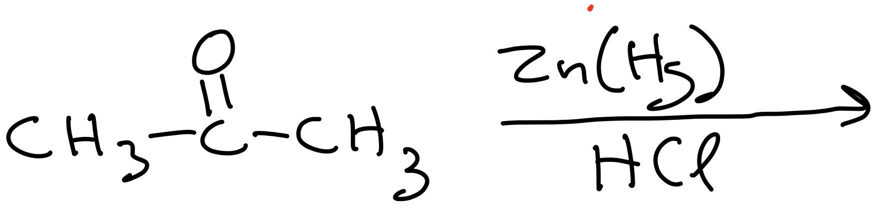


2° (secondary)
Amine -
only one
H atom

Conversion of ketone and aldehyde C=O groups to $-CH_2-$

In acid

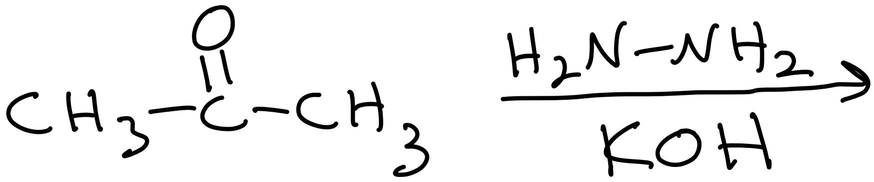
Clemmenson Reduction



$$CH_3-\overset{\overset{O}{\|}}{C}-CH_3 \xrightarrow[HCl]{Zn(Hg)}$$

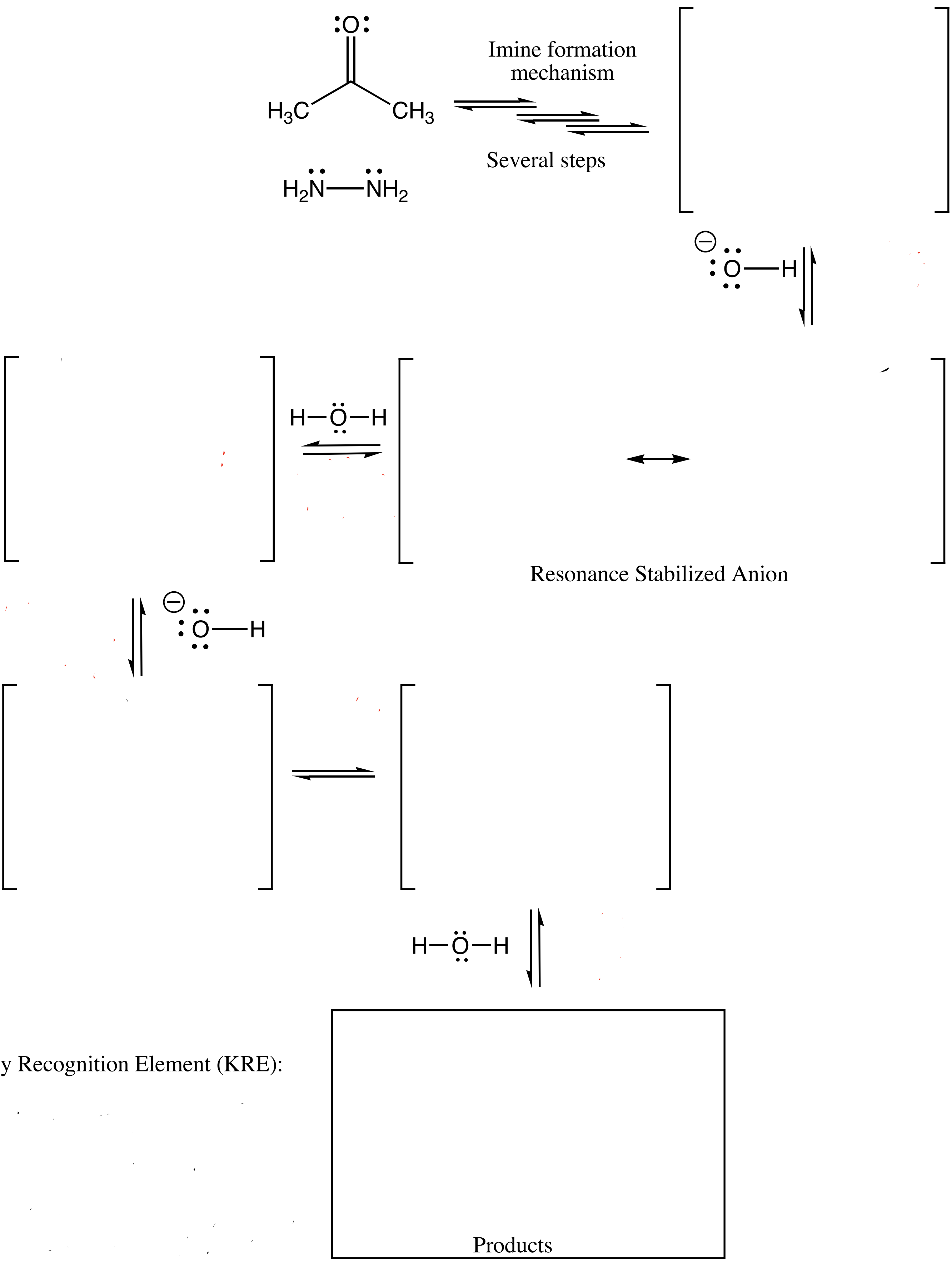
In base

Wolff-Kishner Reduction



$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3 \xrightarrow[KOH]{H_2N-NH_2}$$

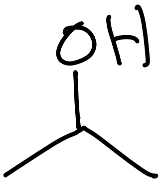
Wolff-Kishner Reduction of an Aldehyde or Ketone



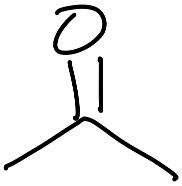
Key Recognition Element (KRE):


Eek! Don’t bite my head off!
O
NH2-NH2
KOH

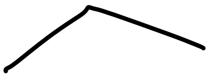
Putting these oxidation and reduction reactions to work in synthesis



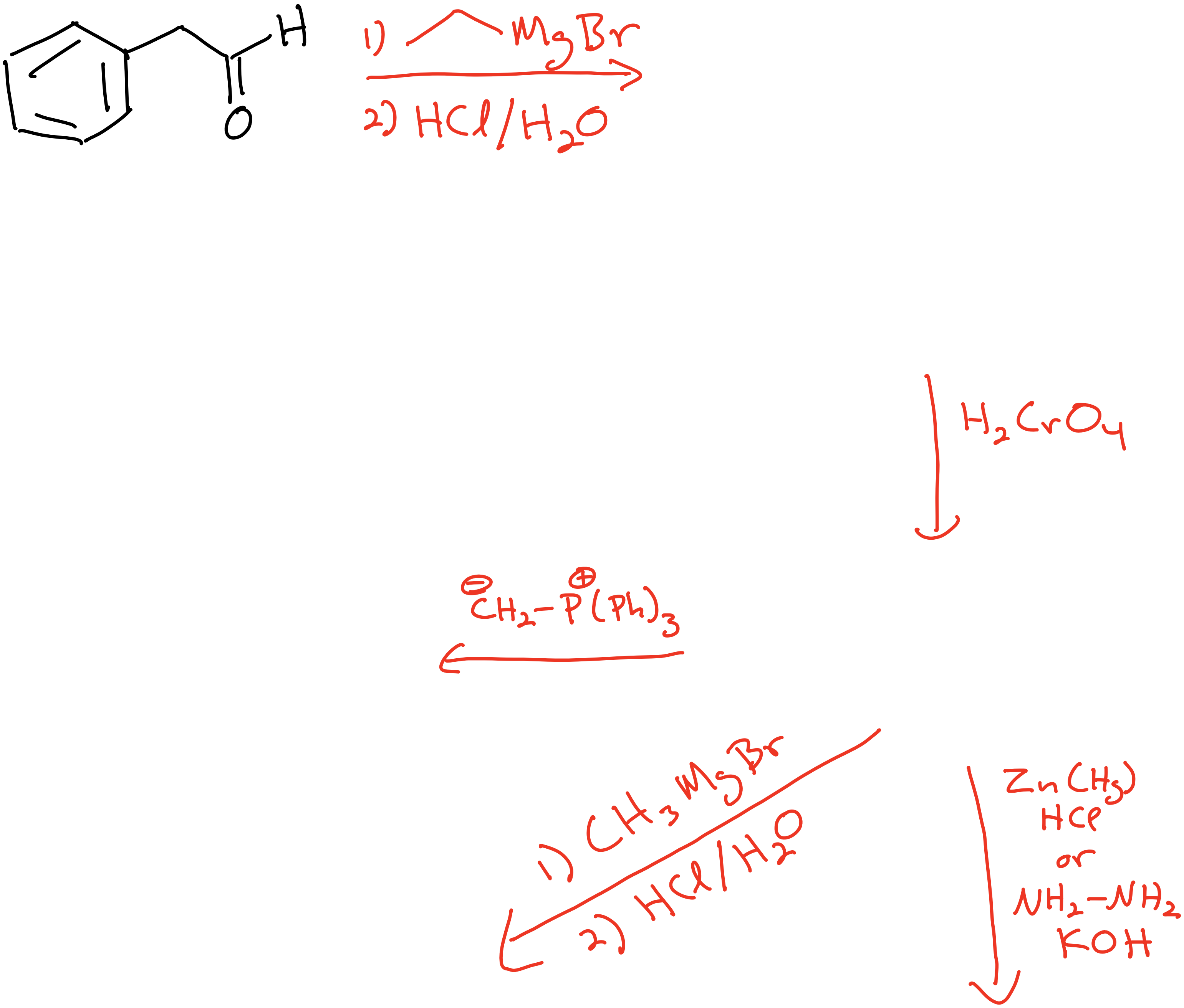
Alcohol

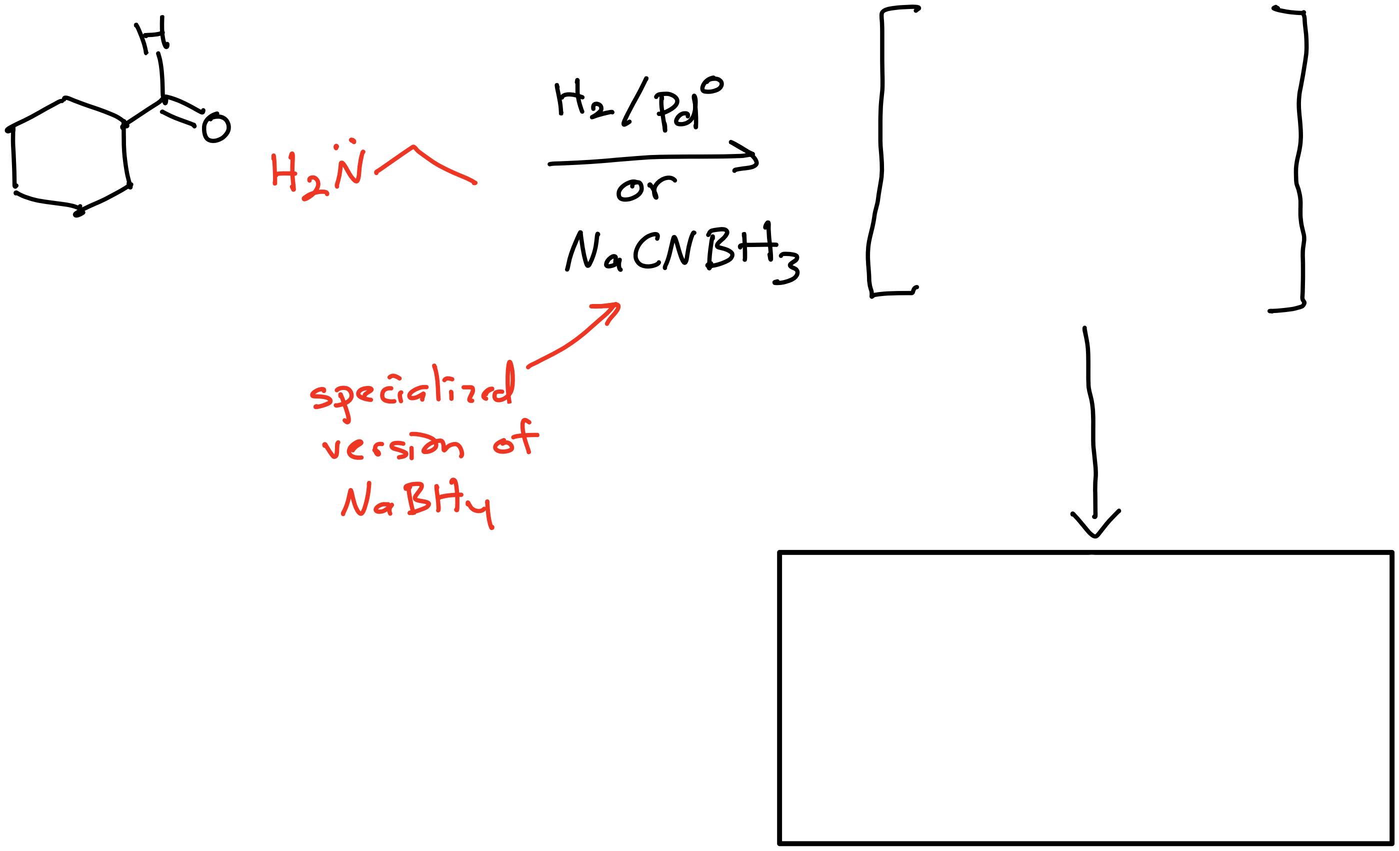


Ketone



Alkane

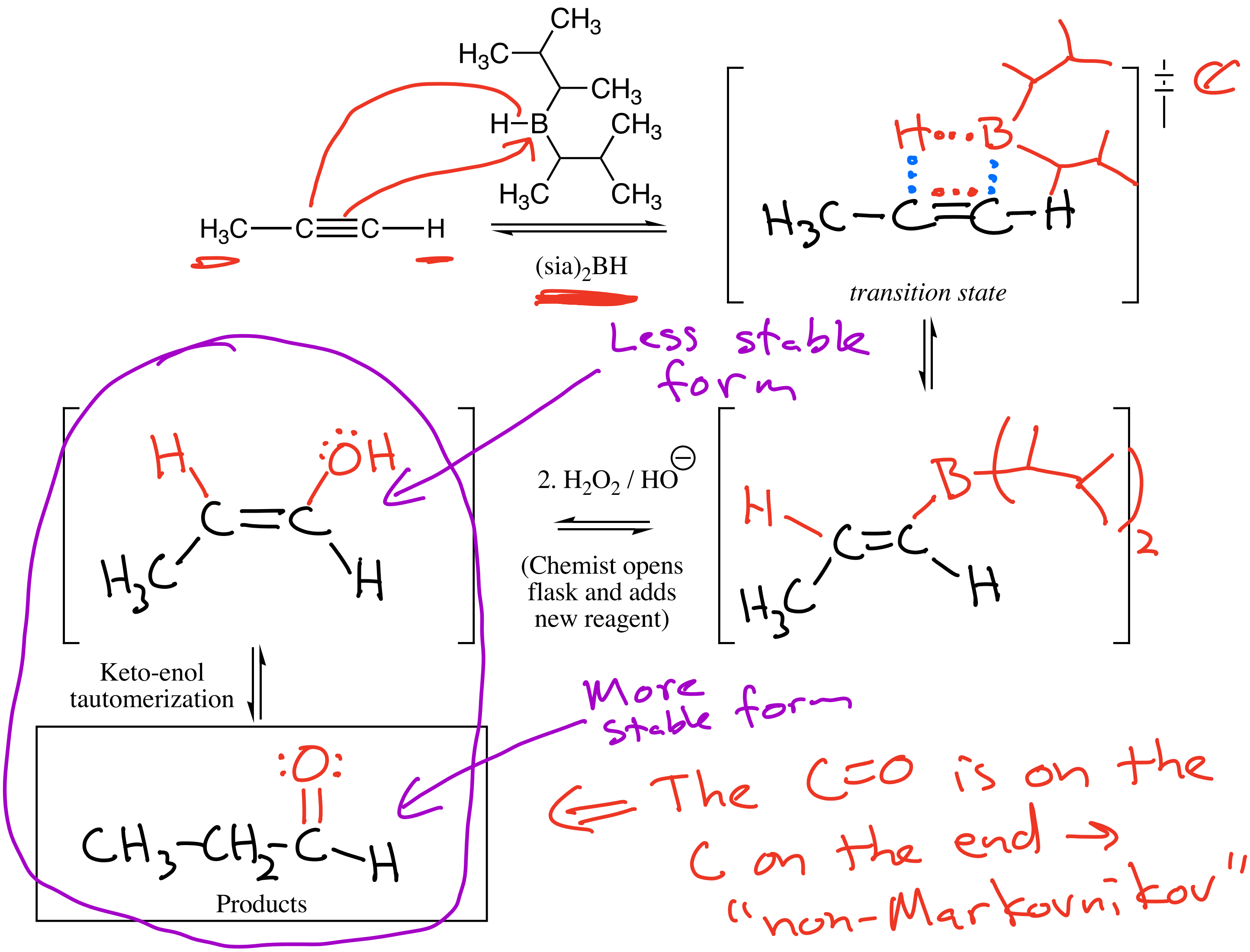

H
O
1) MgBr
2) HCl/H2O
H2CrO4
⊖CH2–P⊕(Ph)3
1) CH3MgBr
2) HCl/H2O
Zn(Hg)
HCl
or
NH2–NH2
KOH



specialized version of $NaBH_4$

Reductive amination → reducing the C=N of an imine as it forms in the reaction.

Terminal Alkyne Hydroboration



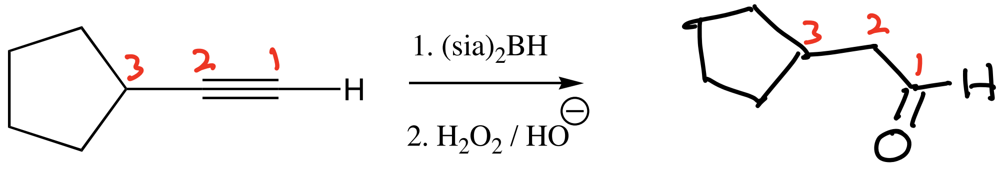
⇐ The C=O is on the C on the end → "non-Markovnikov"

Summary: The (sia)$_2$BH reacts so the B atom attaches to the C atom on the end. The four-membered ring transition states makes both bonds simultaneously. 2. $H_2O_2/HO^{\ominus}$ → enol → keto

Regiochemistry: non-Markovnikov

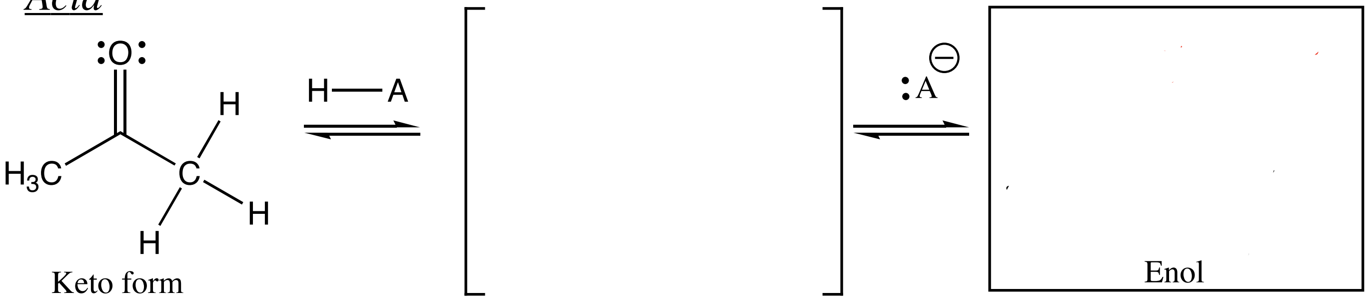
Stereochemistry: N/A

Example:

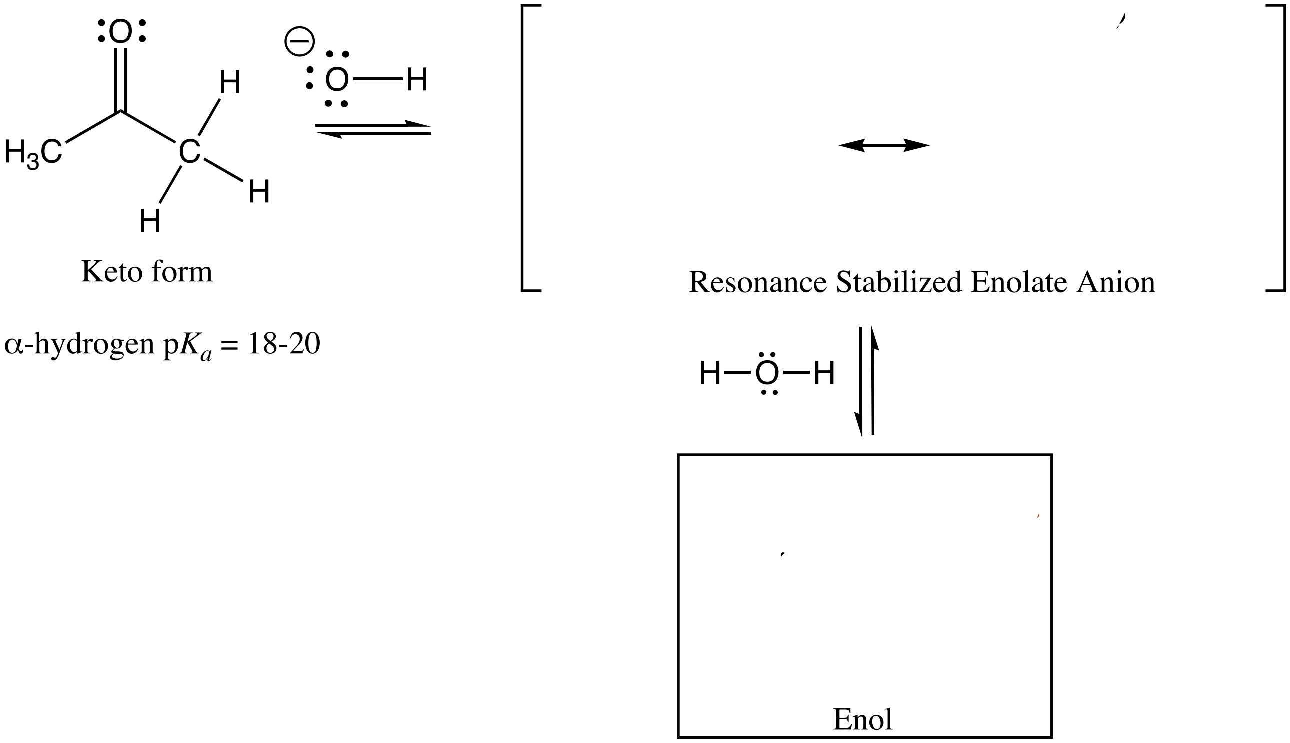


Keto-Enol Equilibrium Catalyzed by Acid or Base

Acid



Base

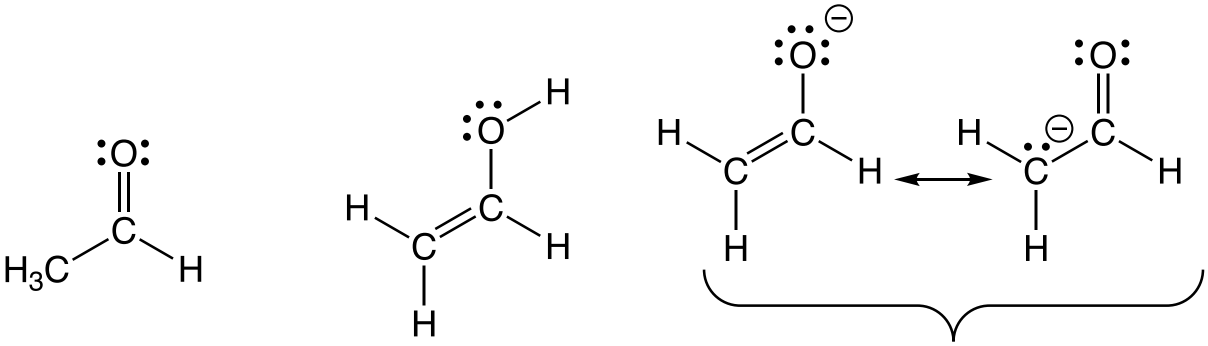


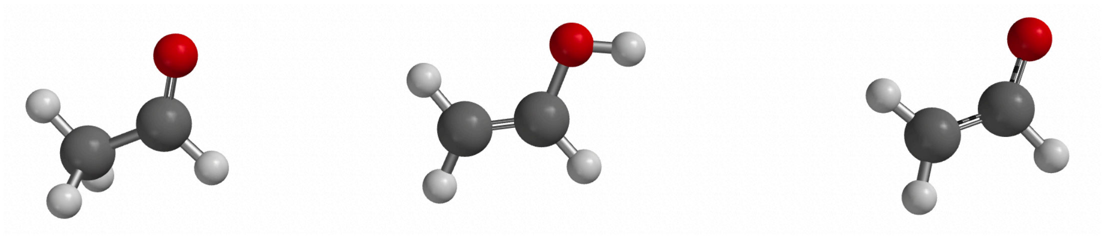
α-hydrogen pK_a = 18-20

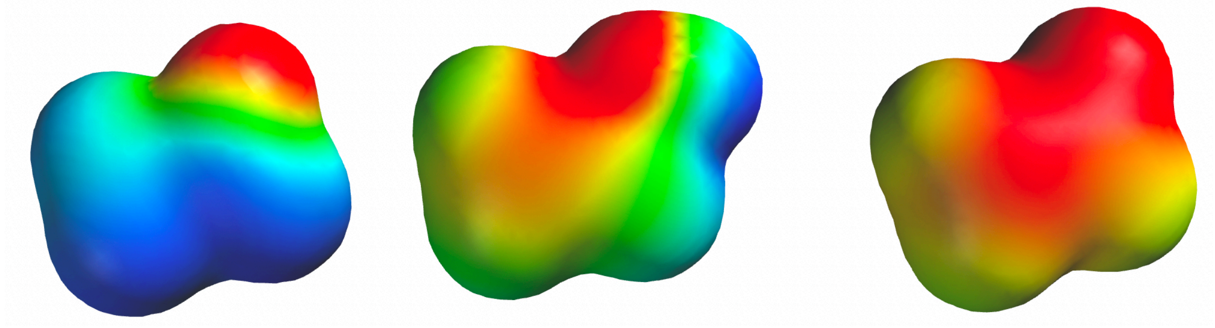
For both aldehydes and ketones, the keto form predominates at equilibrium, because ______________ bonds are stronger than ________________ bonds.

Enols are significant, however, because they react like _______________________, not carbonyls, and this is important in certain situations.

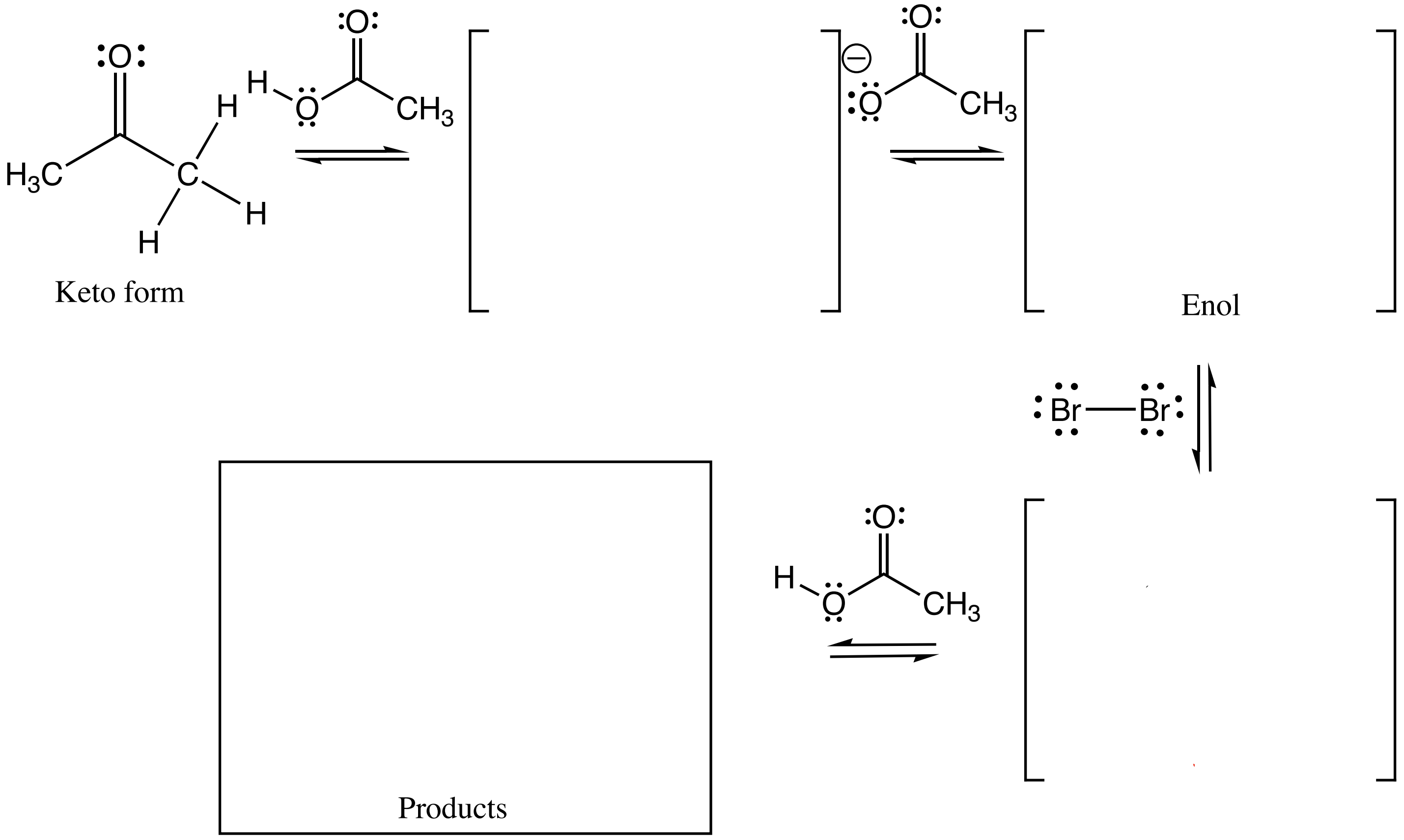
Changing Personality:

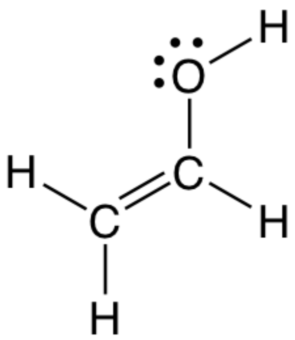


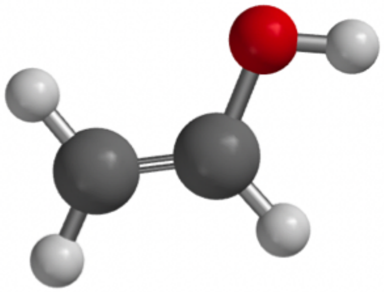


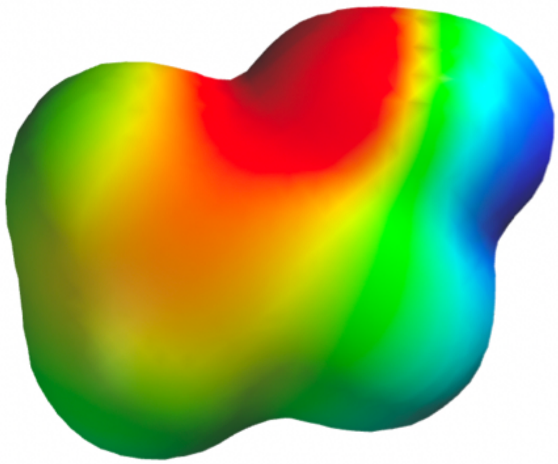


α-Halogenation of an Aldehyde or Ketone Catalyzed by Acid

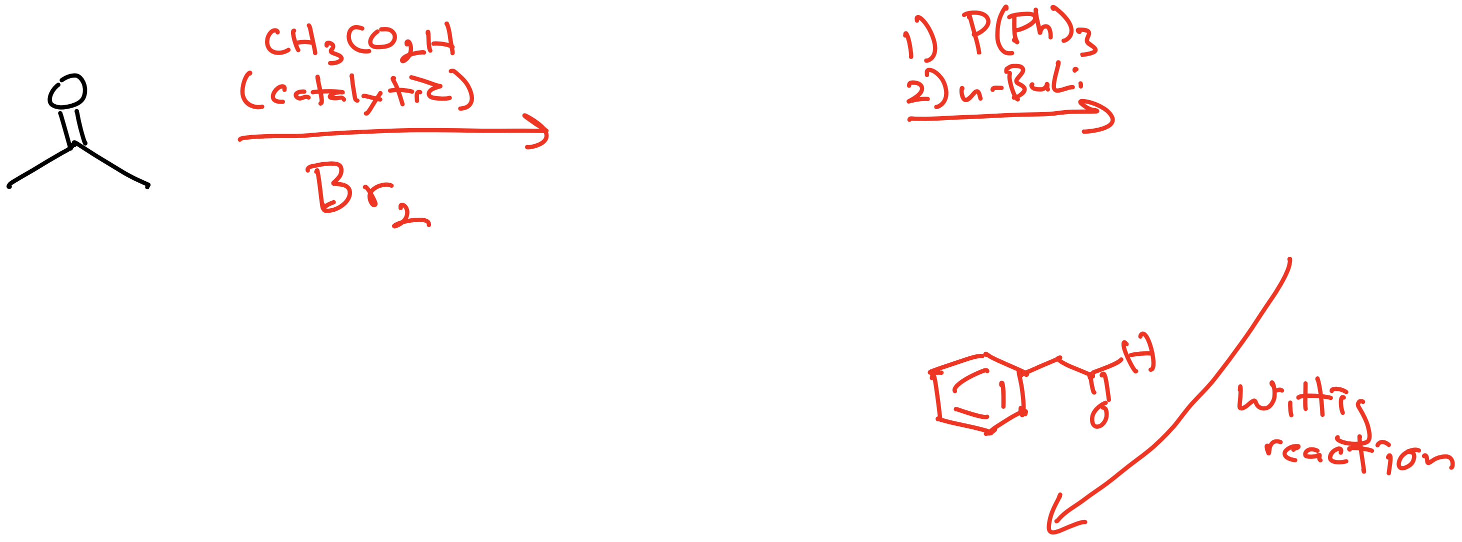


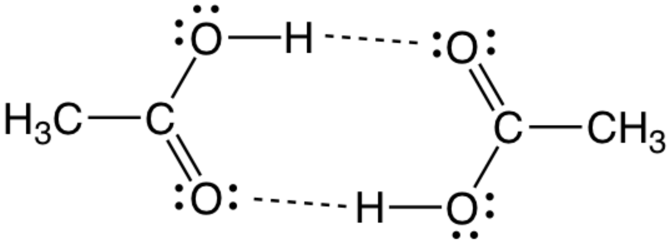




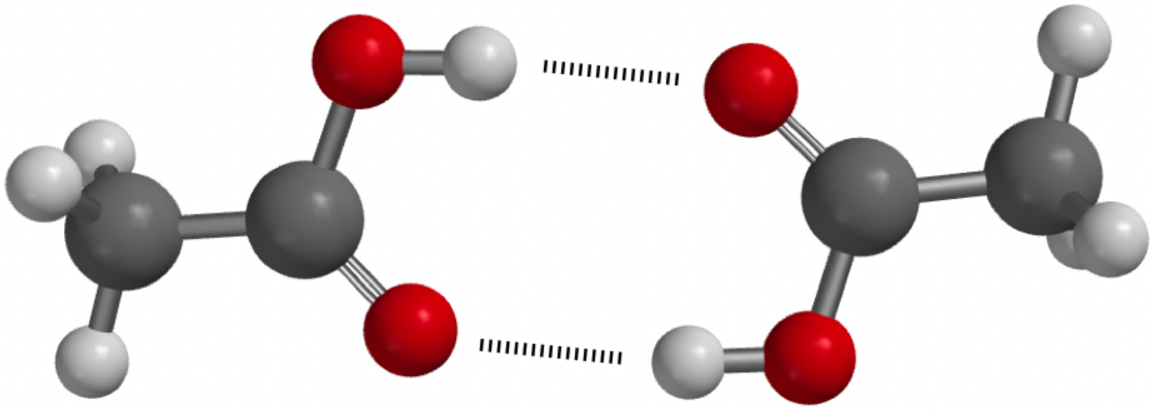


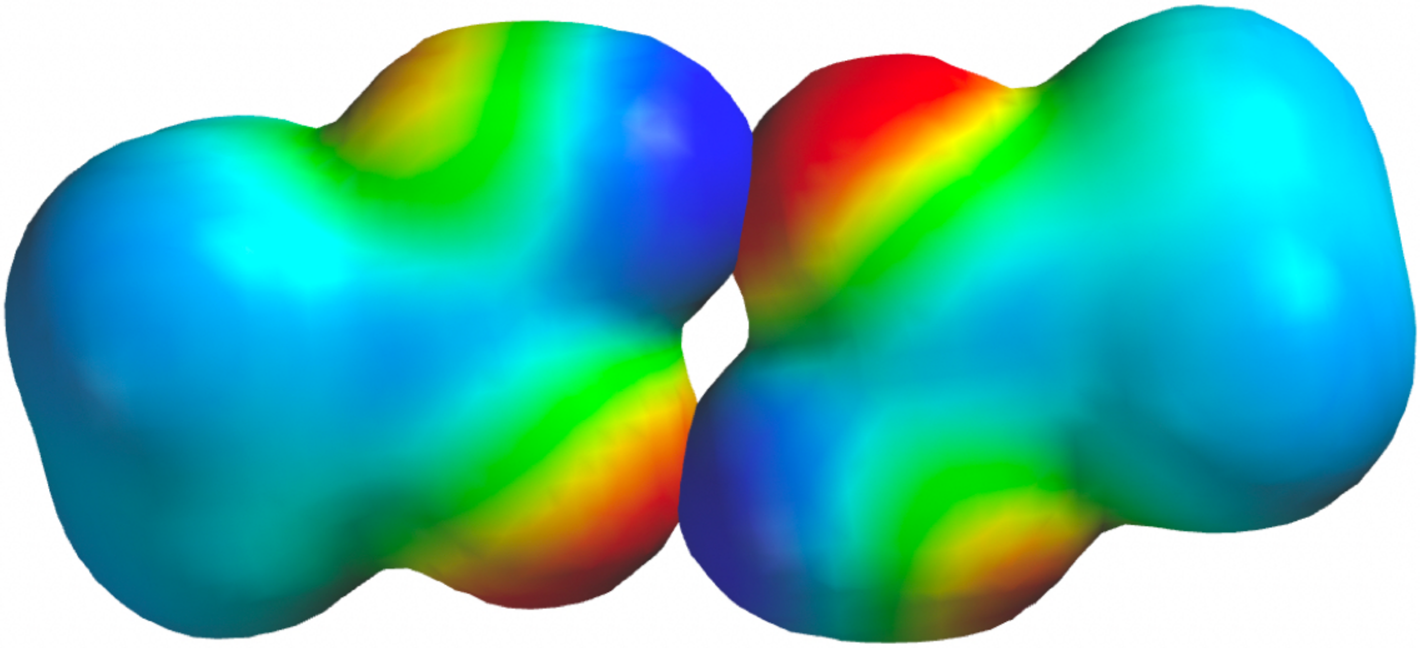
Example





H3C
CH3





Acidity Revisited

$$H{-}A \rightleftharpoons H^{\oplus} + {:}A^{\ominus}$$

$$K_a = \frac{[A{:}^{\ominus}][H^{\oplus}]}{[HA]}$$

$$pK_a = -\log_{10} K_a$$