Lecture 17

Still More Carbonyl Chemistry

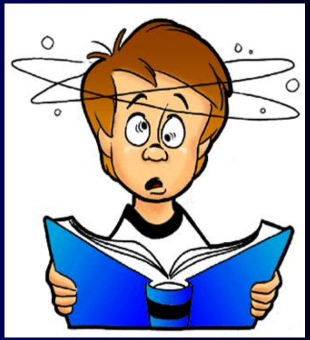
Chromium (VI) trioxide CrO_3

Chromium (III) chloride $CrCl_3$

Chromium (III) oxide CrO_2

Sodium chromate (II) Na_2CrO_4

Second Midterm Exam



- When: Tomorrow, Wednesday, **3/27**
- When: 7-9 PM (please do not be late)
- Where: Painter 3.02!!!
- What: Covers through last Thursday's lecture
- Remember: Homework problems!!
- Please…bring pencils and an eraser no calculator and no phones …….**Do a good job!!!**

Early Exam

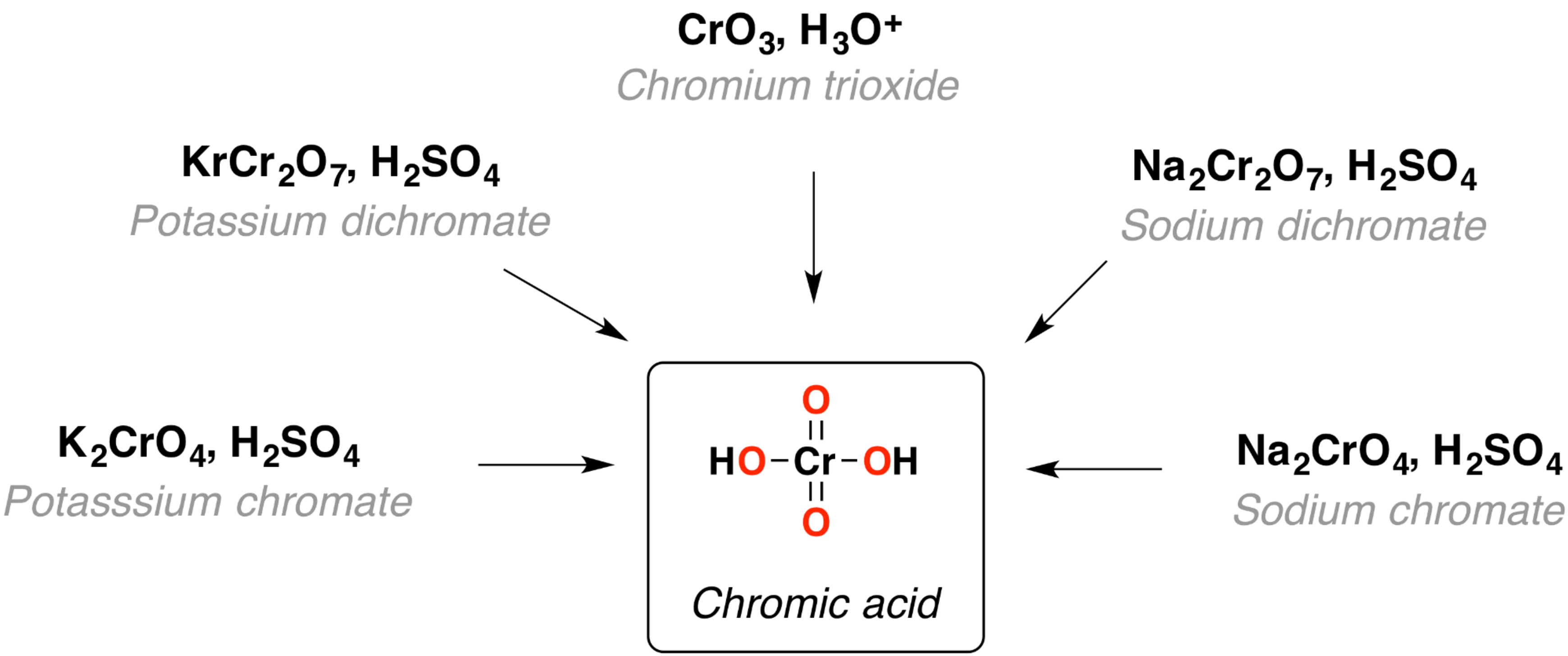
- Authorized students with exam conflict
- When: 5-7 PM Tomorrow, 3/27
- Where: ETC 2.136
- Pencil and eraser no calculator and no phone
- You must stay in the exam room until 7 PM

Chromic Acid Oxidations

Chemistry of the Breathalyzer Test

Chromic (VI) acid   Chromium (III) sulfate

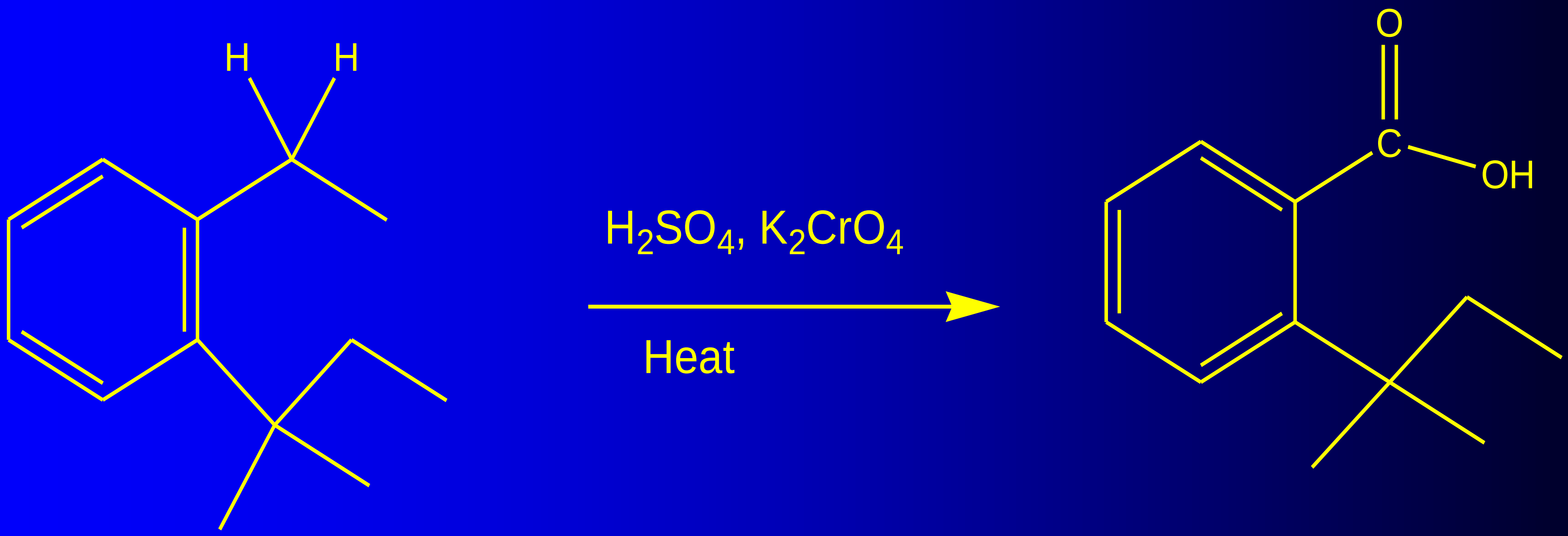
1. Chromic (III) acid (aka Jones Reagent) is made by combining sulfuric acid and sodium dichromate.
2. Jones Reagent immediately oxidizes ethyl alcohol in your breath to acetic acid.
3. Simultaneously, chromium (III) is converted to chromium (VI) sulfate (green).
4. You are hosed.



Chromic acid is often made "in situ" (that is, in the reaction flask) through the addition of acid to sources of chromium (such as chromate salts). The large number of possible chromium sources (and acids!) can make this confusing, but it is chromic acid that is the active reagent.

Erin Brokovich

Oxidation at Benzylic Positions

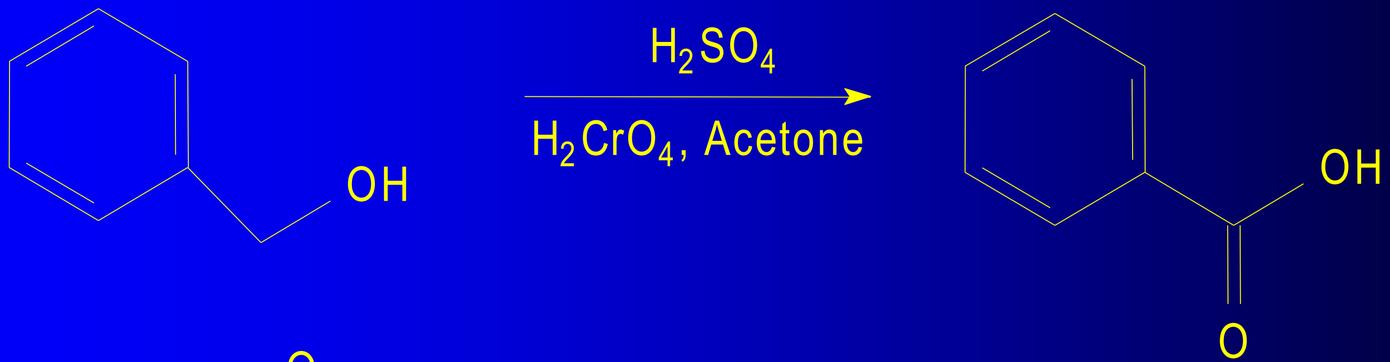


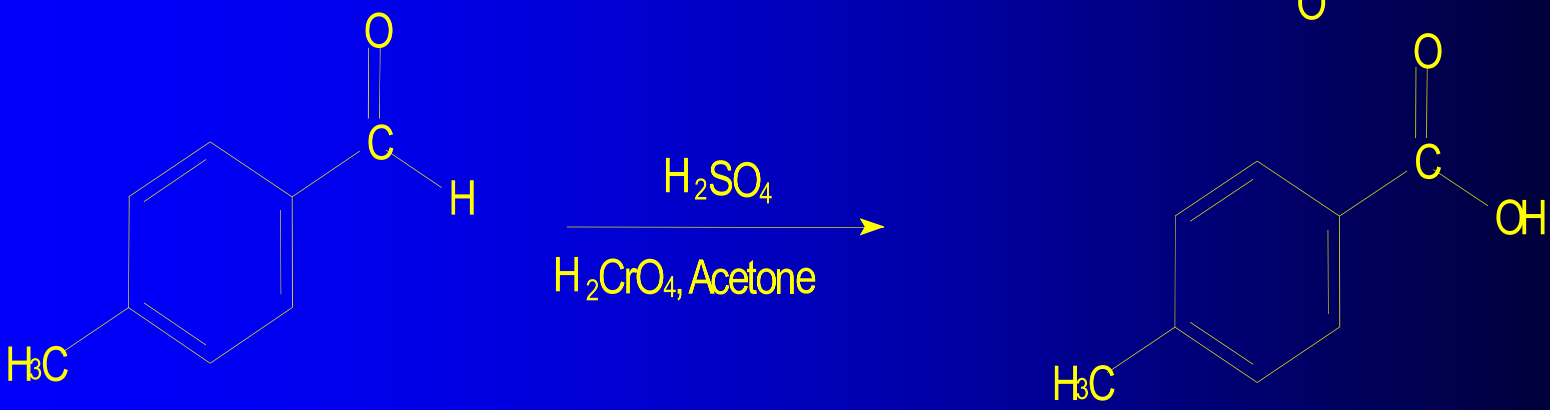
KMnO4 in Base also works

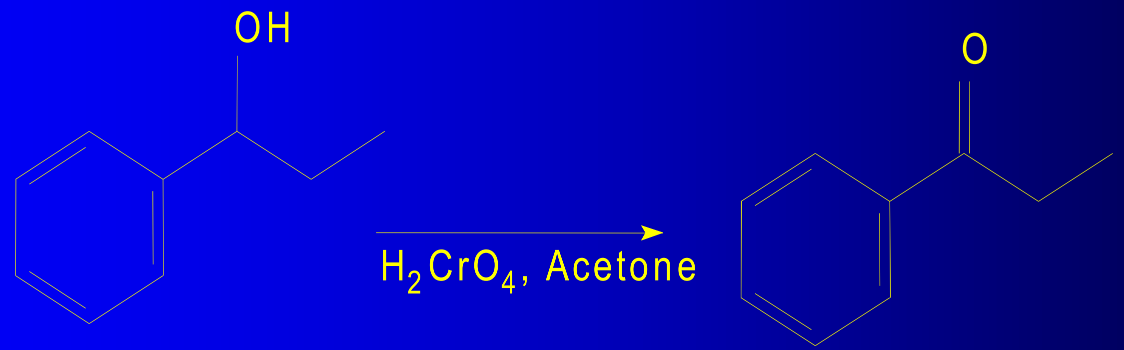
Selective Chromate Oxidations

- **Chromic acid and heat** Oxidizes benzylic positions bearing at least one hydrogen to acids
- **Jones Reagent** (H_2CrO_4 in acetone) takes primary alcohols to acids and secondary alcohols to ketones…The acetone keeps the reaction cool. Jones oxidation does not oxidize benzylic positions even with a hydrogen.
- **PCC** (pyridinium chlorochromate) is weaker yet, it only oxidizes primary alcohols to aldehydes (!) and seconday alcohols to ketones.

The Jones Oxidation Examples

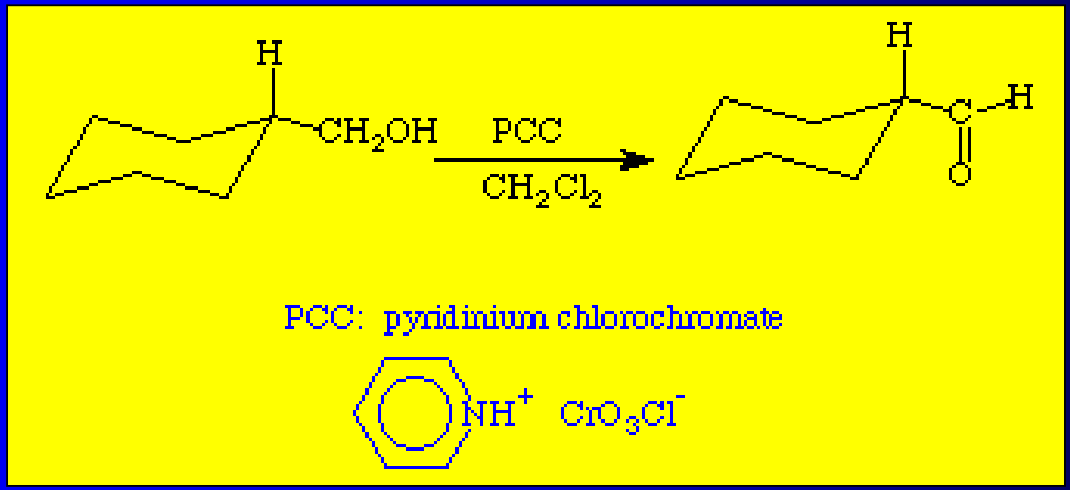


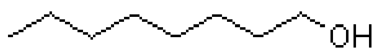
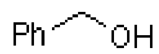
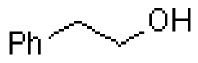
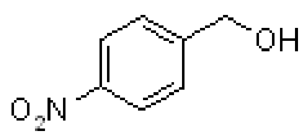
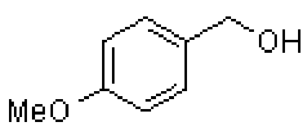




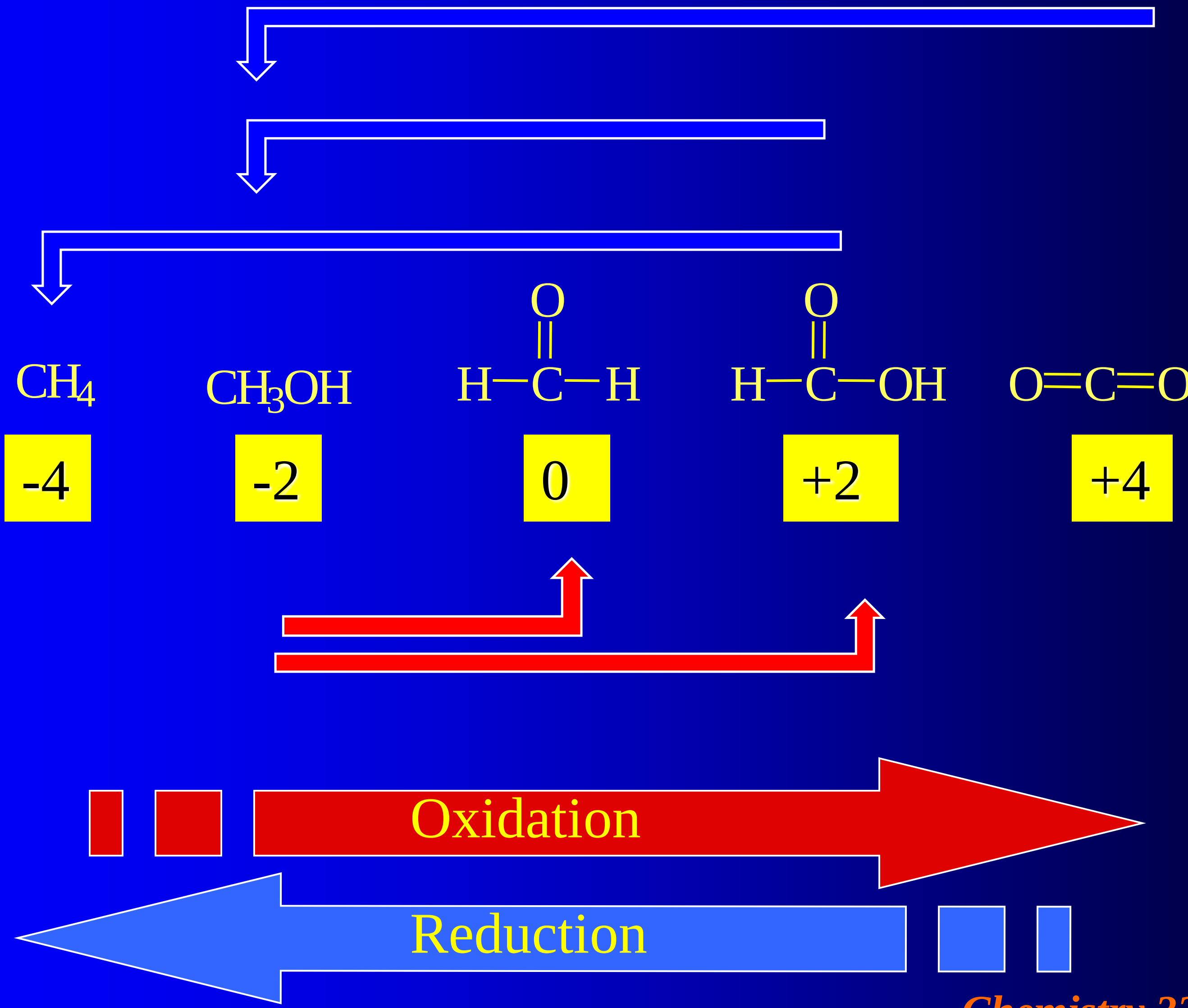
PCC Oxidations

$$C_5H_5N + HCl + CrO_3 \rightarrow [C_5H_5NH][CrO_3Cl]$$



Substrate	Yield (%, isol.)
	99
	96
	99
	99
	97

Selectivity !! ?



Selective Oxidation Reactions

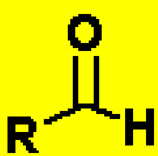
- **Jones Reagent** (H_2CrO_4 in acetone) takes primary alcohols to acids and secondary alcohols to ketones
- **The Tollen's Test** $Ag(NH_3)_2OH$…the silver mirror reaction is a qualitative test for aldehydes and an efficient but expensive way to make acids form aldehydes

Tollens Test

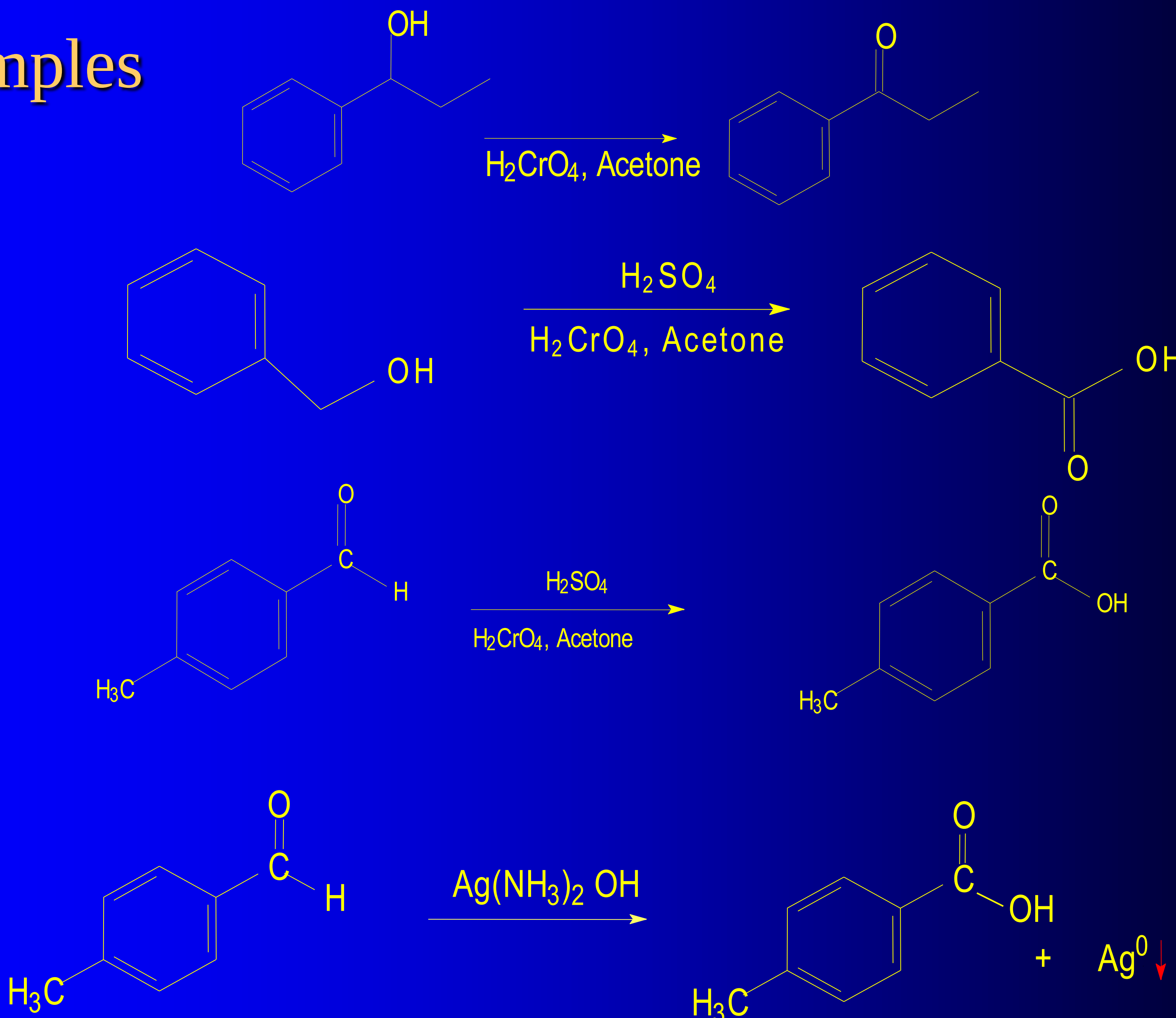
*

$$2\,AgNO_3 + 2\,NaOH \longrightarrow Ag_2O(s) + H_2O + 2\,Na^{+1} + 2\,NO_3^{-1}$$

$$Ag_2O(s) + 4NH_3 + H_2O \longrightarrow 2Ag(NH_3)_2^{+} + 2OH^{-} \quad \text{(Totally Dissolved)}$$

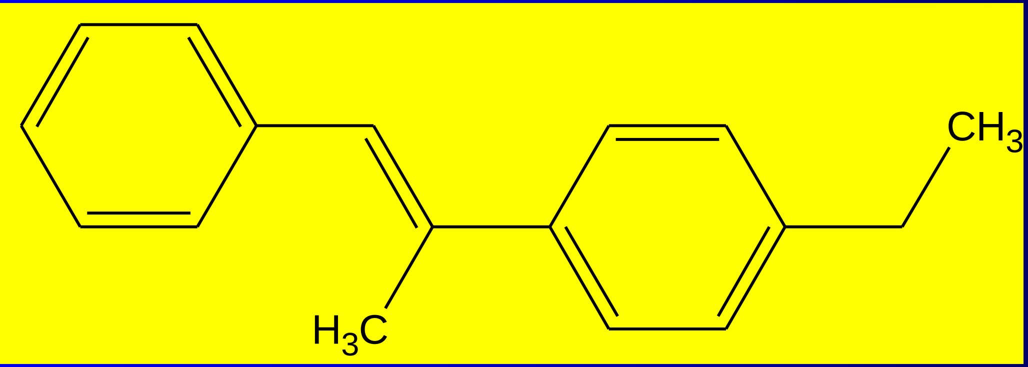
$2(Ag(NH_3)_2^{+}\ OH^{-})$ +  $\longrightarrow 2Ag + RCOO^{-}\ NH_4^{+} + H_2O + 3NH_3$

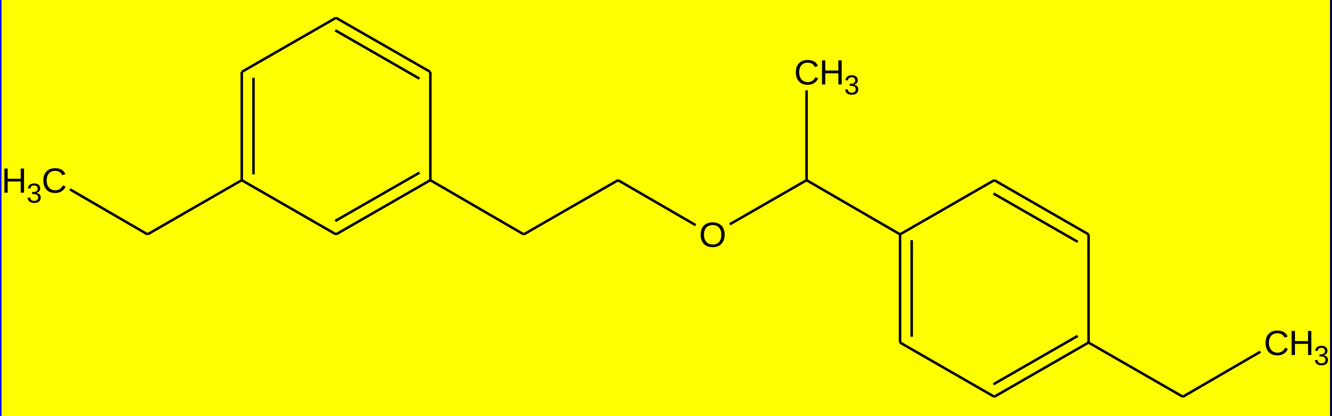
Examples


OH
H2CrO4, Acetone
O
H2SO4
H2CrO4, Acetone
OH
OH
O
O
C
H
H2SO4
H2CrO4, Acetone
H3C
O
C
OH
H3C
O
C
H
H3C
Ag(NH3)2 OH
O
C
OH
+ Ag0
H3C

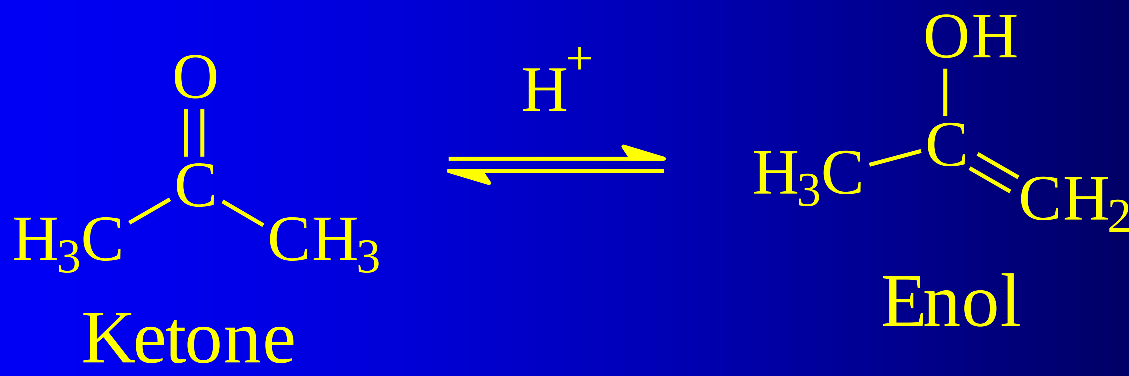
Ok…more synthesis

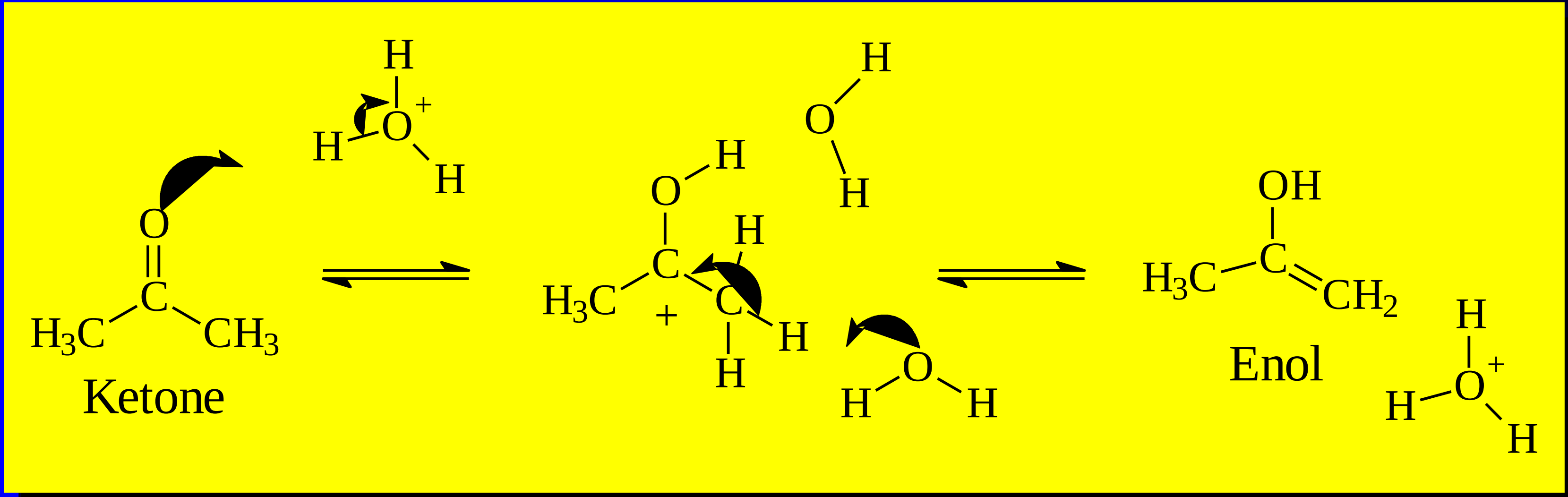
From benzene, any thing with less than 3 carbons, and any other reagents that do not become part of the structure.



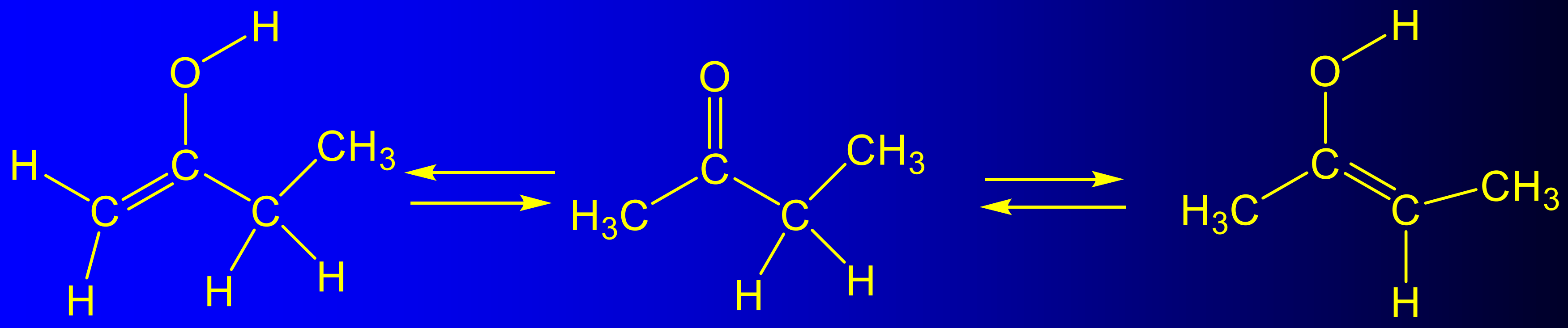


Keto-enol Tautomerism





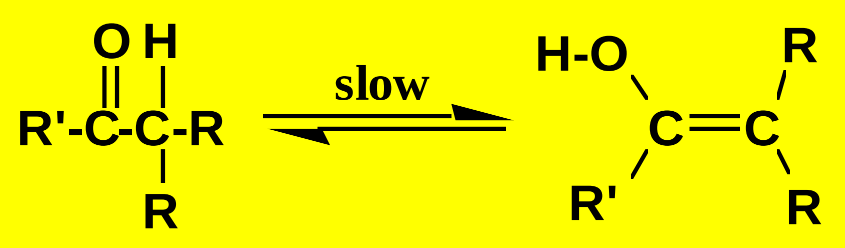
Selectivity in Acid Catalysis



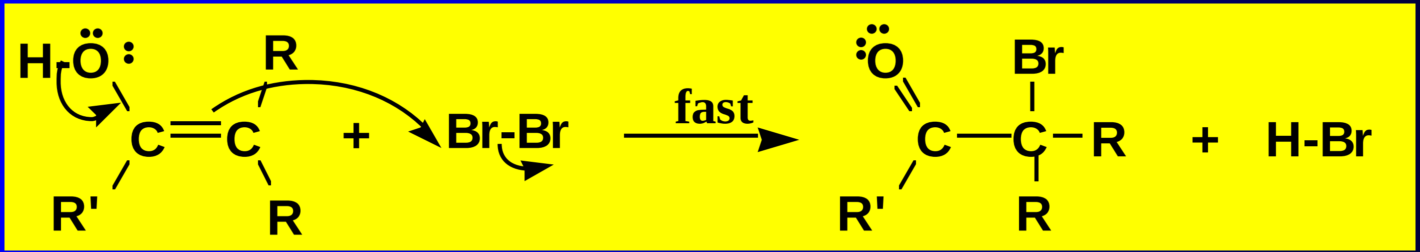
α-Halogenation

- Acid-catalyzed α-halogenation

  Step 1: acid-catalyzed enolization

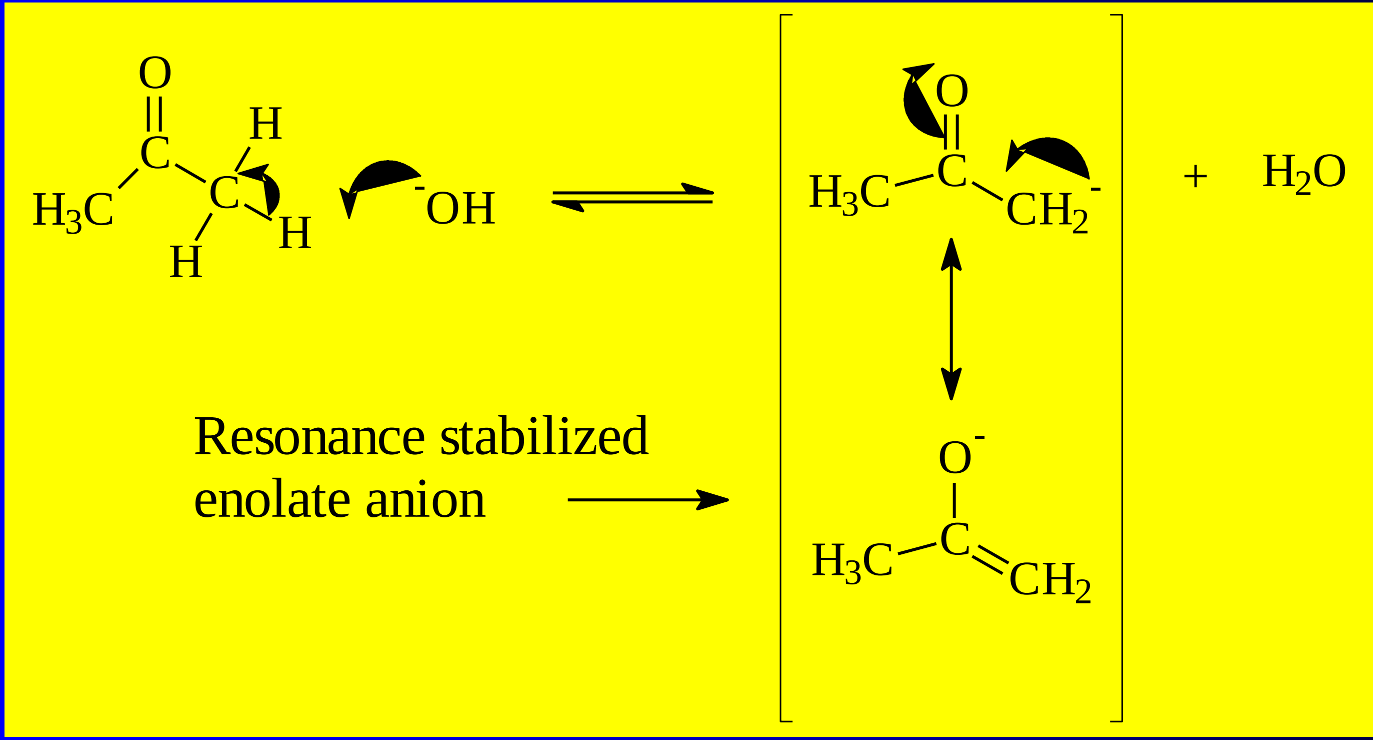


  Step 2: Nucleophilic attack of the enol on halogen

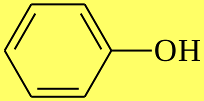
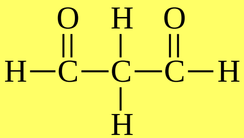


Enolate anions

Hydrogens α to carbonyls are "acidic"



pKa of some acids and some α protons

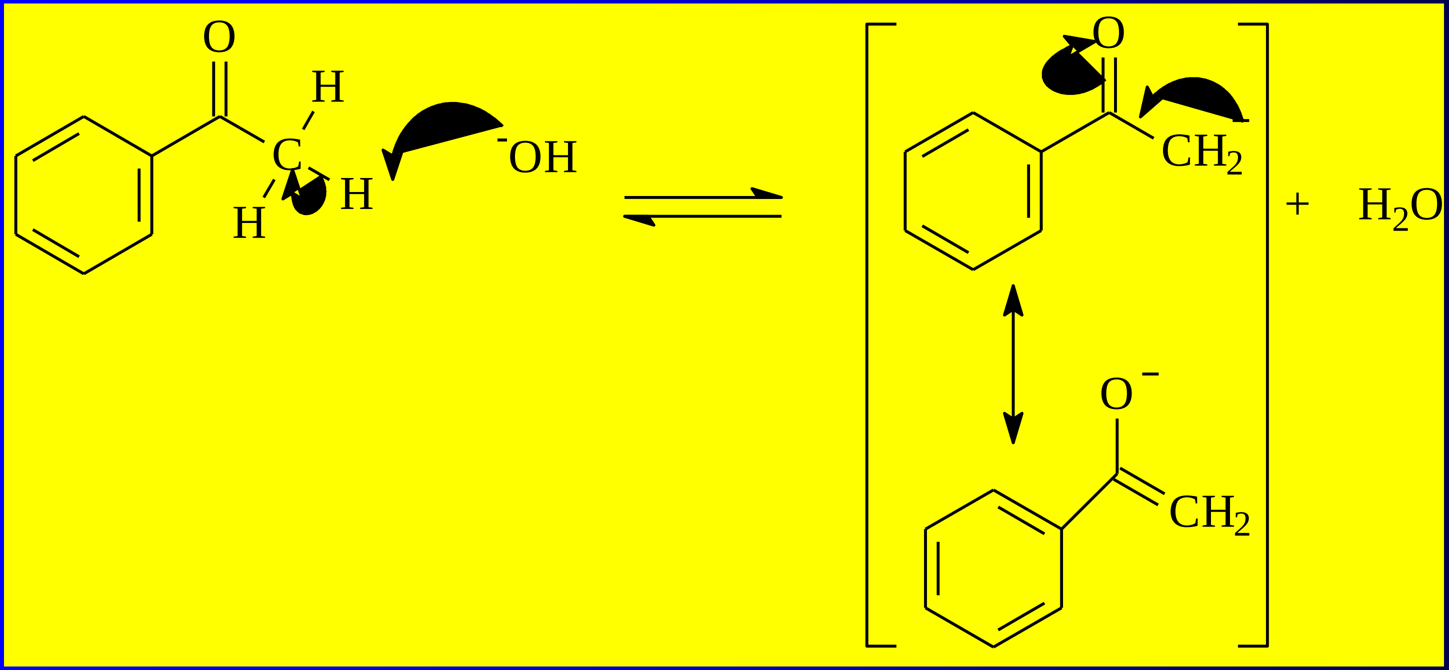
CH_3CO_2H	4.75
HF	3.45
HCl	-9.0!!
	10
	5.0
CH_3OH	16
$CH_3C(=O)CH_2C(=O)CH_3$	9
$CH_3C(=O)CH_3$	20
CH_3CH_3	50

A span of 59 powers of 10!!!

α-Halogenation

- Base-promoted α-halogenation

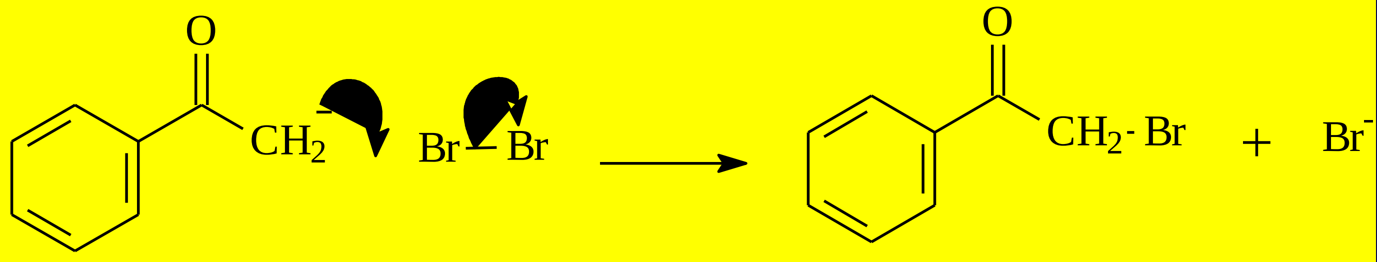
  Step 1: formation of an enolate anion



Base catalyzed α-Halogenation

- Base-promoted α-halogenation

  Step 2: nucleophilic attack of the enolate anion on halogen

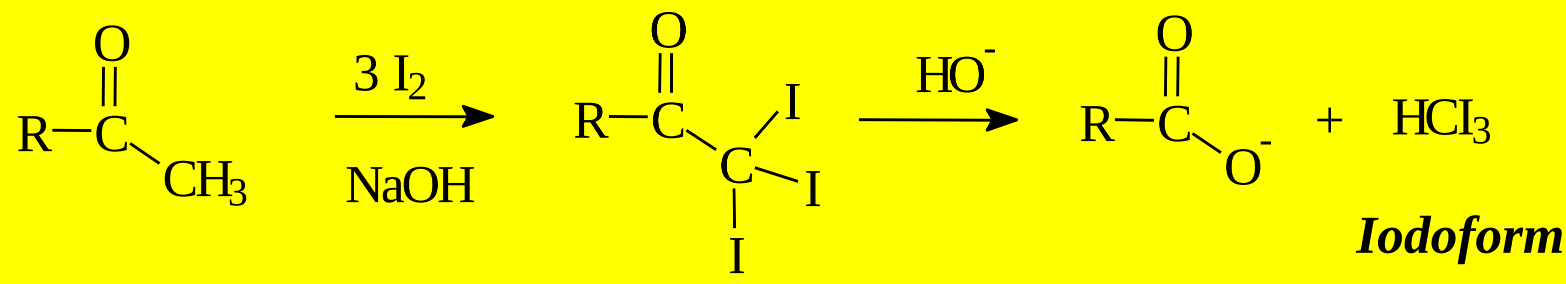


α-Halogenation

- In base catalyzed α-halogenation, *each successive halogenation is more rapid than the previous one*
  - the introduction of the electronegative halogen on the α-carbon increases the acidity of the remaining α-hydrogens and, thus, each successive α-hydrogen is removed more rapidly than the previous one

Haloform Reaction

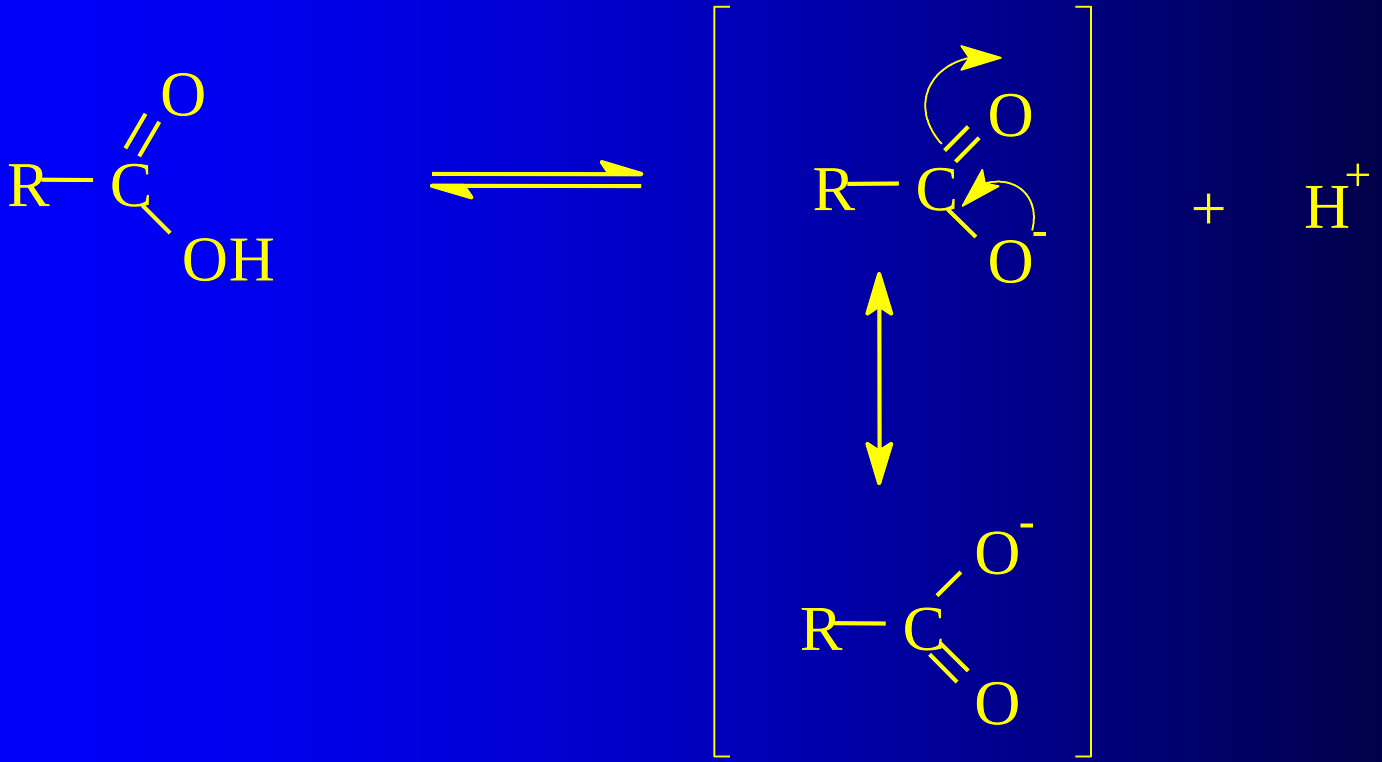
- Iodoform Reaction
- A qualitative test for <u>**methyl ketones**</u>
- A decent way to synthesize carboxylic acids



α-Halogenation

- There are *major* differences between acid-catalyzed and base-promoted α-halogenation
- Acid catalysis gives the most substituted product
- The rate of acid-catalyzed introduction of a second halogen is slower than the first
  - introduction of the electronegative halogen on the α-carbon decreases the basicity of the carbonyl oxygen toward protonation so monosubstitution is possible.
  - base promoted halogenation goes "all the way" because the product is more acidic than the starting material

Carboxylic Acids



Nomenclature – IUPAC ...

- IUPAC names: drop the -e from the parent alkane and add the suffix -oic acid
- If the compound contains a carbon-carbon double bond, change the infix -an- to -en-

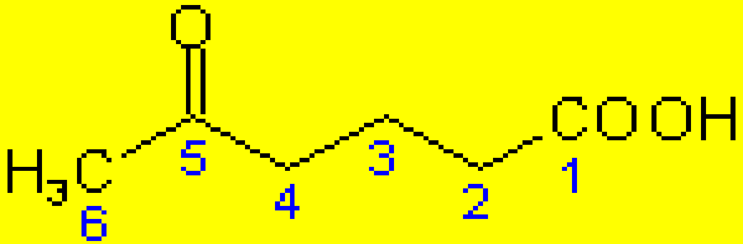
CH_4	Methane	Methanoic acid	Formic Acid
CH_3CH_3	Ethane	Ethanoic acid	Acetic acid
$CH_3CH_2CH_3$	Propane	Propanoic acid	Propionic acid
$CH_3CH_2CH_2CH_3$	Butane	Butanoic acid	Butyric acid

Alkanoic acids

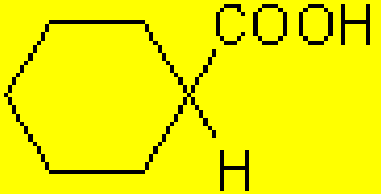
Formula	Common Name	Source	IUPAC Name	Melting Point	Boiling Point
HCO_2H	formic acid	ants (L. formica)	methanoic acid	8.4 ºC	101 ºC
CH_3CO_2H	acetic acid	vinegar (L. acetum)	ethanoic acid	16.6 ºC	118 ºC
$CH_3CH_2CO_2H$	propionic acid	milk (Gk. protus prion)	propanoic acid	-20.8 ºC	141 ºC
$CH_3(CH_2)_2CO_2H$	butyric acid	butter (L. butyrum)	butanoic acid	-5.5 ºC	164 ºC
$CH_3(CH_2)_3CO_2H$	valeric acid	valerian root	pentanoic acid	-34.5 ºC	186 ºC
$CH_3(CH_2)_4CO_2H$	caproic acid	goats (L. caper)	hexanoic acid	-4.0 ºC	205 ºC
$CH_3(CH_2)_5CO_2H$	enanthic acid	vines (Gk. oenanthe)	heptanoic acid	-7.5 ºC	223 ºC
$CH_3(CH_2)_6CO_2H$	caprylic acid	goats (L. caper)	octanoic acid	16.3 ºC	239 ºC
$CH_3(CH_2)_7CO_2H$	pelargonic acid	pelargonium (an herb)	nonanoic acid	12.0 ºC	253 ºC
$CH_3(CH_2)_8CO_2H$	capric acid	goats (L. caper)	decanoic acid	31.0 ºC	219 ºC

Naming acids

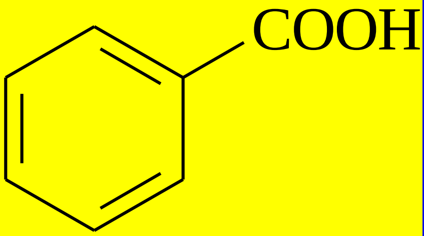
$CH_2{=}CH{\cdot}CH_3$ Propene Propenoic acid acrylic acid



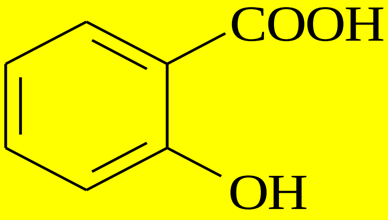
5-Oxohexanoic acid



Cyclohexanecarboxylic acid



Benzoic acid



2-hydroxybenzoic acid
Salicylic acid

Nomenclature-Common

- When common names are used, the letters α, β, γ, δ, etc. are often used to locate substituents

δ γ β α O (double-bonded to C-1)

C-C-C-C-C-OH

5 4 3 2 1

$HOCH_2CH_2CH_2CO_2H$

4-Hydroxybutanoic acid

(γ-Hydroxybutyric acid)

$CH_3CH(NH_2)CO_2H$

2-Aminopropanoic acid

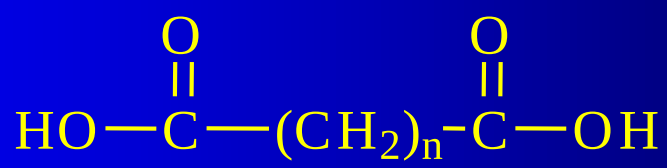
(α-Aminopropionic acid; Alanine)

Naming the Salts

- To name the salt of the carboxylic acid, name the cation followed by the name of the anion (two words).
- The anion is named by removing -oic acid and adding ate

Benzoic acid →	Sodium benzoate
Butyric acid →	Ammonium butyrate

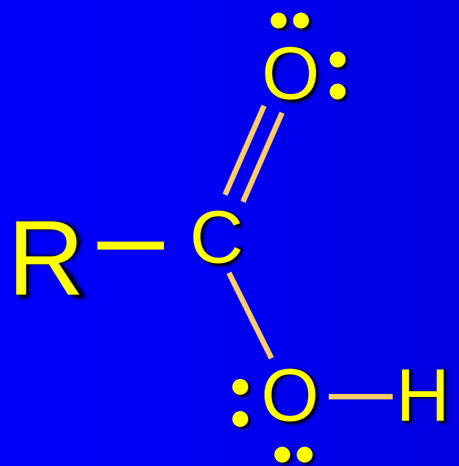
The Simple Dibasic Acids



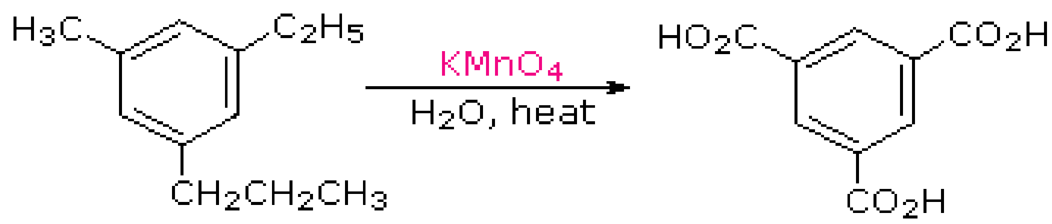
n	*Total C's*	*Name* (acid)
0	2	Oxalic
1	3	Malonic
2	4	Succinic
3	5	Glutaric
4	6	Adipic
5	7	P???


Sour Grass (Oxalis)

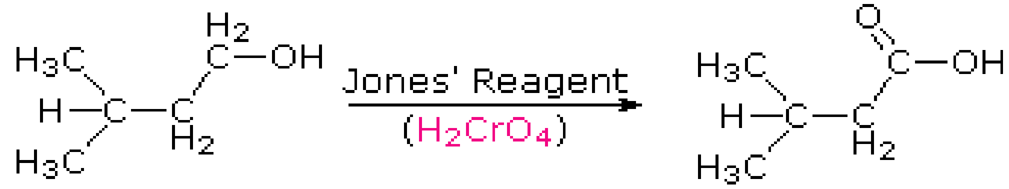
Synthesis of Carboxylic acids



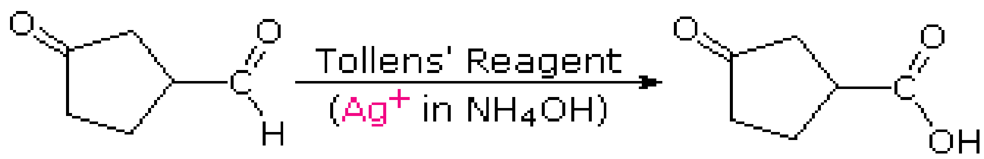
1. Oxidation of Arene Side-Chains



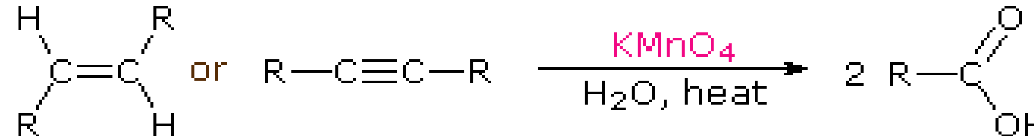
2. Oxidation of 1°-Alcohols



3. Oxidation of Aldehydes

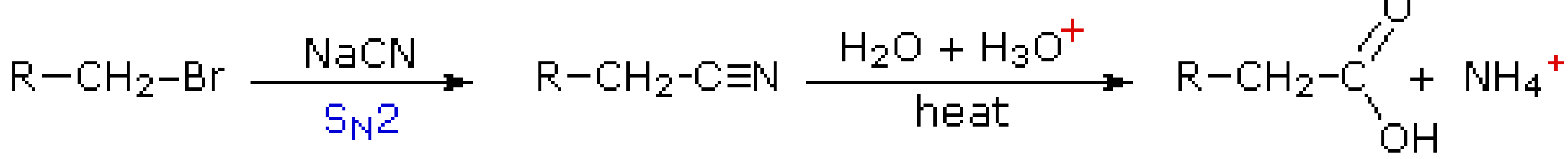


4. Oxidative Cleavage of Alkenes and Alkynes



Synthesis of Carboxylic acids

Hydrolysis of Nitriles



Carboxylation of Organometallic Reagents