

Ch 19 Aldehydes and Ketones

Aldehydes (RCHO), with the exception of formaldehyde (H₂CO), are compounds with both an H and an organic group attached to a carbonyl.

Ketones (R₂CO) are compounds with two organic groups attached to a carbonyl.

Naming Aldehydes

1. Replace final “e” of alkane parent with “al”, such as ethanal (acetaldehyde) and pentanal.
2. Number the C’s in the parent, starting with carbonyl as #1.
3. If CHO is the substituent on a ring, follow the parent name with “carbaldehyde”, such as cyclohexanecarbaldehyde and benzenecarbaldehyde (benzaldehyde).
4. Both “al” and “carbaldehyde” may be preceded with “di” if there are two.
5. If a double bond is present, the compound is an enal. The carbonyl is automatically #1, so precede “en” only with the number for the double bond.

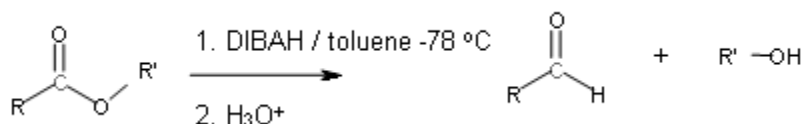
Naming Ketones

1. Replace final “e” of alkane parent with “one”, such as 2-propanone.
2. Number the C’s in the parent, starting with as the end that is closest to carbonyl as #1, such as 2-pentanone.
3. If RCO is the substituent on a ring, it is an acyl group.
For instance, CH₃CO is an acetyl group.
4. If there are two internal carbonyls, the compound is a dione, such as 2,4-pentanedione.
5. If there is an internal carbonyl as well as a terminal CHO, then the aldehyde is the parent. The internal carbonyl is an “oxo” substituent, and is numbered, such as 3-oxopentanal.
6. If a double bond is present, the compound is an enone.
Number both the “en” and the “one”, such as pent-3-en-2-one.

Preparation

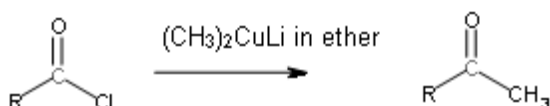
- PCC (pyridinium chlorochromate, or C₅H₅NH⁺CrO₃Cl⁻) will convert 1° alcohols to aldehydes without further oxidation to carboxylic acids.
- CrO₃ and Na₂Cr₂O₇ (in acid) will convert 1° alcohols to carboxylic acids and 2° alcohols to ketones. See chapter 17 ([Alcohols](#)).
- Cleavage of alkenes with 1. O₃ 2. Zn/CH₃COOH splits the double bond to create two carbonyl compounds. A vinyl C with an H will become an aldehyde carbonyl, while a vinyl C without an H will become a ketone carbonyl.
See chapter 8 ([Alkene Reactions](#)).

- Diisobutylaluminum hydride (DIBALH), where an isobutyl is $(\text{CH}_3)_2\text{CHCH}_2-$, is used in toluene over dry ice (-78°C), then followed with acid, to reduce an ester (RCOOR') to an aldehyde (without further reduction to an alcohol).



- Friedel-Crafts acylation can be used to create an alkyl aromatic ketone by combining an aromatic ring an acid chloride (RCOCl) and AlCl_3 . See chapter 16 ([Electrophilic Aromatic Substitution](#)).

- An acid chloride (RCOCl) can also be combined with a Gilman reagent (R_2CuLi) in ether to create a ketone.

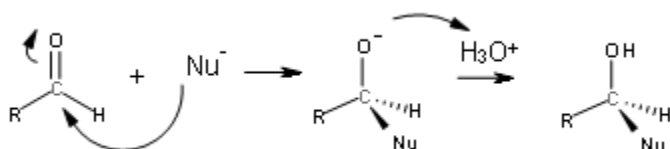


Oxidation

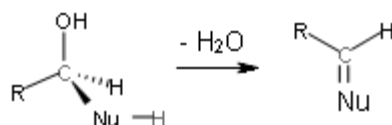
- Aldehydes (RCHO) can be oxidized easily to create carboxylic acids (RCOOH).
- Typically, CrO_3 is used with H_3O^{+1} in acetone and over ice (0°C). The intermediate is a 1,1-diol, which is called a hydrate.
- For acid-sensitive molecules, Ag_2O is used with NH_3 in water and ethanol. This is the Tollen's reagent, and is sometimes called the silver mirror test (for aldehydes) because the side-product is $\text{Ag}_{(s)}$.
- Ketones typically do not oxidize, although hot alkaline permanganate will cleave the molecule and convert both the carbonyl and one adjacent C to acid (RCOOH).

Nu Addition

- A Nu^- will attach to a carbonyl C (δ^+) at a 75° angle to the plane and create an alkoxide anion. This changes the carbonyl C to sp^3 hybridization.
- The alkoxide can be treated with H_3O^{+1} to convert it into an alcohol.



- If the Nu possesses an H, then the H can be removed along with the alcohol OH to create an alkene (or other Π bond) by dehydration.

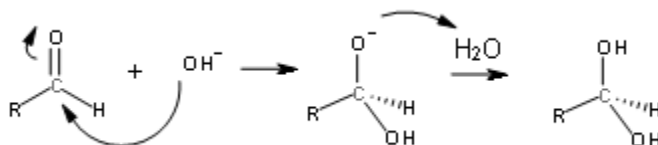


Relative Reactivity

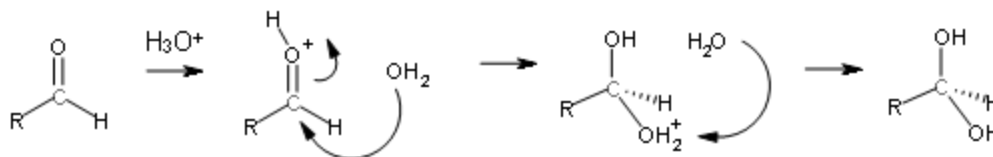
- Aldehydes are more reactive than ketones for both steric and electronic reasons.
- First, the H creates less steric hindrance so that the carbonyl C is more accessible.
- Second, an organic group provides e^{-1} donating induction which stabilizes the $\delta+$ carbonyl C and makes it less reactive.
- Formaldehyde is more reactive than the other aldehydes.
- Aromatic aldehydes and ketones are less reactive due to the e^{-1} donating resonance from the ring, which makes the carbonyl C less $\delta+$ and less reactive.

Nu Addition of Water

- H and OH can be reversibly added across the C=O with acid or base (catalysts) to create a 1,1-diol, such as formaldehyde hydrate: $H_2C(OH)_2$.
- Generally, the hydrate is not favored by equilibrium, such as with acetone hydrate (only 0.1% at eqm). Formaldehyde hydrate, however, is heavily favored (99.9%).
- In base, an OH^{-1} is added as the Nu to create an alkoxide anion. The alkoxide removes an H^{+1} from water to create the hydrate and an OH^{-1} .

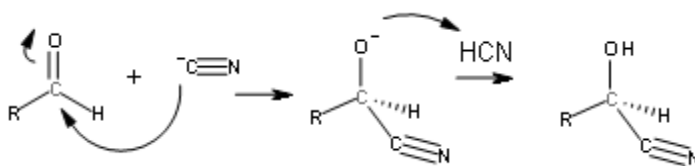


- In acid, the carbonyl O is protonated first, and the + charge make the carbonyl C more $\delta+$. Water is added to the C as the Nu. Then, a second water molecule removes the extra H to create the hydrate and an H_3O^{+1} .



Nu Addition of HCN

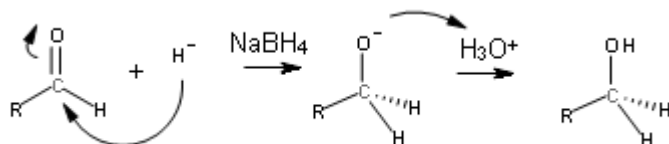
- H and $C\equiv N$ can be reversibly added across the C=O to create a cyanohydrin.
- $N\equiv C^{-1}$ is first added as the Nu to create an alkoxide.
- Then, HCN donates an H^{+1} to create the cyanohydrin.



- The nitrile group ($-C\equiv N$) can be further used a reagent. It can be either reduced to an amine ($-CH_2NH_2$) with $LiAlH_4$, or hydrolyzed to carboxylic acid ($-COOH$) with acid or base.

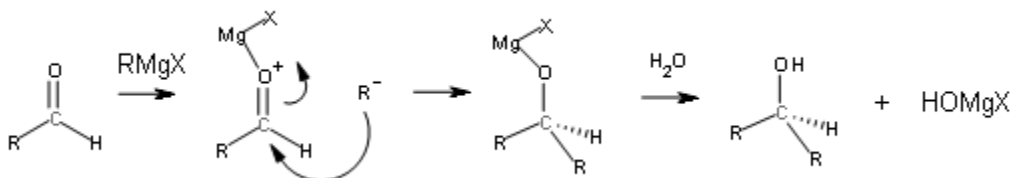
Nu Addition of Hydrides (NaBH₄)

- In the hydride reaction, H⁻¹ is first added as the Nu to create an alkoxide. Acid is then added to create a 1° or 2° alcohol.



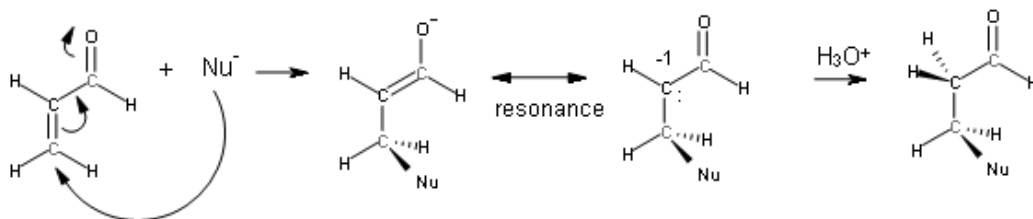
Nu Addition of Grignard Reagents (RMgX)

- The first step in the Grignard reaction is addition of MgX⁺¹ to the carbonyl O. The + charge makes the carbonyl C become more δ⁺ and a stronger nucleophile.
- Next, the carbanion (R⁻¹) is added to the C as the Nu.
- Finally, a water molecule will replace the MgX with an H to create a 2° or 3° alcohol and HOMgX.



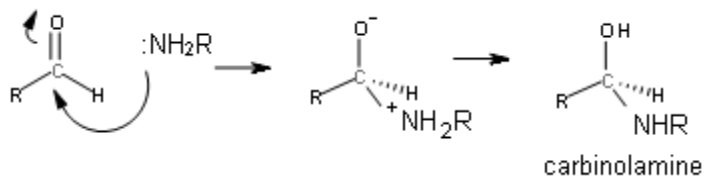
Conjugated Nu Addition

- A Nu can be added to a conjugated enone (C=C-C=O).
- However, many Nu's add preferentially to the β C rather than the carbonyl C.
- This results in an enolate intermediate (Nu-C=C-O⁻¹) rather than an alkoxide.
- This happens because the enolate is stabilized by resonance:
$$\text{C}=\text{C}-\text{O}^{-1} \leftrightarrow {}^{-1}\text{C}-\text{C}=\text{O}$$
- Adding H₃O⁺ will then protonate the anionic α C, to create a saturated carbonyl product.
- The carbonyl will remain, but there will be no C=C.
- Amines, water, and Gilman reagents (R₂CuLi) can be added as the Nu.

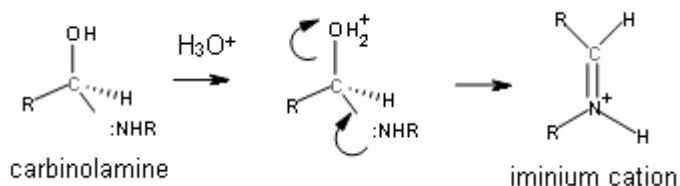


Nu Addition of Amines

- Both 1° and 2° amines (RNH₂ and R₂NH) can add to a carbonyl C as the Nu in a reversible acid-catalyzed reaction.
- Addition of RNH₂ results in an imine (R'₂C=NR), while addition of R₂NH results in an enamine (C=C-NR₂).
- After the amine adds to the carbonyl C and creates an alkoxide, an H moves from the N to the O to create a carbinolamine.



- The O is protonated again, this time with H₃O⁺.
- Water separates from the C to create an iminium anion (C=N⁺).



- If RNH₂ was added initially, the H remaining on the N can be removed from the iminium anion by water to create a neutral imine (R'₂C=NR).
- If R₂NH was added, there will be no H remaining on the N. An H will be removed from an adjacent C on the anion to create an enamine (C=C-NR₂).

