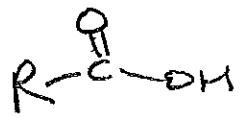
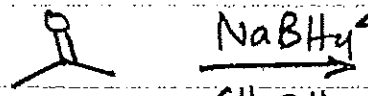
CHM 201 – Elements of Organic Chem – Dr. L. Stanley
Ch 13 Carboxylic Acids + Ch 14 Carb. Acid Derivatives



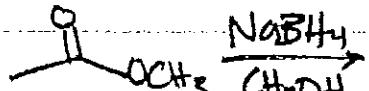
carboxylic acid (RCO_2H) * resonance stabilized

→ OH group donates e⁻ density to carbonyl
→ RCO_2H is more e⁻ rich than ket/ald
→ ket/ald more δ+ better E+

Note: difference in reactivity (B&P 13.5)

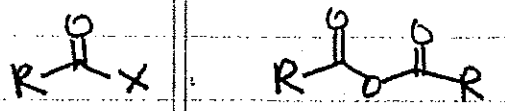


ketone — $NaBH_4$, CH_3OH ← less reactive than LAH

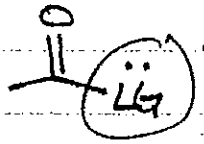


ester — $NaBH_4$, CH_3OH

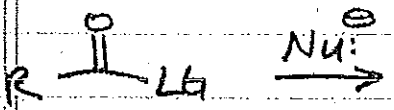
Carboxylic Acid Derivatives



acid halide (usu. X = Cl) | anhydride | ester | amide | nitrile

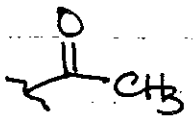
General Structure  ← an atom with lone pair(s) (a heteroatom – not C or H)

General Rxns of CA. Derivatives (14.2)

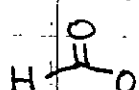


→ overall, a <u>substitution</u> rxn. (not S_N1/S_N2)
→ mech. called "addition-elimination"
→ has both acid- and base-catalyzed mechs.

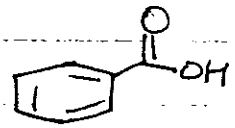
Nomenclature (13.2, 14.1)

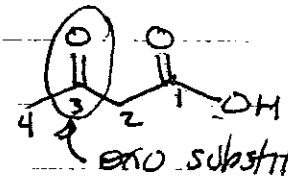
 = Acet- (Ac) Acetyl group

Ⓐ Carboxylic acids  (RCO_2H) "alkanoic acid"

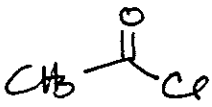

methanoic acid (formic acid)

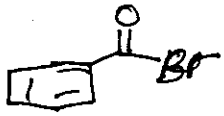

ethanoic acid (acetic acid) (AcOH, vinegar)

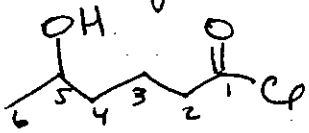

benzoic acid


3-oxobutanoic acid

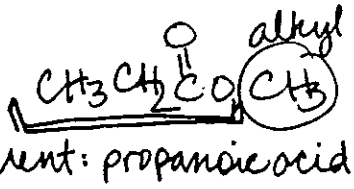
Ⓑ acid halides  ($RCOX$) "alkanoyl halides"

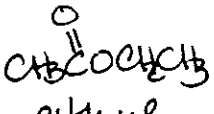

acetyl chloride (AcCl)


benzoyl bromide

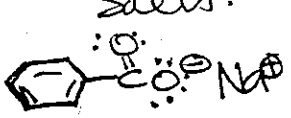

5-hydroxyhexanoyl chloride

Ⓒ esters  (RCO_2R') "alkyl alkanoate"

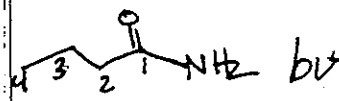

parent: propanoic acid — methyl propanoate

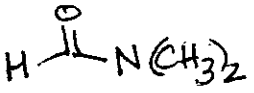

ethyl acetate

also for salts:


Sodium benzoate

Ⓓ amides  ($RCONH_2$) "alkanamide"

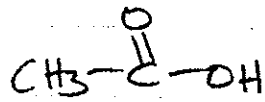

butanamide


N,N-dimethyl formamide (DMF)

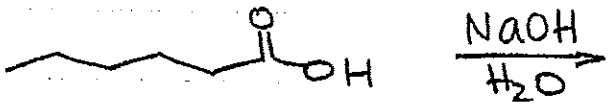
Draw (Z)-2-hexenoic acid

Draw isopropyl butanoate ("butyrate" common)

Physical Properties of Carboxylic Acids (13.3-13.4)



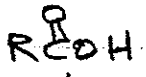
acetic acid (AcOH)



insoluble in neutral H_2O, but soluble in basic H_2O (aq NaOH)

Acidity of RCO_2H (20-4) → see pka Table 20-4
→ see Appendix 2 in Solutions Manual

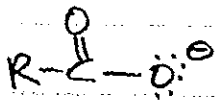
RCH_2OH —NaH→
alcohol (pka ~ 18)



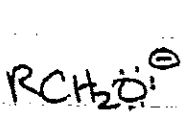
carb. acid (pka ~ 5)

*in basic conditions (HO^-/RO^-), RCO_2H becomes $RCO_2^{\ominus}$ *
19,000,000,009,000 times more acidic!!

Why are pka's so different? Look @ conj bases!



vs.

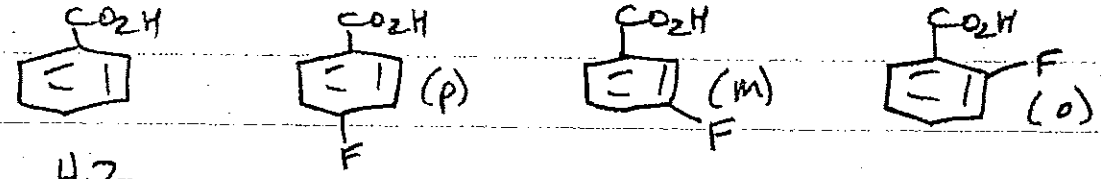


Something that stabilizes the conj. base will make a stronger acid

Which is the stronger acid? 13/14-4

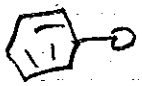
Ⓐ CH_3CO_2H vs. Ⓑ CF_3CO_2H

* Note: Inductive effects decrease with distance



pka 4.2

Common Acids (Table 2.2)

Strong acids pka < 0	Weak acids pka ~ 5	pka ~ 10	pka ~ 16
$H_3O^{\oplus}$	$R-CO_2H$	$RNH_3^{\oplus}$	ROH
$ROH_2^{\oplus}$			H_2O
completely dissociate in H_2O: HX, H_2SO_4, HNO_3			

Ka, pKa and pH, (2.3)

Ka, pKa: acidity of a compound

pH: acidity of a solution

$$HA + H_2O \rightleftharpoons H_3O^+ + A^-$$

HA: acid

$$K_{eq} = \frac{[products]}{[reactants]}$$

K_{eq}: equilibrium constant

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

K_a: acid dissoc. constant

$$pK_a = -\log K_a$$

↑ Ka (>1) = stronger acid

↓ pKa = stronger acid

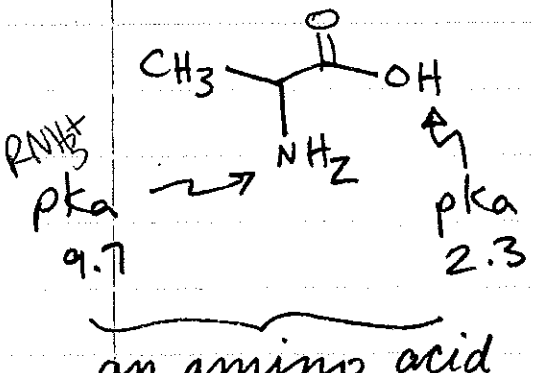
$$pH = -\log[H_3O^+]$$

pH scale: 0 — 7 — 14

H+ available

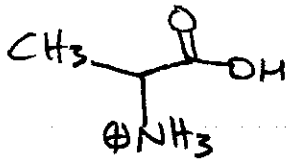
H+ gets removed

FYI: How does pH of a solution affect structure?



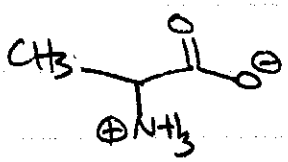
an amino acid

@ low pH

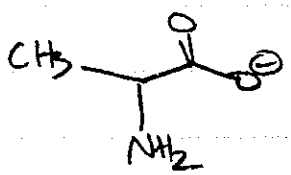


everything is protonated

@ pH 7.3 (body)



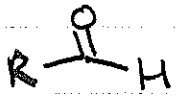
@ high pH



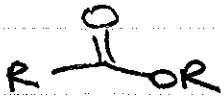
everything is deprotonated

Relative reactivities of carbonyls (14.6)

* All C=O groups are electrophiles ($E^{\oplus}$)
* Some are more reactive (better $E^{\oplus}$) than others - depends on what groups are attached to carbonyl

aldehyde 

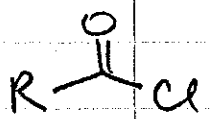
Ketone 

ester 

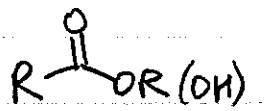
amide 

amide carbonyl is most electron-_____ (poor E^{+}, unreactive)

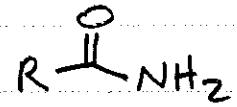
Carboxylic Acid Deriv: Overall order of electrophilicity (based on leaving group ability!)



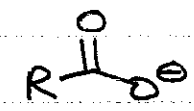
acid chlorides



ester (acid)



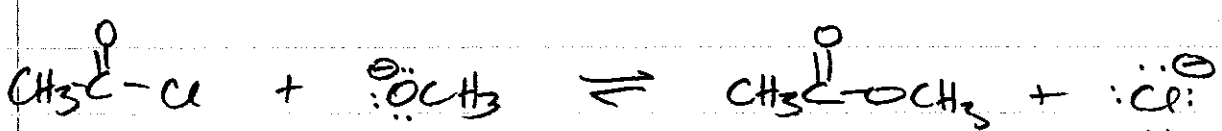
amide



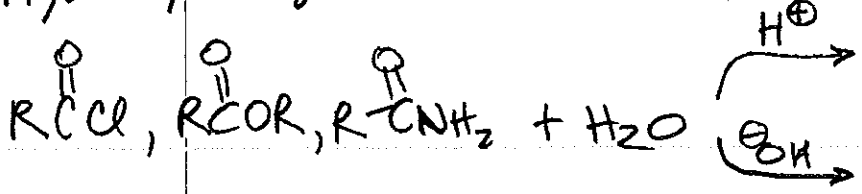
carboxylate

LG:

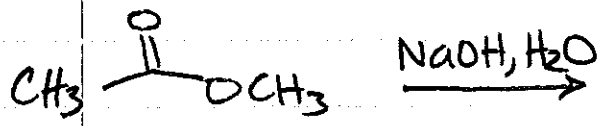
CA. Derivative Interconversion



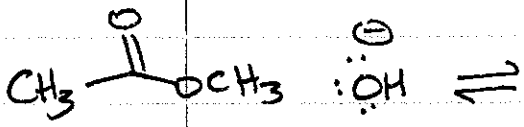
Hydrolysis of Carb. Acid Derivs. (14.3)



Base-promoted Ester Hydrolysis (saponification - makes soap)

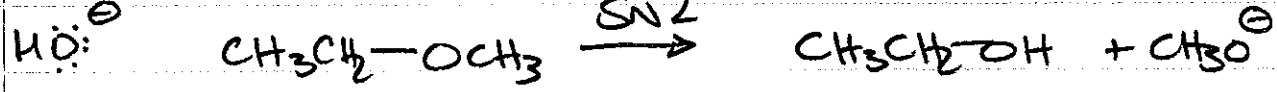


mechanism

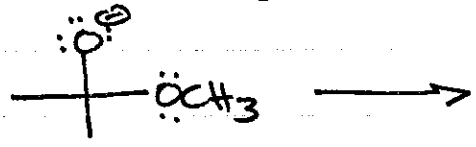


Overall, a substitution reaction LG → Nu Nu =
LG =

* $RO^{\ominus}$ (alkoxide) is a bad LG for S_N1/S_N2



* $RO^{\ominus}$ is an okay LG for collapse of CTI!



charged tetrahedral intermediate (CTI)

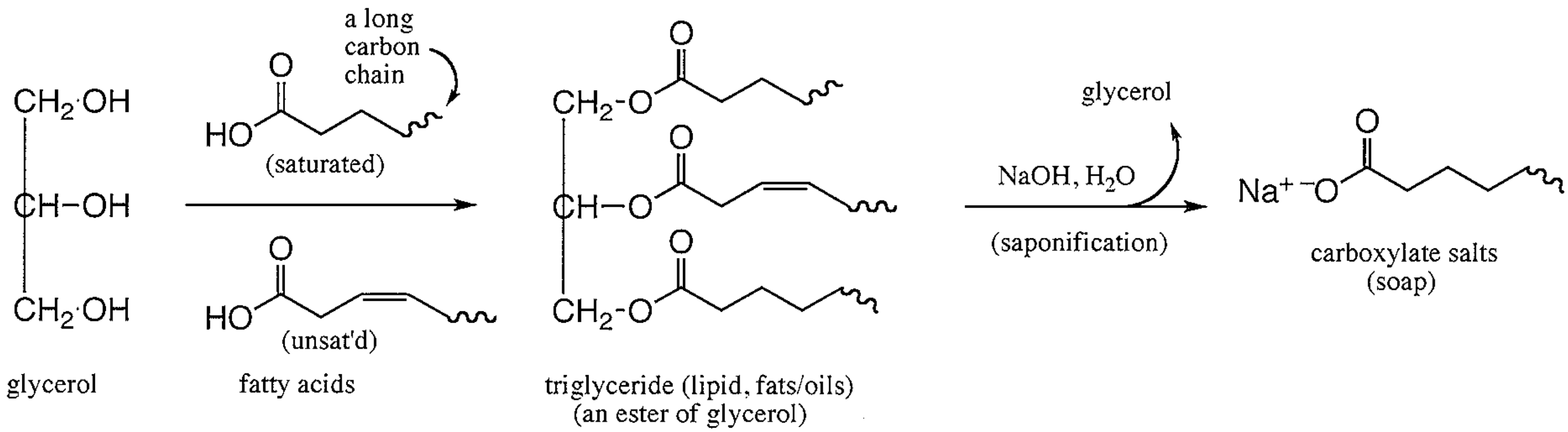
How is this reaction used to make soap?

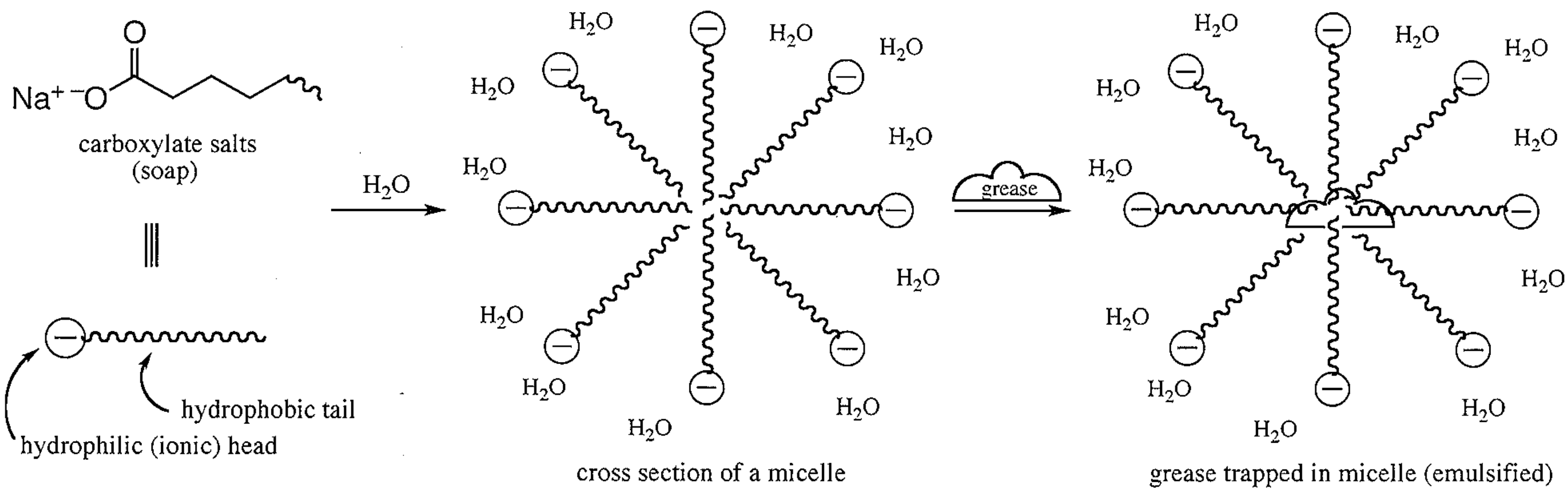
History: Animal fat + wood ash $\xrightarrow[\Delta]{H_2O}$ soap!

California State Polytechnic University, Pomona

Dr. Laurie S. Starkey, Organic Chemistry CHM 316

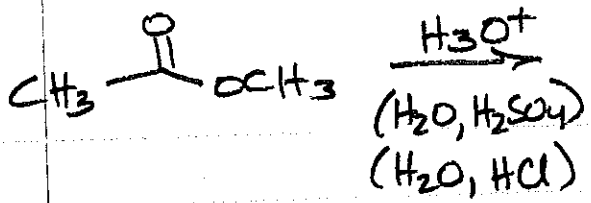
Applications of Carboxylic Acid Derivatives: Saponification Reaction



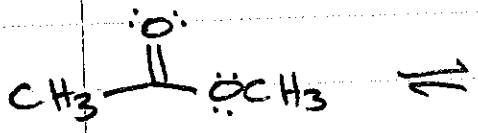


13/14 - 8

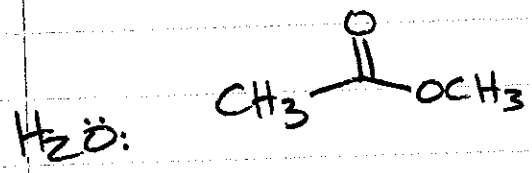
Ester Hydrolysis: Acid-catalyzed mechanism 13/14-9



Mechanism 1st step?



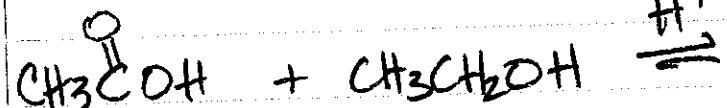
*Need acid or base for reaction to occur (can't both be neutral)



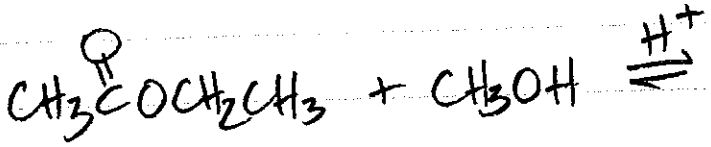
in base:
strong Nu:

in acid:
strong E^+

Fischer Esterification Reaction (13.6)



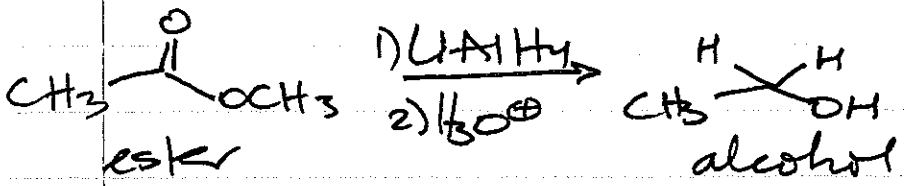
Transesterification Reaction



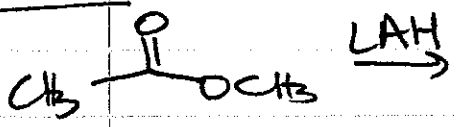
III Reactions of Grignard + Hydride with Esters 13/14-10

A) Hydride Nu (13.5, 14.8) $LiAlH_4$ needed ($NaBH_4$ N/R w/esters)

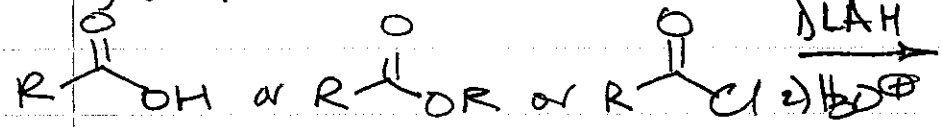
(why CH_3CO_2R less reactive than CH_3COR?)

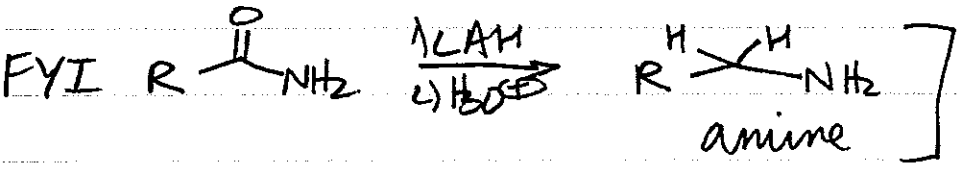


mechanism



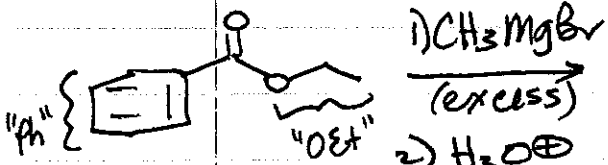
Summary of Hydride Reductions



[FYI 

]

B) Grignard Nu: (14.7)



Predict: