

# The Carbonyl Functional Group: Reactivity

# Learning Outcomes

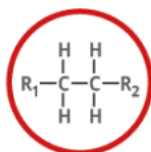
1. Describe why the carbonyl carbon is reactive
2. Evaluate the mechanism for ester hydrolysis and why the products gives soap!
3. Describe how soaps and detergents work.

# Common Functional Groups

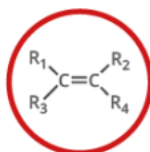
## FUNCTIONAL GROUPS IN ORGANIC CHEMISTRY

FUNCTIONAL GROUPS ARE GROUPS OF ATOMS IN ORGANIC MOLECULES THAT ARE RESPONSIBLE FOR THE CHARACTERISTIC CHEMICAL REACTIONS OF THOSE MOLECULES. IN THE GENERAL FORMULAE SHOWN BELOW FOR EACH FUNCTIONAL GROUP, 'R' REPRESENTS THE REST OF THE MOLECULE, AND 'X' REPRESENTS ANY HALOGEN ATOM.

● HYDROCARBONS ● SIMPLE OXYGEN HETEROATOMICS ● HALOGEN HETEROATOMICS ● CARBONYL COMPOUNDS ● NITROGEN-BASED ● SULFUR-BASED ● AROMATIC



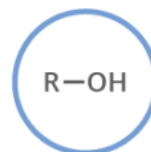
**ALKANE**  
Naming: -ane  
e.g. ethane



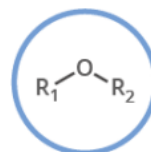
**ALKENE**  
Naming: -ene  
e.g. ethene



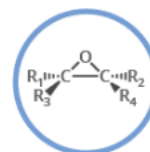
**ALKYNE**  
Naming: -yne  
e.g. ethyne



**ALCOHOL**  
Naming: -ol  
e.g. ethanol



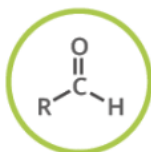
**ETHER**  
Naming: -oxy -ane  
e.g. methoxyethane



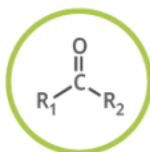
**EPOXIDE**  
Naming: -ene oxide  
e.g. ethene oxide



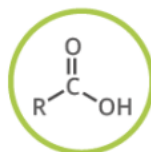
**HALOALKANE**  
Naming: halo-  
e.g. chloroethane



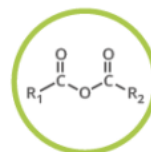
**ALDEHYDE**  
Naming: -al  
e.g. ethanal



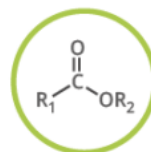
**KETONE**  
Naming: -one  
e.g. propanone



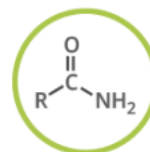
**CARBOXYLIC ACID**  
Naming: -oic acid  
e.g. ethanoic acid



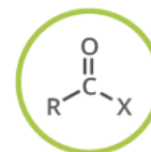
**ACID ANHYDRIDE**  
Naming: -oic anhydride  
e.g. ethanoic anhydride



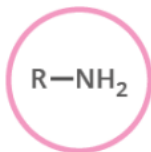
**ESTER**  
Naming: -yl -oate  
e.g. ethyl ethanoate



**AMIDE**  
Naming: -amide  
e.g. ethanamide



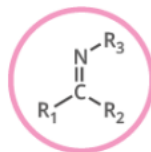
**ACYL HALIDE**  
Naming: -oyl halide  
e.g. ethanoyl chloride



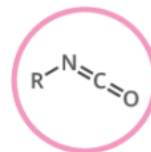
**AMINE**  
Naming: -amine  
e.g. ethanamine



**NITRILE**  
Naming: -nitrile  
e.g. ethanenitrile



**IMINE**  
Naming: -imine  
e.g. ethanimine



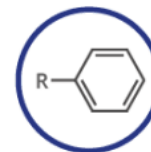
**ISOCYANATE**  
Naming: -yl isocyanate  
e.g. ethyl isocyanate



**AZO COMPOUND**  
Naming: -azo  
e.g. azoethane

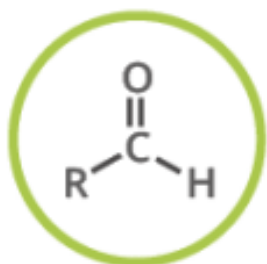


**THIOL**  
Naming: -thiol  
e.g. methanethiol

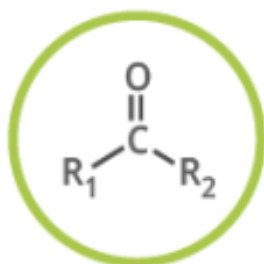


**ARENE**  
Naming: -yl benzene  
e.g. ethyl benzene

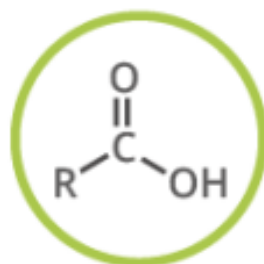
# Carbonyl Compounds for CHEM 60



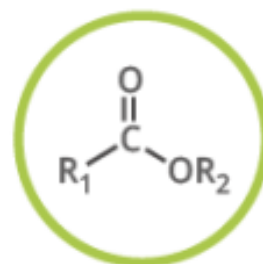
**ALDEHYDE**  
Naming: *-al*  
e.g. ethanal



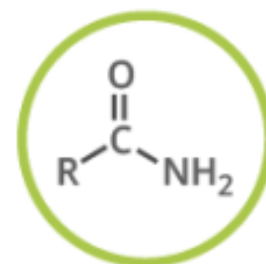
**KETONE**  
Naming: *-one*  
e.g. propanone



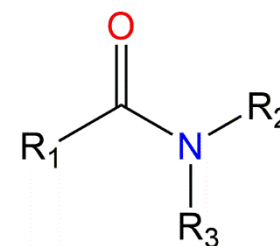
**CARBOXYLIC ACID**  
Naming: *-oic acid*  
e.g. ethanoic acid



**ESTER**  
Naming: *-yl -oate*  
e.g. ethyl ethanoate

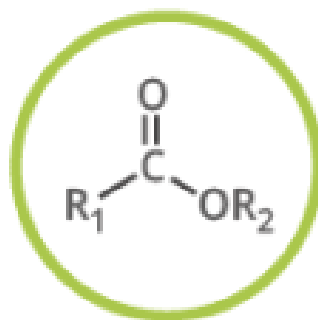


**AMIDE**  
Naming: *-amide*  
e.g. ethanamide



Amide

# Esters

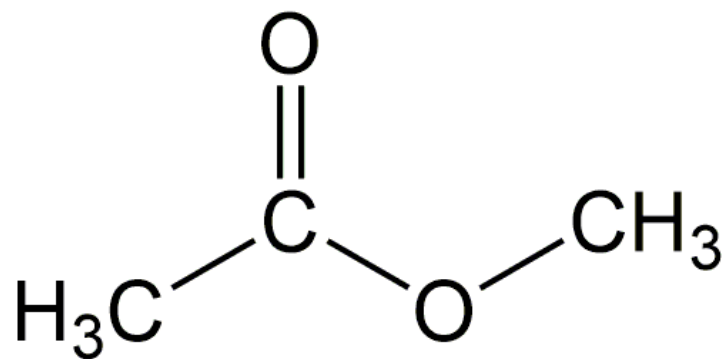
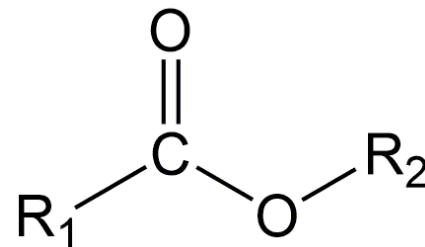


**ESTER**

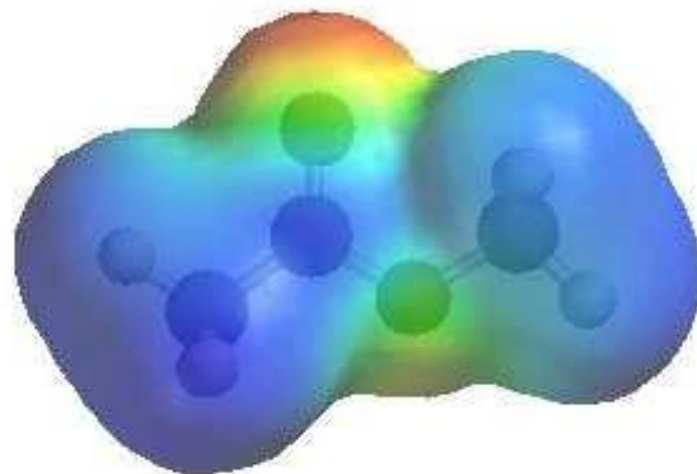
*Naming: -yl -oate*  
e.g. ethyl ethanoate

# Reactions of Esters

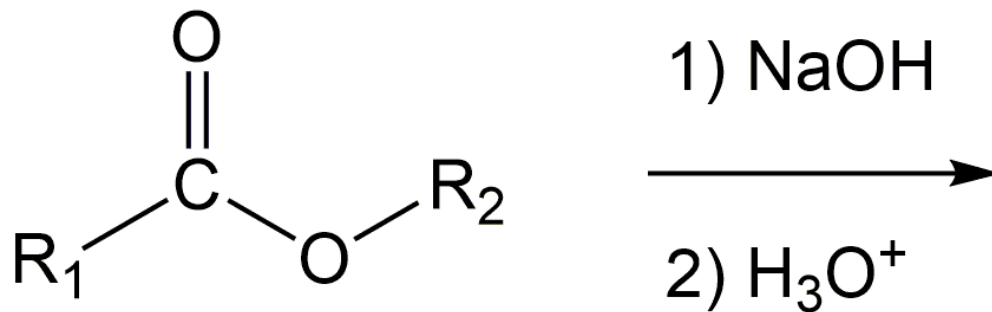
Are esters electrophilic?



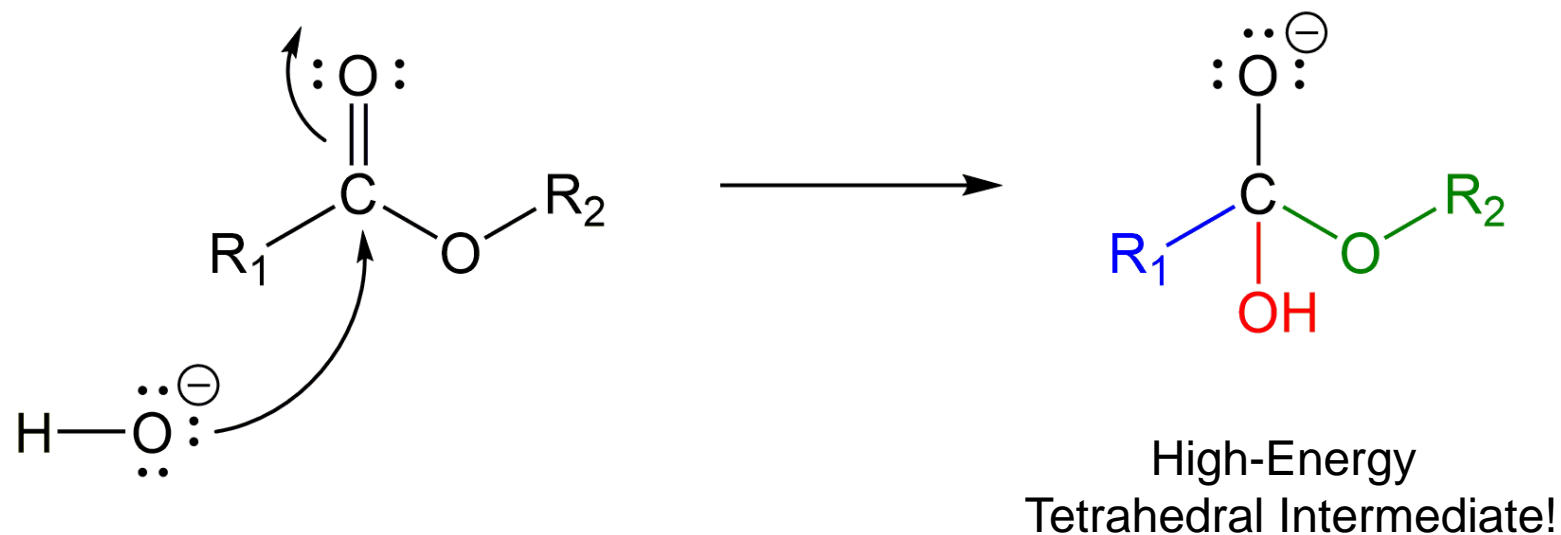
Methyl Ethanoate



# Saponification of Esters

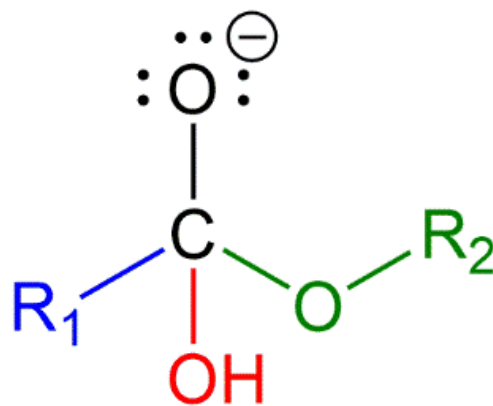


# Saponification of Esters





# Saponification of Esters: What Happens Next?

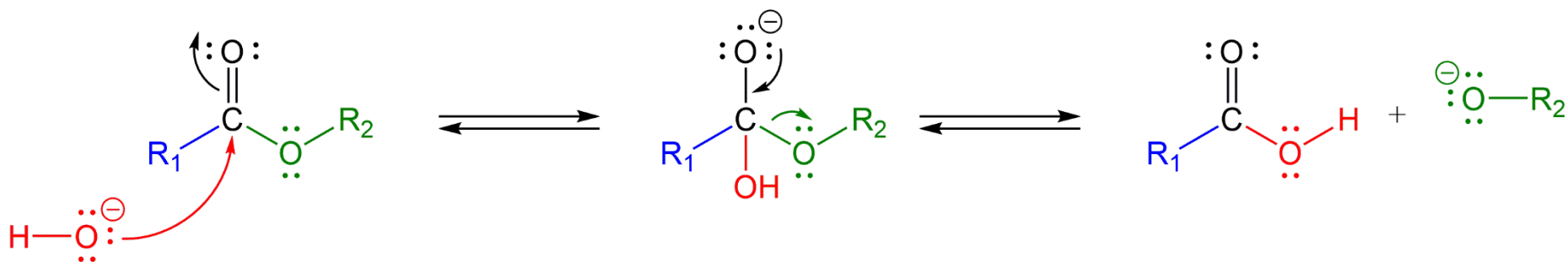


# Revisit pK<sub>a</sub> Table

**Recall that weaker bases are better leaving groups.**

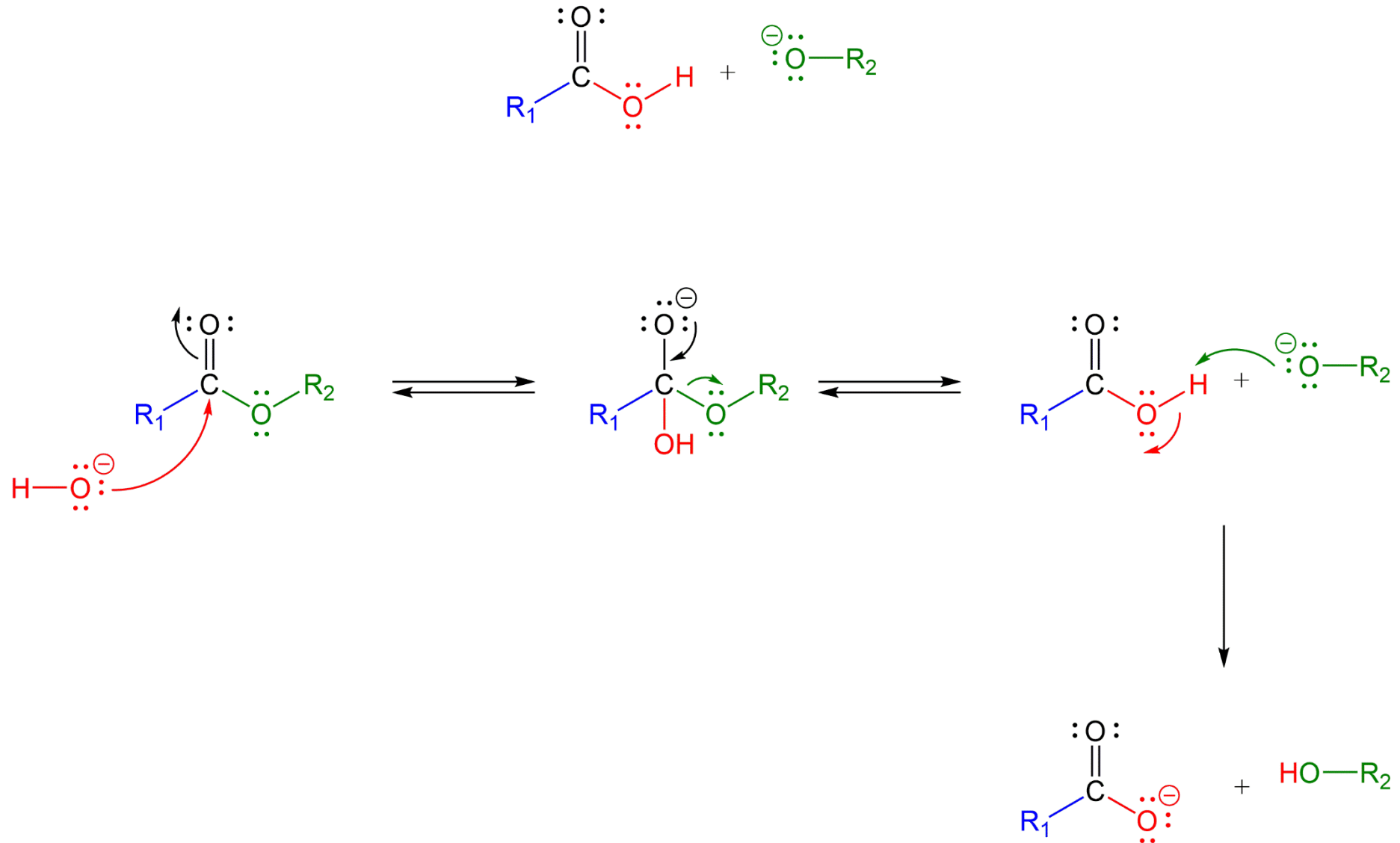
Hydrofluoric acid	$\text{H-F}$	3.2	$\text{F}^{\ominus}$	<b>Exception:</b> $\text{F}^{\ominus}$ is typically an extremely poor leaving group (forms strong bonds to carbon)	$\text{HO}-\overset{\text{:O:}}{\parallel}{\text{C}}-\text{O}-\text{R}_2 + \text{:R}_1^{\ominus}$
Carboxylic acids	$\text{H}_3\text{C}-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$	4	$\text{H}_3\text{C}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}^{\ominus}$		<b>Moderate leaving groups (weak bases)</b>
Protonated amines	$\text{NH}_4^{\oplus} \text{Cl}^{\ominus}$	9-11	$\text{NH}_3$	<b>Poor leaving groups (strong bases)</b>	
Water	$\text{HO}-\text{H}$	14	$\text{HO}^{\ominus}$		
Alcohols	$\text{CH}_3\text{O}-\text{H}$	16-18	$\text{CH}_3\text{O}^{\ominus}$	<b>Extremely poor leaving groups (very strong bases)</b>	$\text{R}_1-\overset{\text{:O:}}{\parallel}{\text{C}}-\text{OH} + \text{:OR}_2^{\ominus}$
Amine	$\text{NH}_3$	~35	$\text{NH}_2^{\ominus}$		
Hydrogen	$\text{H}-\text{H}$	42	$\text{H}^{\ominus}$		
Alkane	$\text{H}_3\text{C}-\text{CH}_2-\text{CH}_2-\text{CH}_3$	~50	$\text{H}_3\text{C}-\text{CH}_2-\text{CH}_2-\text{CH}_2^{\ominus}$		

# Saponification Is An Equilibrium Reaction

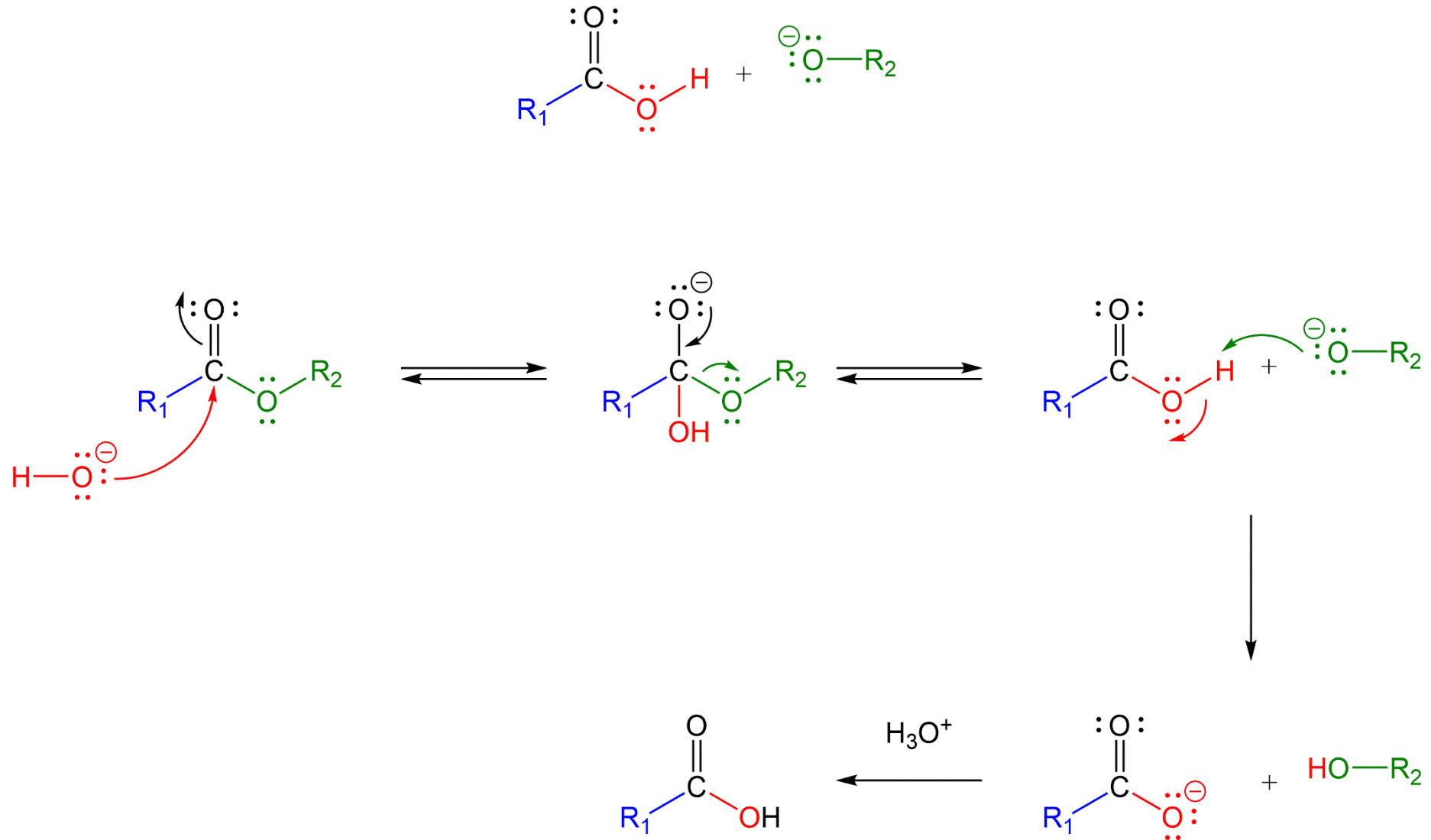


***Hydroxide is a suitable leaving group in basic conditions.***

# Saponification: Are We Done??

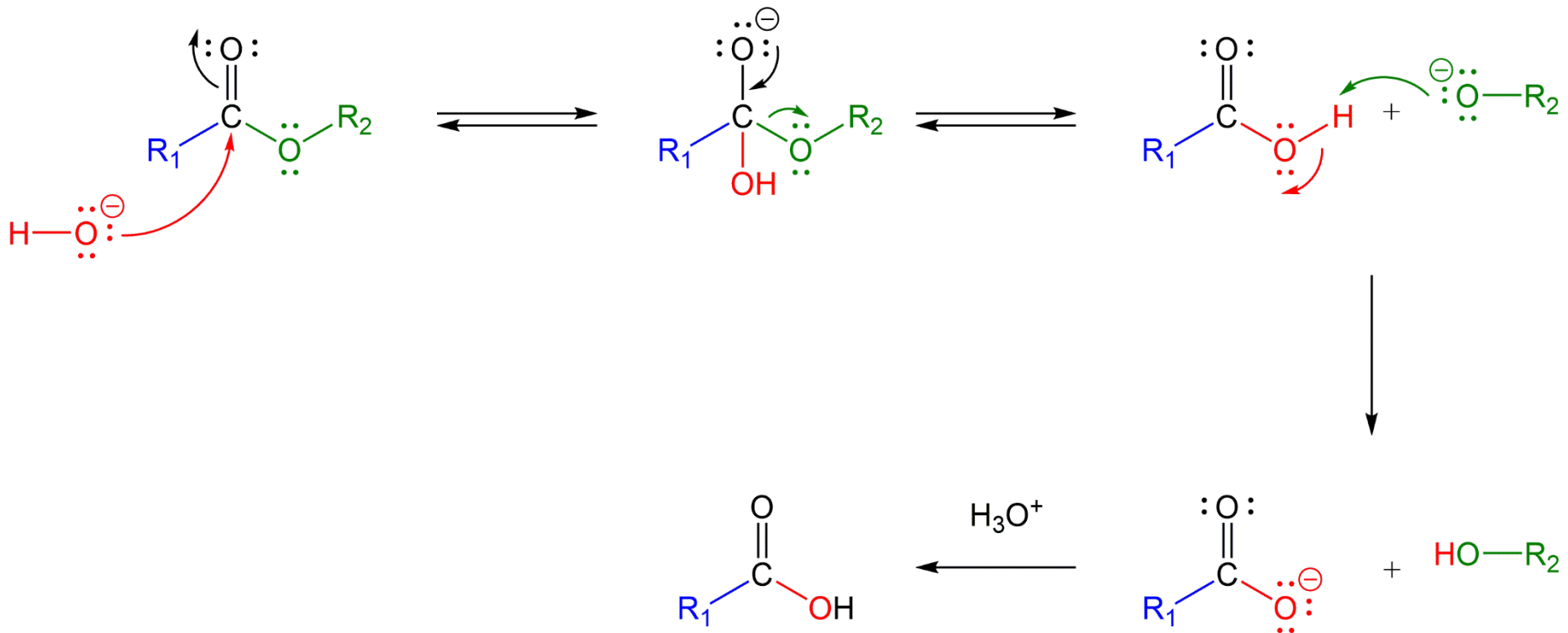
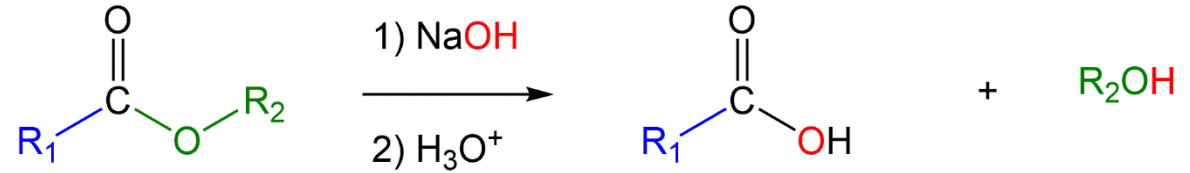


# Saponification: Acid Workup



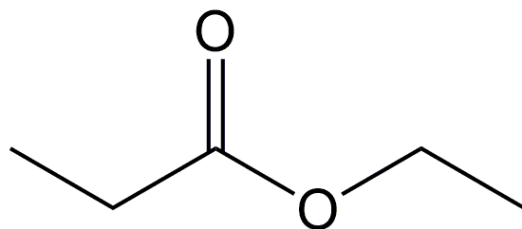
# Saponification: Overall Reaction

Overall Reaction:

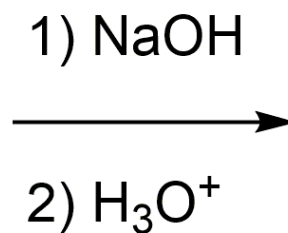


# Problem 1

What is the product for the following reaction?

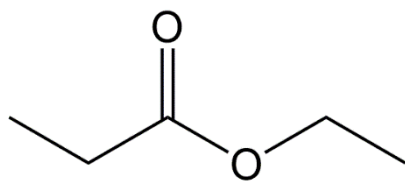
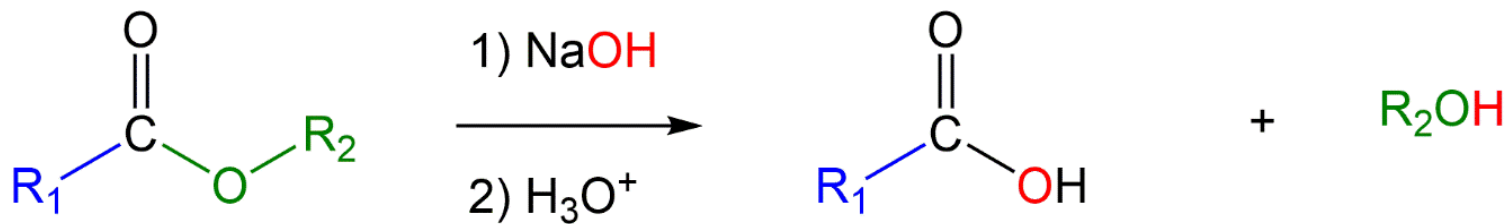


Ethyl Propanoate

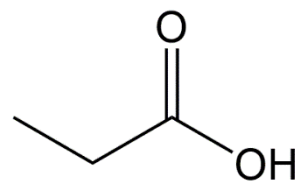
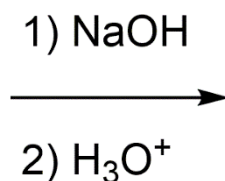


# Problem 1 - Solutions

What is the product for the following reaction?

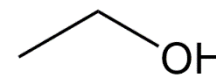


Ethyl Propanoate



Propanoic Acid

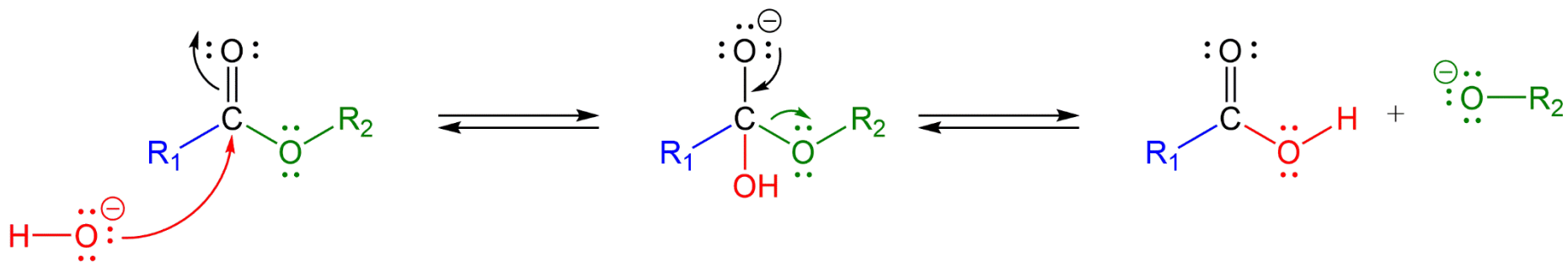
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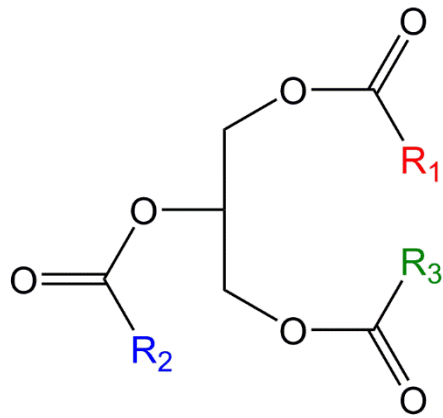
Ethanol



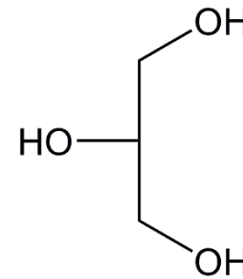
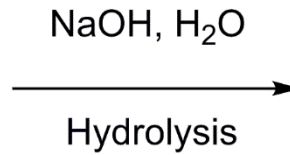
# What if We Don't Add Acid And Just Do The First Saponification Step?



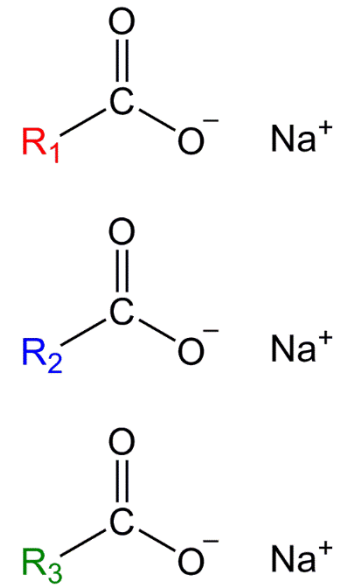
# Production of Soap!



Triacylglycerol



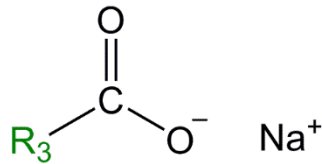
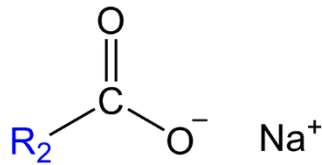
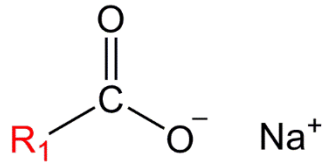
Glycerol



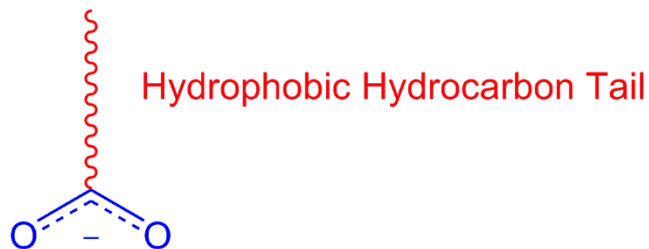
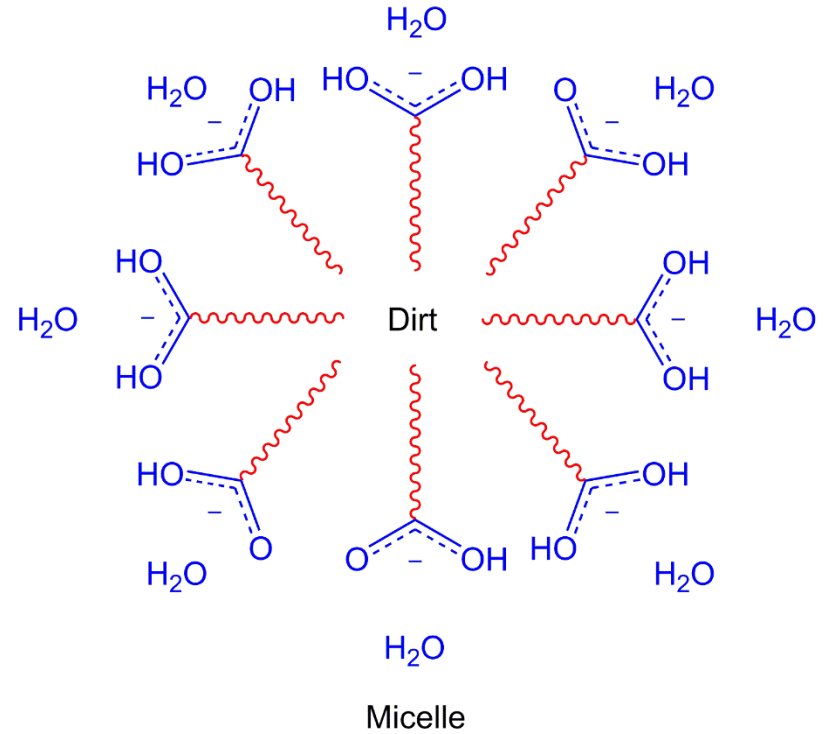
Carboxylate Anions

**Soap!**

# Soap is a Mixture of Carboxylate Anions!



Carboxylate Anions



Hydrophilic COO<sup>-</sup> Head

