

# The Carbonyl Functional Group: Structure

# Learning Outcomes

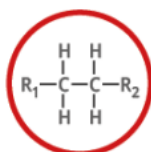
1. Classify a carbonyl compound as either an aldehyde, ketone, carboxylic acid, ester, or amide
2. Note, by example, that heteroatom derivatives are common in biology
3. Describe ketosis in your own authentic voice and state what ketone bodies are
4. Recognize the role of esters as scents and flavoring agents
5. At Home: Use homework questions to investigate the physical properties of carbonyl compounds.

# Common Functional Groups

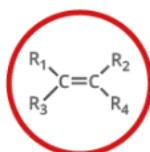
## FUNCTIONAL GROUPS IN ORGANIC CHEMISTRY

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.

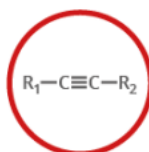
● HYDROCARBONS ● SIMPLE OXYGEN HETEROATOMICS ● HALOGEN HETEROATOMICS ● CARBONYL COMPOUNDS ● NITROGEN-BASED ● SULFUR-BASED ● AROMATIC



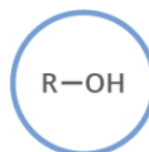
**ALKANE**  
Naming: -ane  
e.g. ethane



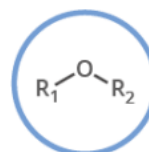
**ALKENE**  
Naming: -ene  
e.g. ethene



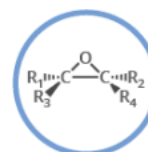
**ALKYNE**  
Naming: -yne  
e.g. ethyne



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



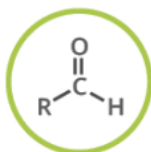
**ETHER**  
Naming: -oxy-ane  
e.g. methoxyethane



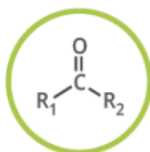
**EPOXIDE**  
Naming: -ene oxide  
e.g. ethene oxide



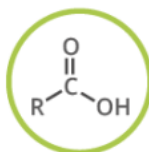
**HALOALKANE**  
Naming: halo-  
e.g. chloroethane



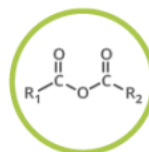
**ALDEHYDE**  
Naming: -al  
e.g. ethanal



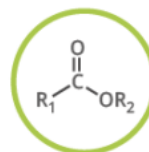
**KETONE**  
Naming: -one  
e.g. propanone



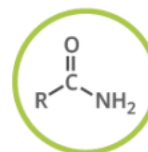
**CARBOXYLIC ACID**  
Naming: -oic acid  
e.g. ethanoic acid



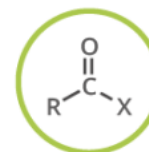
**ACID ANHYDRIDE**  
Naming: -oic anhydride  
e.g. ethanoic anhydride



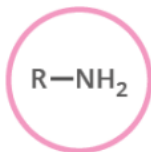
**ESTER**  
Naming: -yl -oate  
e.g. ethyl ethanoate



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



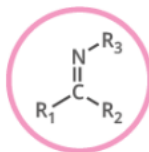
**ACYL HALIDE**  
Naming: -oyl halide  
e.g. ethanoyl chloride



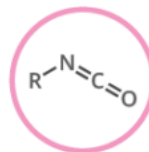
**AMINE**  
Naming: -amine  
e.g. ethanamine



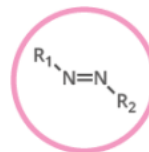
**NITRILE**  
Naming: -nitrile  
e.g. ethanenitrile



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



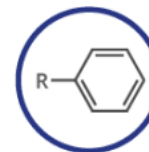
**ISOCYANATE**  
Naming: -yl isocyanate  
e.g. ethyl isocyanate



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



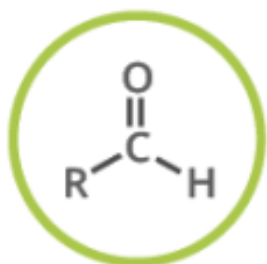
**THIOL**  
Naming: -thiol  
e.g. methanethiol



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

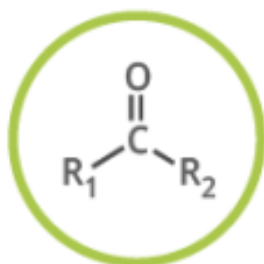


# Carbonyl Compounds for CHEM 60



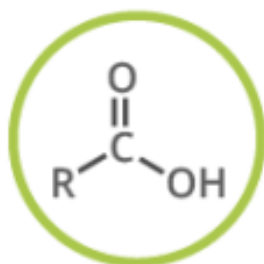
**ALDEHYDE**

Naming: -al  
e.g. ethanal



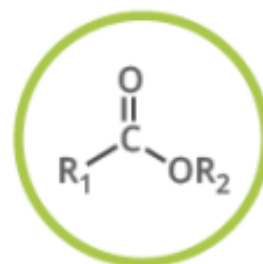
**KETONE**

Naming: -one  
e.g. propanone



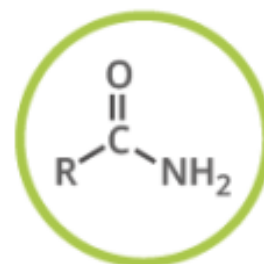
**CARBOXYLIC ACID**

Naming: -oic acid  
e.g. ethanoic acid



**ESTER**

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

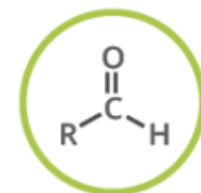


**AMIDE**

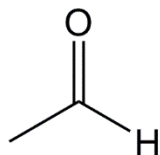
Naming: -amide  
e.g. ethanamide

# Some Common Aldehydes

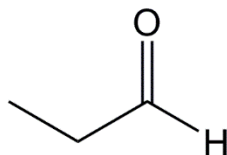
Aldehydes are often used in fragrances



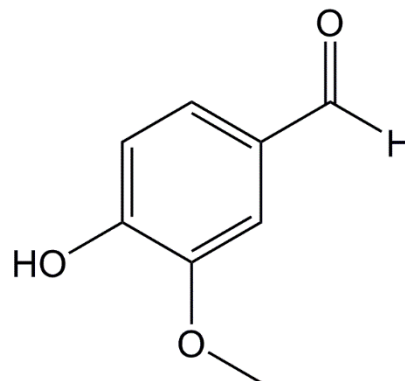
ALDEHYDE  
Naming: -al  
e.g. ethanal



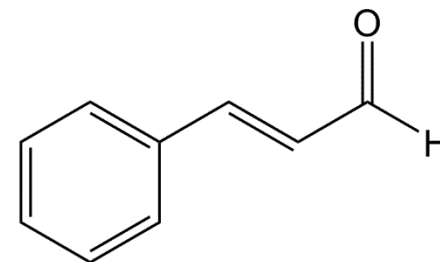
Formaldehyde



Acetaldehyde



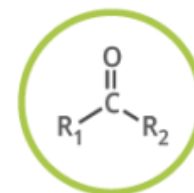
Vanillin



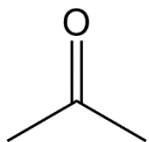
Cinnamaldehyde

# Some Common Ketones

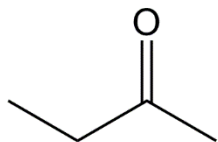
Ketones are often used as solvents, pharmaceuticals, and precursors to polymers.



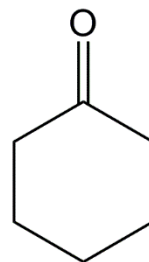
KETONE  
Naming: -one  
e.g. propanone



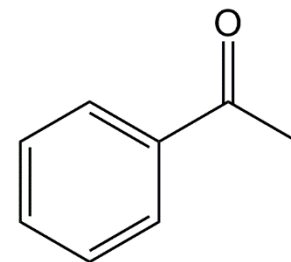
Acetone



Butanone

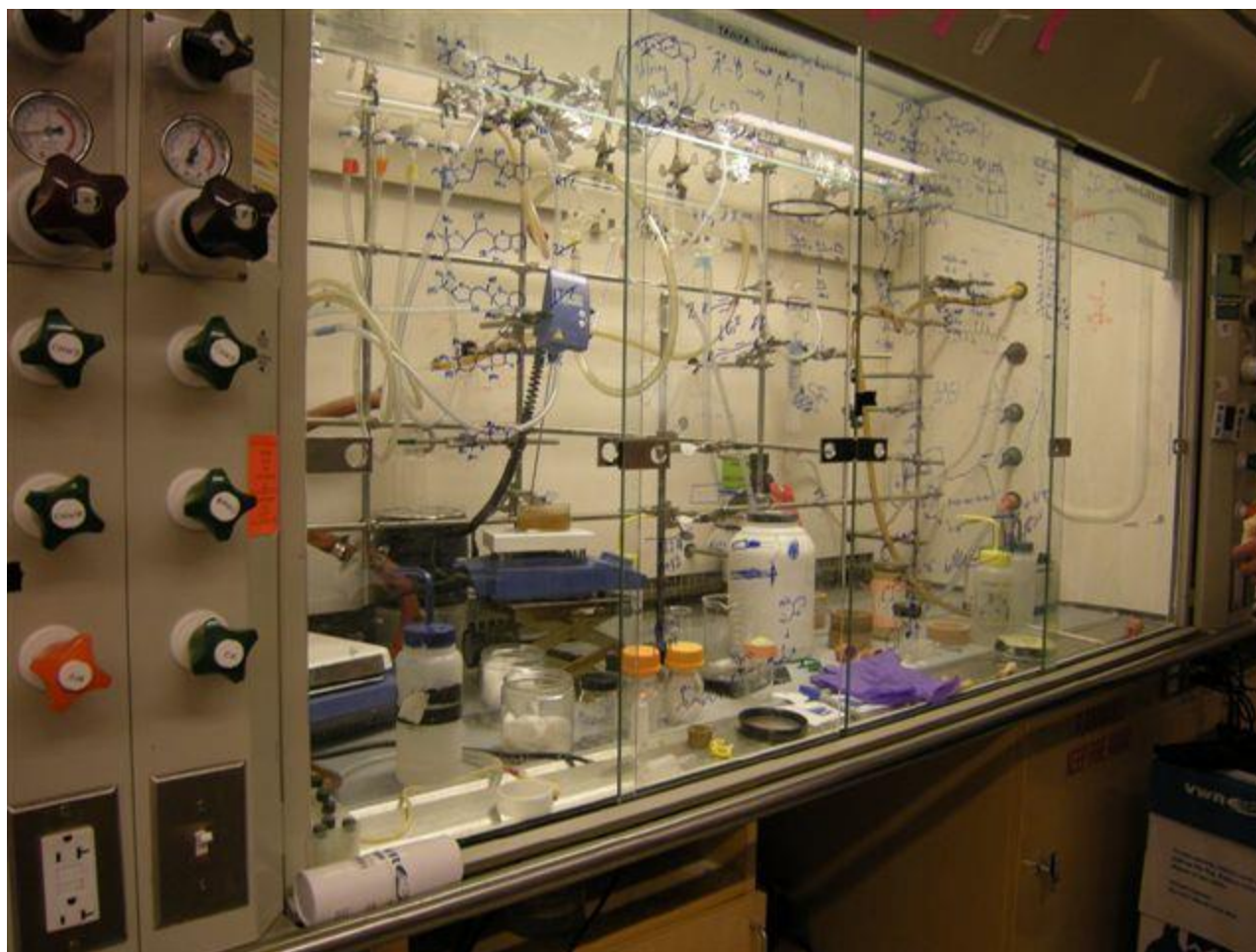


Cyclohexanone



Acetophenone

# Fume Hoods Make Great Writing Spaces



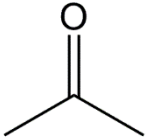
# Acetone Cleaning



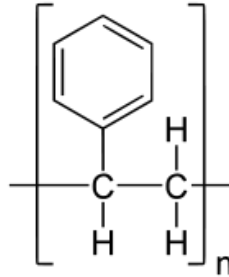


# Which of the Following Polymers Dissolves in Acetone?

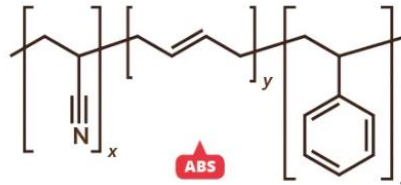
Acetone



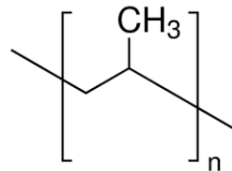
Polystyrene  
PS



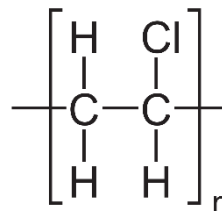
Acrylonitrile Butadiene Styrene  
ABS



Polypropylene  
PPE



Polyvinyl Chloride  
PVC



# Acetone Cleaning Revisited

Spend no more than **FIVE** minutes  
watching links and then “return” to class.

Acetone vs. PS and ABS (watch first 2:10)

<https://www.youtube.com/watch?v=tkOeqa-y890>

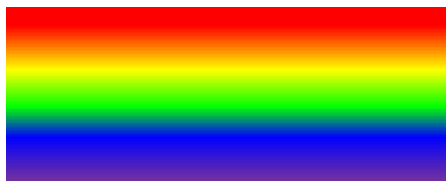
Acetone vs. PVC (skip forward for about 1 minute in  
total)

<https://www.youtube.com/watch?v=LusMOtGwTrA>

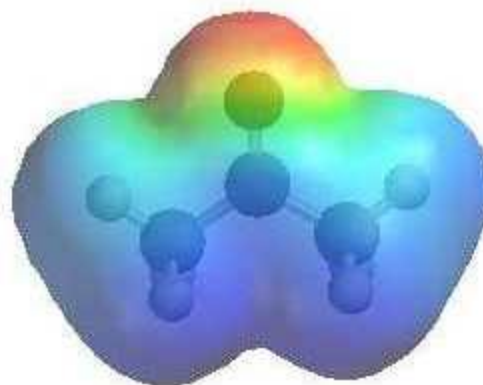
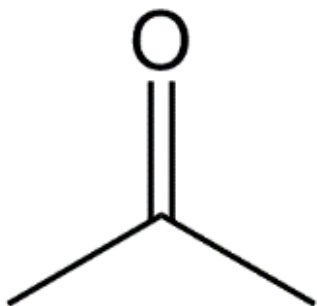
Acetone vs PPE (watch the entire video)

[https://www.youtube.com/watch?v=3TldqzJq\\_xo](https://www.youtube.com/watch?v=3TldqzJq_xo)

# Acetone Electron Density Map: Electron Localization



Red: High Electron Density  
Blue: Low Electron Density



# Extra! Chemistry of LEGO!!!



## Injection-moulded into shapes

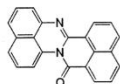
Granules of ABS mixed with a colouring agent are melted at 230°C then injected into moulds at extremely high pressure. After about seven seconds, the newly-formed Lego® pieces cool and fall onto a conveyor.

Lego® bricks have been injection-moulded this way since 1947. Today, Lego® uses state-of-the-art NX CAD/CAM software to design the moulds to within 2 µm of precision. All Lego® bricks thus lock together perfectly.



## 'Melts' between 80 and 100°C

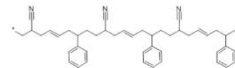
Amorphous polymers such as ABS have no definite melting point. Lego® bricks destabilise around 80°C and the 'glass point' of ABS is around 105°C. Continued heating causes the brick to decompose, producing toxic CO and HCN gases.



## Multicoloured!

Lego® bricks are coloured with thermoplastic colorants such as MACROLEX®. There are 25 different colorants available, many of them structurally similar to food dyes, and the chemists at Lego® mix them into 37 signature colour blends. The dye pictured is a perinone derivative called

Red 179, and is used in red Lego® bricks. Most red dyes, including food dyes, are either perinones or azo dyes.



## Acrylonitrile butadiene styrene

Lego® bricks are made from ABS, a thermoplastic polymer made from three different monomers:



### Monomer 1: acrylonitrile (~25%)

Synthetic monomer produced from propylene and ammonia. Polar nitrile groups on acrylonitrile attract other chains and bind the chains together, which gives the Lego® bricks **strength**.



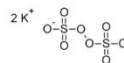
### Monomer 2: 1,3-butadiene (~15%)

This petroleum hydrocarbon obtained from the C<sub>4</sub> fraction of steam cracking gives Lego® bricks **resilience** at low temperatures. 1,3-butadiene is also used in the production of synthetic rubber.



### Monomer 3: styrene (~60%)

Styrene is made by dehydrogenating ethyl benzene (which, in turn, is made by reacting ethene with benzene). Delocalised electrons in the benzene ring give the Lego® brick a **shiny, hard surface**. Styrene is also used in the production of polystyrene.



## Polymerisation reaction initiator

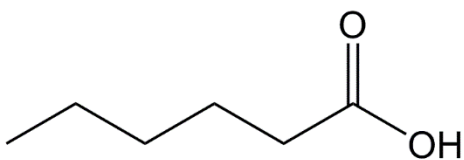
Potassium peroxydisulfate, K<sub>2</sub>S<sub>2</sub>O<sub>8</sub>, initiates the polymerisation reaction.

# What is Ketosis?

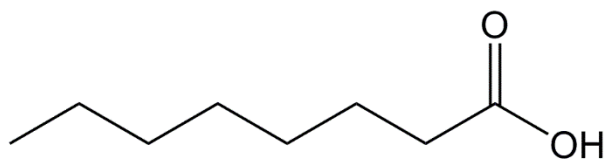


# Some Carboxylic Acids and Sonoma County Goat Cheese!!

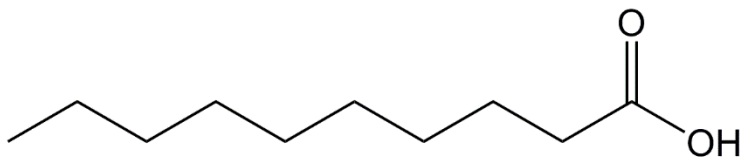
Caproic acid, caprylic acid, and capric acid all have names derived from the Latin word *caper*, which means “a male goat.” All these acids are named after the goat because they have a goat-like smell and are present in goat’s milk. The structures for the three acids are shown below.



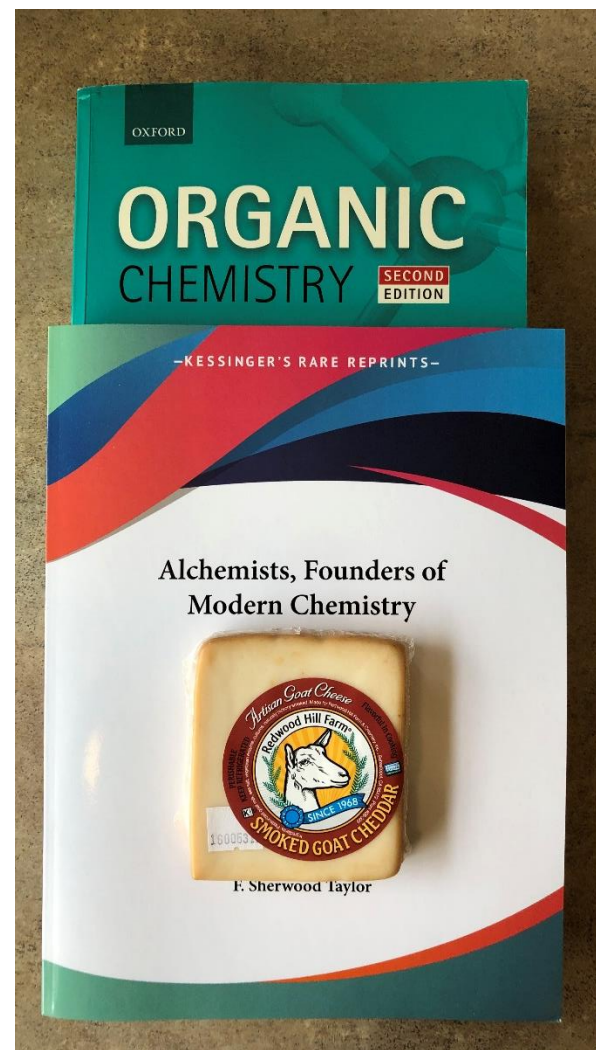
Caproic Acid



Caprylic Acid



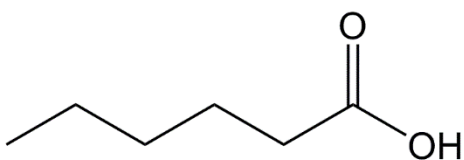
Capric Acid



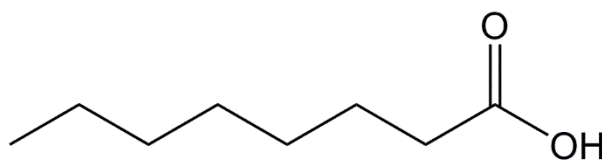


# Some Carboxylic Acids and Sonoma County Goat Cheese!!

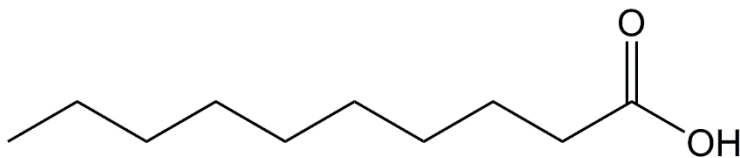
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Caproic Acid



Caprylic Acid



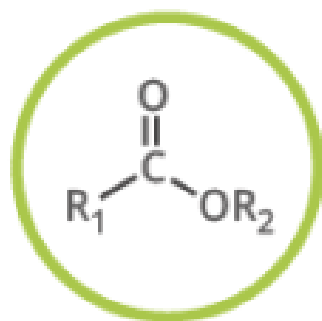
Capric Acid

Alchemists, Founders of  
Modern Chemistry



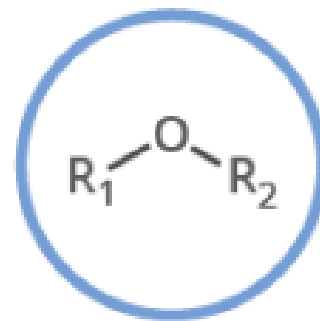
F. Sherwood Taylor

# Esters Are *NOT* Ethers



ESTER

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

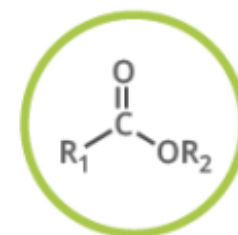


ETHER

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

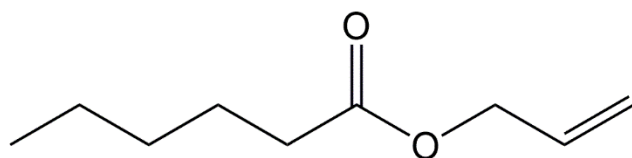


# Some Common Esters

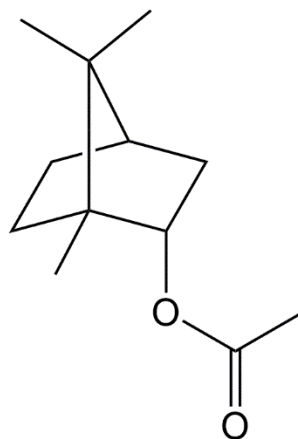


ESTER

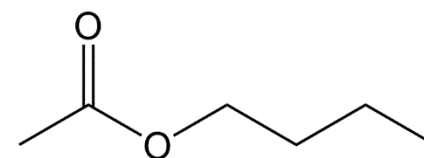
Naming: -yl -oate  
e.g. ethyl ethanoate



Allyl Hexanoate  
(Pineapple)



Bornyl Acetate  
(Pine)









































































































































Butyl Acetate  
(Apple)

# Esters Are Responsible for Many Everyday Smells!!

## Esters

Table of esters and their smells

		from the alcohol (first word)											
		methyl 1 carbon	ethyl 2 carbons	propyl 3 carbons	2-methyl propyl-	butyl 4 carbons	pentyl 5 carbons	hexyl 6 carbons	benzyl benzene ring	heptyl 7 carbons	octyl 8 carbons	nonyl 9 carbons	
from the carboxylic acid (second word)	methanoate 1 carbon	ETHEREAL			ETHEREAL			"GREEN" 				?	
	ethanoate 2 carbons								JASMINE 				
	propanoate 3 carbons											?	
	2-methyl propanoate 4 carbons, branched		ETHEREAL									?	
	butanoate 4 carbons											?	
	pentanoate 5 carbons					ETHEREAL					?	?	
	hexanoate 6 carbons												
	benzoate benzene ring	YLANG YLANG 	NUTS 	BALSAMIC 							?		
	heptanoate 7 carbons						?					?	
	salicylate from salicylic acid			MINT 	WINTERGREEN 	STRONG 			DIFFERENT PEOPLE PERCEIVE DIFFERENT AROMAS! 	?		?	
	octanoate 8 carbons												
	phenylacetate benzene ring + 2 carbons	STRONG 							JASMINE 	none!		?	
	nonanoate 9 carbons										?		
	cinnamate benzene ring + propenol												?
	decanoate 10 carbons			OIL 		JAVA DANIEL'S OLD MEX 		?	?	?	?	?	

Produced by James at [jameskennedymonash.wordpress.com](http://jameskennedymonash.wordpress.com). Visit website for more infographics. Free to use!

# Perfumes Use Esters

## Inis

Inis fragrance notes

### Top Notes

Sicilian lemon, Bergamot, Neroli, Marine notes

### Heart Notes

Lily of the valley, Geranium

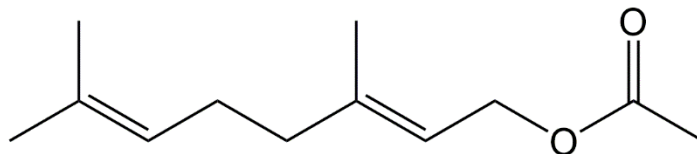
### Base notes

Clove, Nutmeg, Sandalwood, Oakmoss, Musk



# Perfumes Use Esters

Inis

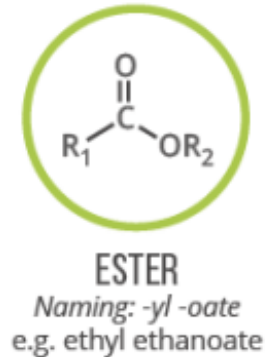
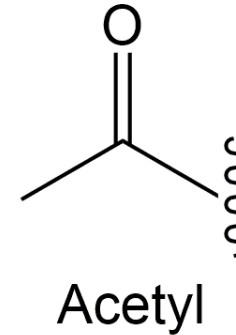


Geranyl Acetate  
(3,7-Dimethylocta-2,6-dien-1-yl Ethanoate)

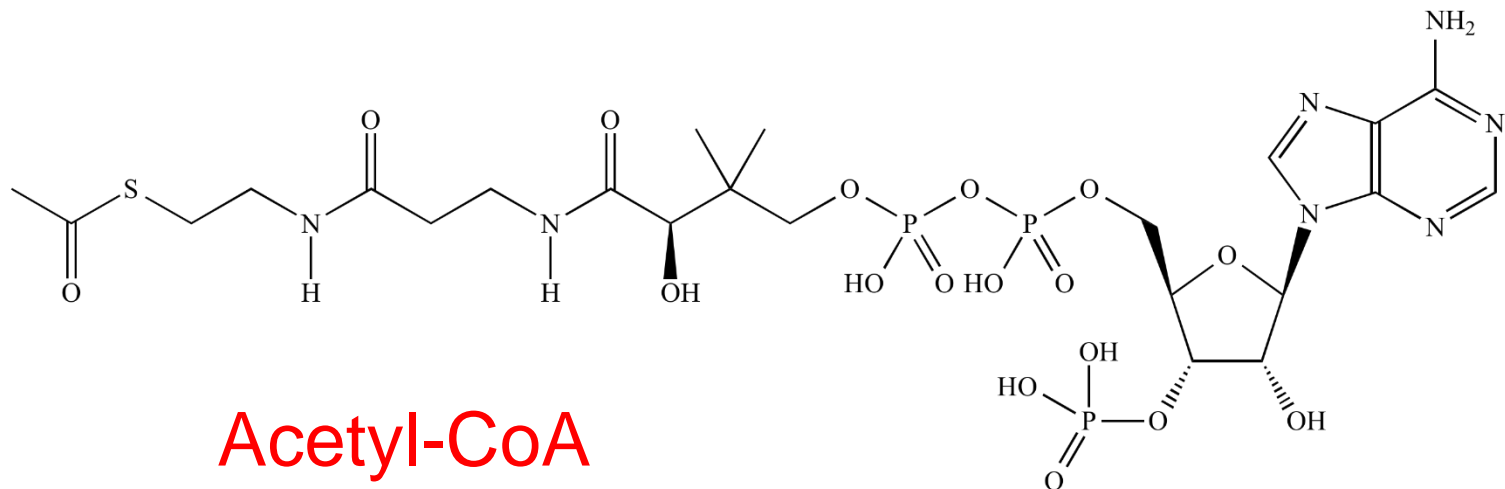
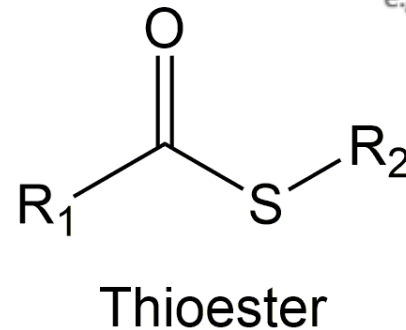
Geranium

# Acetyl-CoA

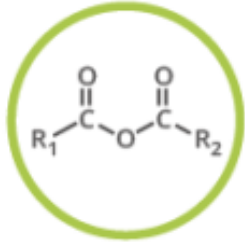
Acetyl-CoA is a co-enzyme that delivers an acetyl group in biosynthesis.



Acetyl-CoA is a thioester.

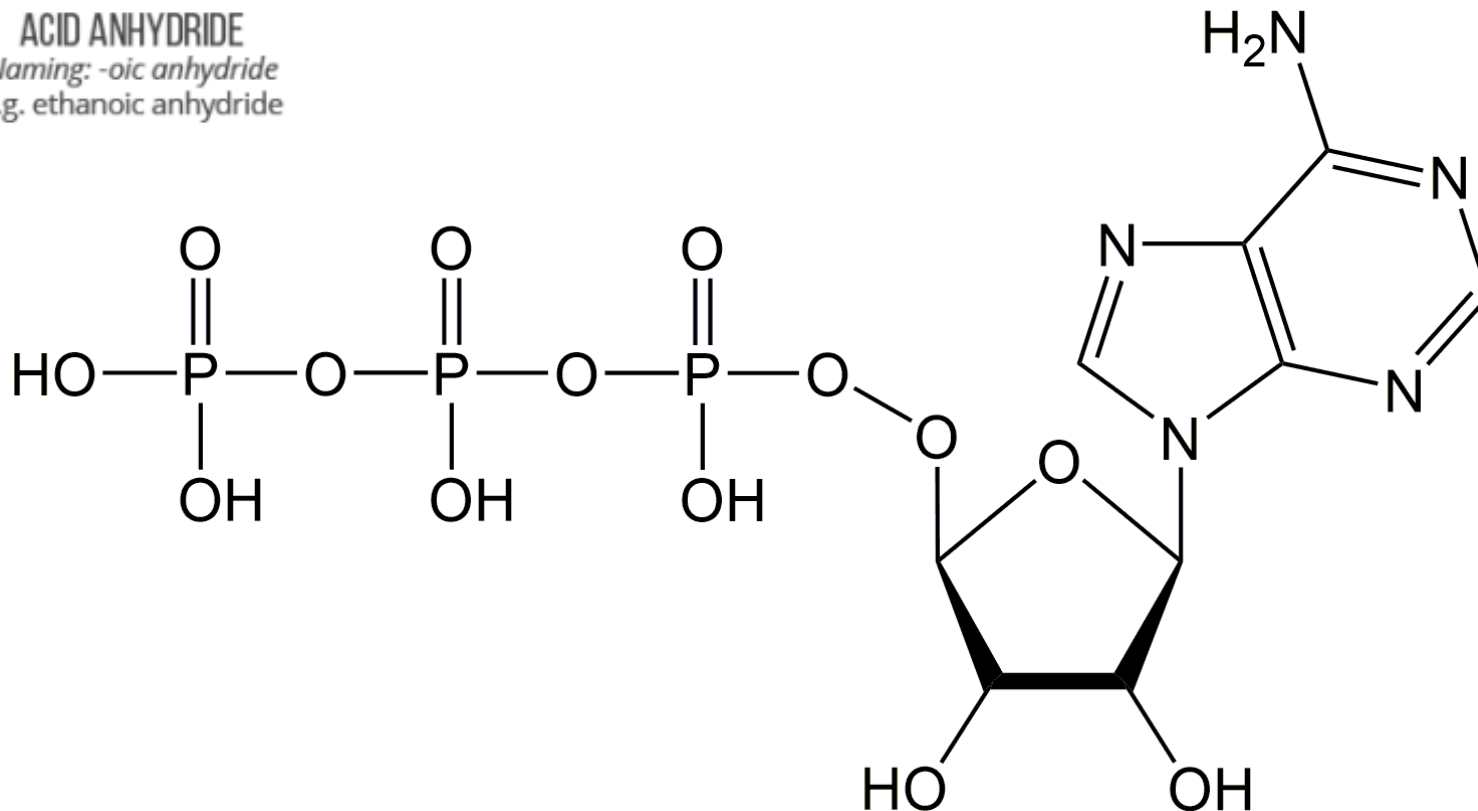


# ATP Contains a Phosphoanhydride Functional Group

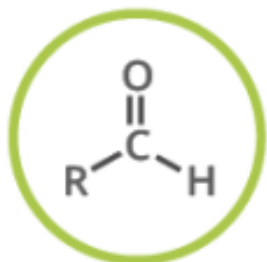


## ACID ANHYDRIDE

Naming: -oic anhydride  
e.g. ethanoic anhydride

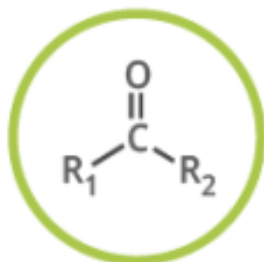


# Classifying Carbonyl Compounds



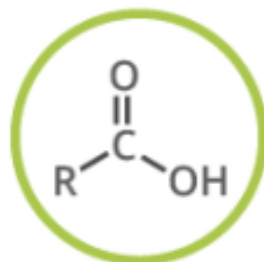
**ALDEHYDE**

*Naming: -al*  
e.g. ethanal



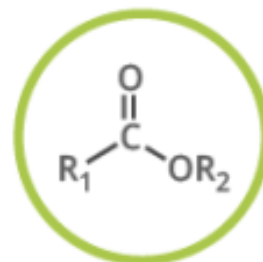
**KETONE**

*Naming: -one*  
e.g. propanone



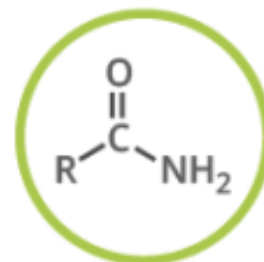
**CARBOXYLIC ACID**

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



**ESTER**

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

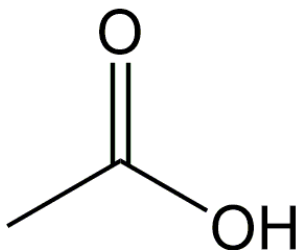


**AMIDE**

*Naming: -amide*  
e.g. ethanamide

# Problem 1

Identify the following molecule as a carboxylic acid, acid chloride, ester, acid anhydride, or amide.

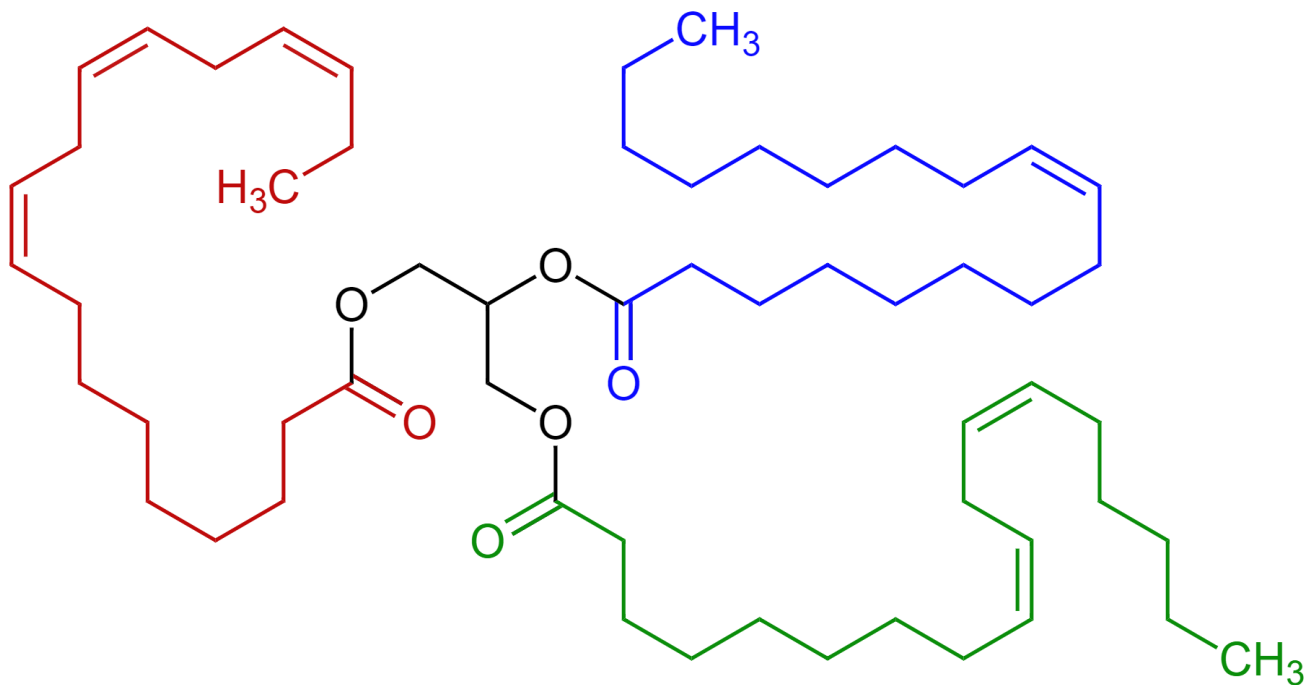




# Problem 2

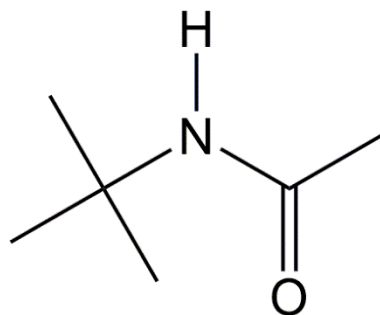
The following molecule is isolated from linseed oil. This triglyceride is derived from **linoleic acid**, **α-linolenic acid**, and **oleic acid**.

Identify the following molecule as a carboxylic acid, acid chloride, ester, acid anhydride, or amide.



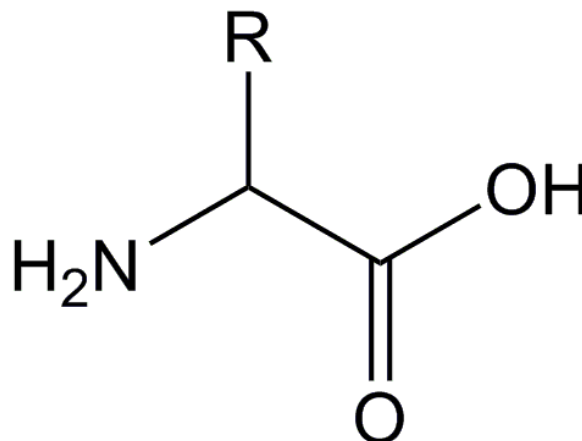
# Problem 3

Identify the following molecule as a carboxylic acid, acid chloride, ester, acid anhydride, or amide.



# Amino Acids

Amino acids are ***amino*** carboxylic ***acids***.



Amino Acid