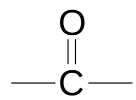
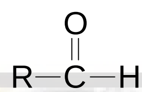
Notes Aldehydes and Ketones

The major similarity between an aldehyde and a ketone is the carbonyl group. A carbonyl group is a carbon atom doubly bonded to an oxygen atom.

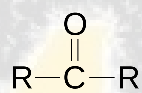


Both molecules have a carbonyl group, the difference the number of carbons bonded to the carbonyl carbon. An aldehyde will have none or one and a ketone will have two carbons.

All aldehydes, except formaldehyde, will have a hydrogen atom on one side of the carbonyl carbon and at least on carbon on the other side.



All ketones have a carbon on each side of the carbonyl carbon.

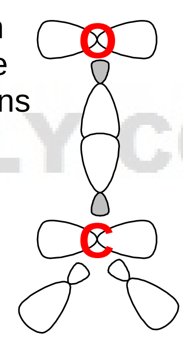


Remember that the 'R' symbolizes any carbon side-chain, from one to a million carbons. Basically, what it comes down to is that in an aldehyde the carbonyl group is on the terminal (last) carbon and the ketones carbonyl group is not.

These compounds are found at the most fundamental levels of biological existence. Glucose is the single most important molecule in providing energy at a cellular level. Without glucose you would die in seconds. Glucose, the most important carbohydrate, not only has a carbonyl group but is an aldehyde. Another common carbohydrate is fructose, fruit sugar, this compound is a ketone.

These compounds are more reactive than your typical alkane, the question you may ask is why? The answer lies in the location of the electrons in the carbonyl group. First, look at the hybridization of a carbonyl carbon. A carbon connected to three other molecules must be doubly bonded to one of those molecules. For a double bond to form p-orbitals must overlap over a sigma bond. The hybridization loses one p-orbital, leaving the carbon as sp^2, allowing the formation of the other bond with the free p-orbital, forming a pi-bond.

Back to our question, why are the aldehyde and a ketone more reactive than an alkane. When the pi-bond forms the electrons in this molecular orbital are more exposed, making them more vulnerable to reacting. Try to visualize the electrons sticking out on each side of the bond, leaving them accessible to other compounds.

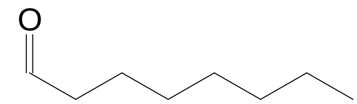


Nomenclature:

Aldehydes – IUPAC Names

1. Count the number of carbons in the longest chain containing the aldehyde group
2. The carbonyl carbon will always be carbon number one
3. Drop the –e suffix and add –al

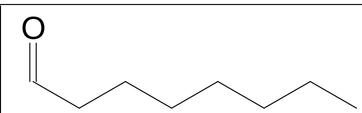
Examples:

$CH_3-C(=O)-H$	$CH_3CH_2-C(=O)-H$	$CH_3CH_2CH_2-C(=O)-H$	
ethanal	propanal	butanal	octanal

Aldehydes – Common Names

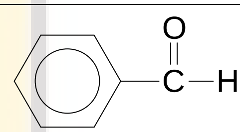
1. Count the number of carbons
2. Use the side-chain abbreviation
3. Add the word aldehyde to the end

Examples:

$CH_3-C(=O)-H$	$CH_3CH_2-C(=O)-H$	$CH_3CH_2CH_2-C(=O)-H$	
ethyl aldehyde	propyl aldehyde	butyl aldehyde	octyl aldehyde

Aldehydes – Very Common Names

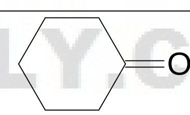
Just as H_2O is referred to as water some aldehydes have very common names. The following is a list of these very specific common names.

$H-C(=O)-H$	$CH_3-C(=O)-H$	
formaldehyde	acetaldehyde	benzaldehyde

Ketones – IUPAC Names

1. Count the number of carbons in the longest chain containing the ketone group
2. The carbonyl carbon will always be given the lowest possible number
3. Drop the –e suffix and add –one

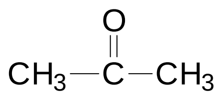
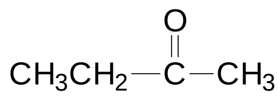
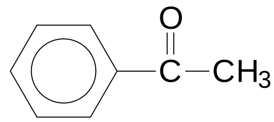
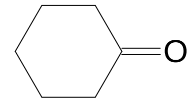
Examples:

$CH_3-C(=O)-CH_3$	$CH_3CH_2-C(=O)-CH_3$	$CH_3CH_2-C(=O)-CH_2CH_3$	
propanone	butanone	3-pentanone	cyclohexanone

Ketones – Common Names

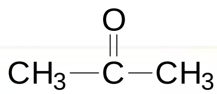
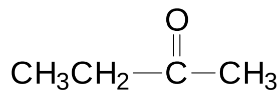
1. Count the number of carbons
2. Use the side-chain abbreviation
3. Add the word ketone to the end

Examples:

			
dimethyl ketone	methyl ethyl ketone	methyl phenyl ketone	cyclohexanone

Ketones – Very Common Names

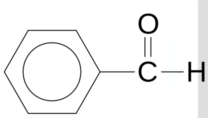
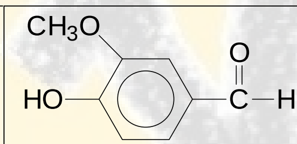
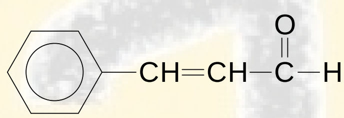
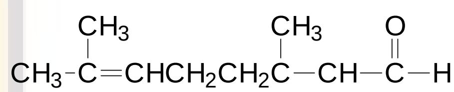
Just as H_2O is referred to as water some ketones have very common names. The following is a list of these very specific common names.

	
acetone	MEK

Common Aldehyde and Ketone Compounds;

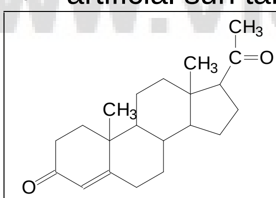
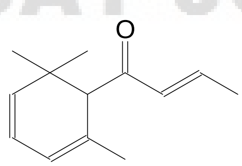
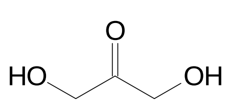
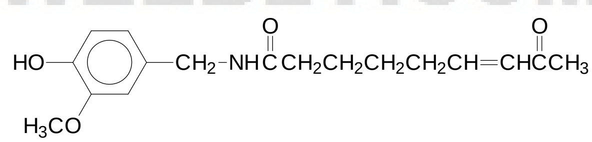
aldehydes:

- glucose – cell energy
- ribose – the “R” in RNA
- plastics – credit cards
- Formica – counter tops
- press board glue – to put together your Ikea entertainment center
- formaldehyde – embalming
- ethanal – produced when your liver metabolizes ethanol (drinking alcohol)
- flavoring and or scent

			
almonds	vanillin	cinnamon	lemongrass

ketones:

- fructose – fruit sugar
- deer musk – yummy
- camphor – moth balls
- flavoring and or scent
    - mushrooms
    - berries
    - red peppers – capsaicin (also found in pain relief patches)
- industrial solvents
- artificial sun tan lotion

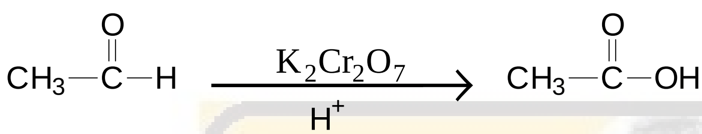
			
progesterone (hormone)	α - demascone berry flavor	dihydroxyacetone fake tan cream	capsaicin (capsicum)

Chemical Reactions:

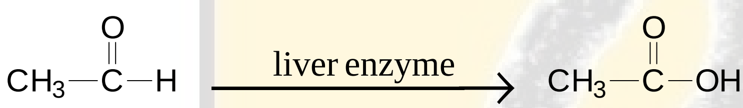
- The carbon of an aldehydes are susceptible to both oxidation and reduction.
- The carbon of a ketone is susceptible to reduction.
- The fact that ketones are not easily oxidized allows one to differentiate between an aldehyde and a ketone.
- Aldehydes are easily oxidized to carboxylic acids.
- To oxidize a ketone a carbon-carbon sigma bond must be broken. This is very difficult to do, and requires one hell of an oxidizing agent. Something like oxygen during combustion will work.

Common Reactions:

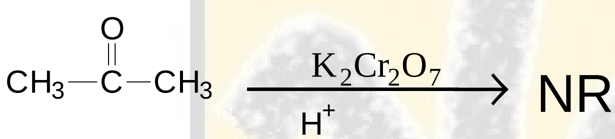
Test Tube Rxn:



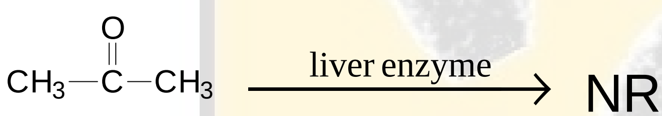
Organism Rxn:



Test Tube Rxn:



Organism Rxn:



Test Reactions:

Tollen's Test (mirror test):

- verification for aldehydes
- used to manufacture mirrors
- silver ion, $Ag^{+}_{(aq)}$ is reduced to silver metal, $Ag_{(s)}$ by an aldehyde
- silver plates out on anything it is close to, for example the test tube walls or anything else
- if one element is reduced another must be oxidized, the carbonyl carbon is oxidized
- procedure
    - o add suspected aldehyde to a basic solution of $AgNO_3$, NH_3, ammonia is normally the base
    - o if the test tube shows a mirrored surface, this is a positive test for an aldehyde
    - o gentle heating may be necessary

$$CH_3-\overset{\overset{O}{||}}{C}-H + H_2O_{(l)} + AgNO_{3(aq)} \xrightarrow{NH_3} CH_3-\overset{\overset{O}{||}}{C}-OH + Ag_{(s)}$$

Benedict's Test:

- verification for aldehydes
- Cu^{+2} in a basic solution
- Cu^{+2} is reduced to Cu^{+}
- Cu^{+} is quickly oxidized by oxygen to form Cu_2O
- Cu^{+2} is **light blue**, Cu_2O is **brick-red**

$$CH_3-\overset{\overset{O}{||}}{C}-H + CuCl_{2(aq)} + H_2O_{(l)} \xrightarrow{OH^{-}} CH_3-\overset{\overset{O}{||}}{C}-OH + Cu_2O_{(s)}$$

Why are these two tests only for aldehydes?

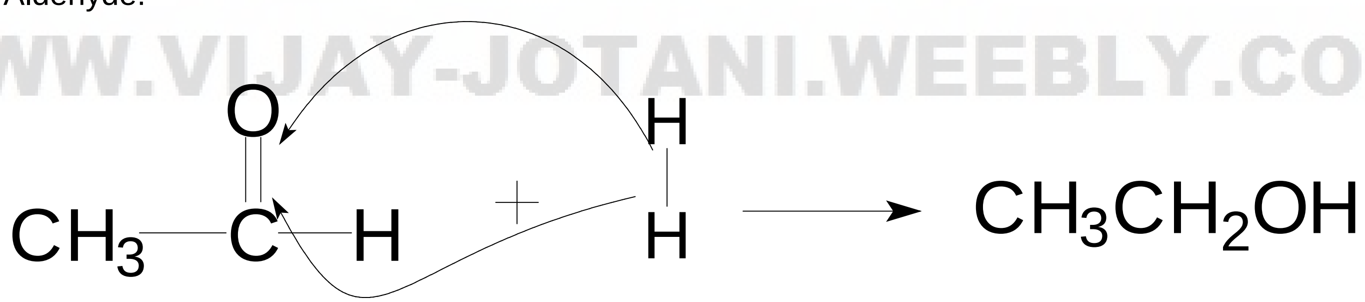
the test reagents are oxidizing agents and can not oxidize ketones

Both aldehydes and ketones can be easily reduced back to alcohols by something as simple as hydrogen gas and a nickel catalyst.

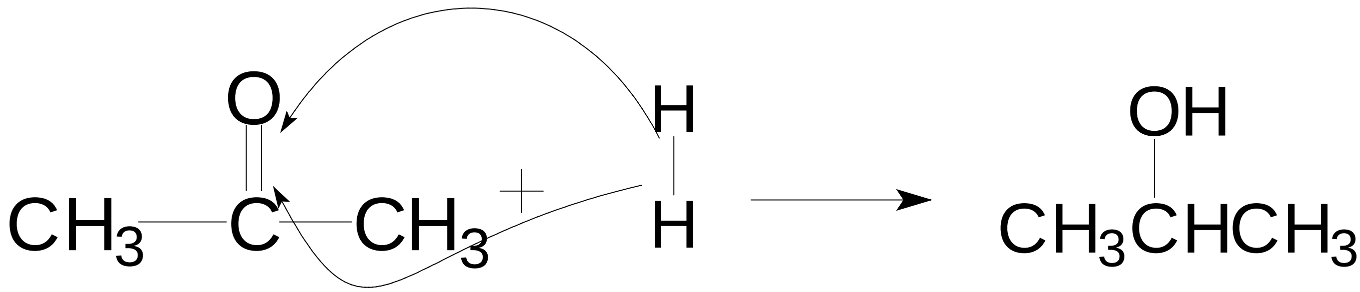
$$CH_3-\overset{\overset{O}{||}}{C}-H + H_{2(g)} \xrightarrow{Ni} CH_3-CH_2-OH$$

addition across a double bond: Reaction Mechanism

Aldehyde:

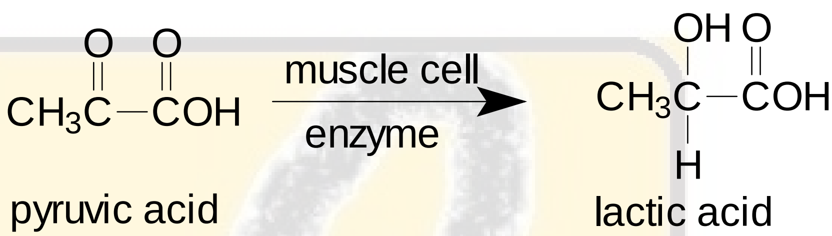


Ketone:

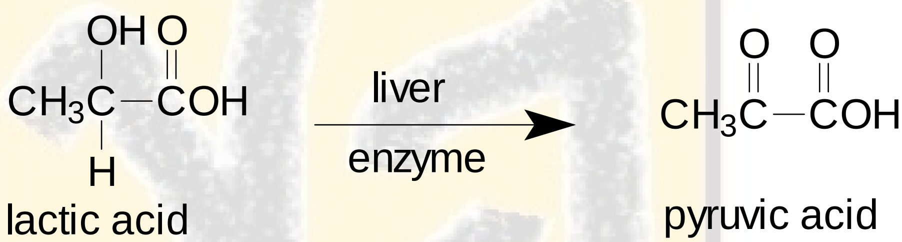


Muscular Rxn:

- pyruvic acid (both a carboxylic acid and a ketone), is converted to lactic acid



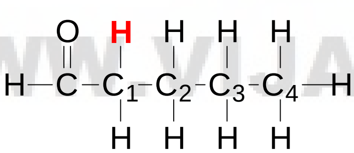
Liver Rxn:



The oxidation of the lactic acid coincides with the production of the glucose, which is used by muscles to make more pyruvic and lactic acids

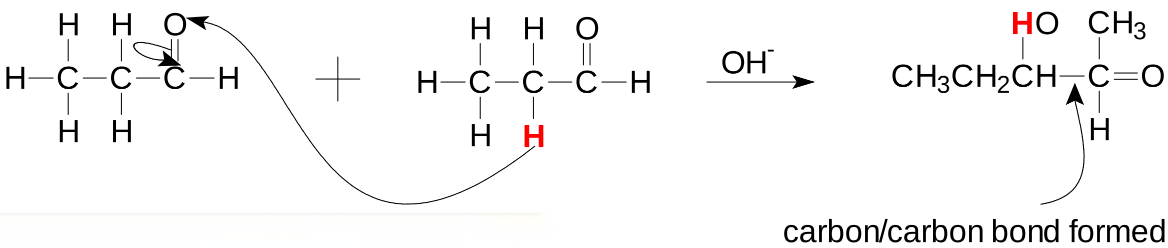
Aldo Condensation Rxn: A step in the creation glucose

- condensation rxns are a type of combination reaction.
- this reaction creates carbon-carbon bonds so larger molecules can be built
- very useful in the building of pharmaceutical drugs



C_1 – alpha carbon
C_2 – beta carbon
C_3 – gamma carbon
C_4 – delta carbon

- the alpha carbon is bonded to the most acidic hydrogen
- this means that if any one of the hydrogens are going to come off, the alpha hydrogen will come off first
- this is caused by oxygen's large electronegativity, drawing that hydrogen's electron away
- knowing this little bit of information allows us to react two aldehydes together



- The base is used to help pull the alpha hydrogen off.