

## Organic Chemistry

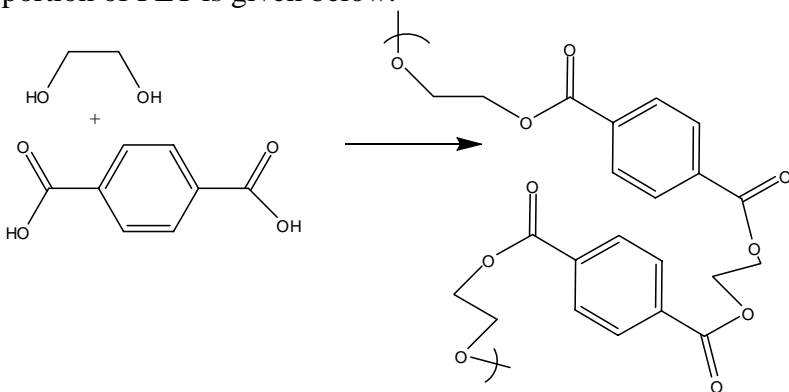
### Notes Part 36

Condensation Polymers (6<sup>th</sup> edition, pg. 898 – 899, 7<sup>th</sup> edition, pg. 1204)

Condensation polymers are formed by the elimination of a small molecule. The small molecule differs depending upon what reagents were used to form the polymer. The condensation polymers can be broken down into polyester, polyamide, polyurethane, and polycarbonate.

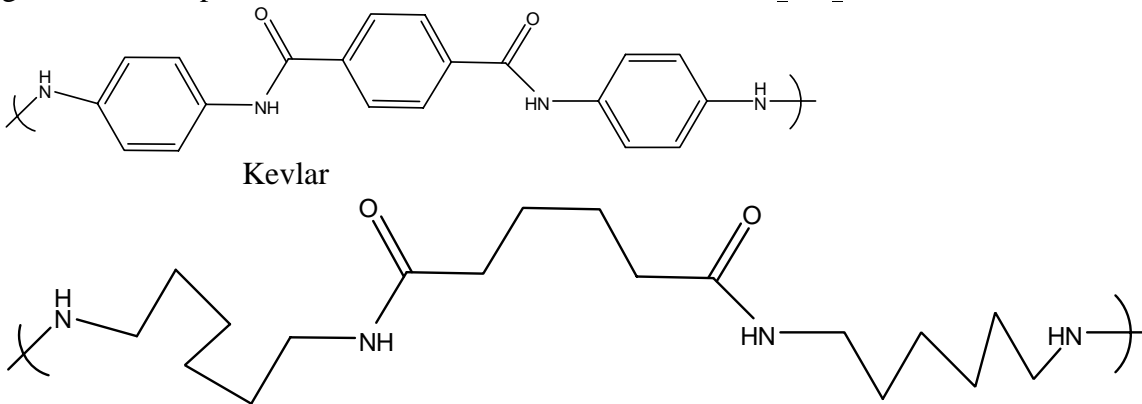
Polyester (6<sup>th</sup> edition, Chapter 29.12, 7<sup>th</sup> edition, same)

Polyesters can be formed by the reaction of a diol with a dicarboxylic acid. The diol for PET is ethylene glycol and the dicarboxylic acid is terephthalic acid. A small portion of PET is given below.



Polyamide (6<sup>th</sup> edition, Chapter 29.11, 7<sup>th</sup> edition, same)

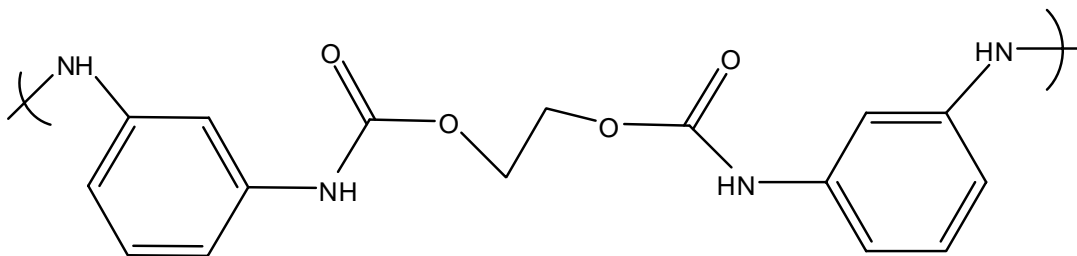
Polyamides can be formed by the reaction of a diamine with a diacid chloride. Two examples are shown below. The first example is Kevlar which is used for bullet proof vests. The second drawing is an example of a Nylon and Nylons are named by indicating how many carbons are between the nitrogens. Two numbers are required and the example below is Nylon 6,6. A base must be added to react with the HCl that is generated. The possibilities for the base are NaOH or Na<sub>2</sub>CO<sub>3</sub>.



### Nylon 6,6

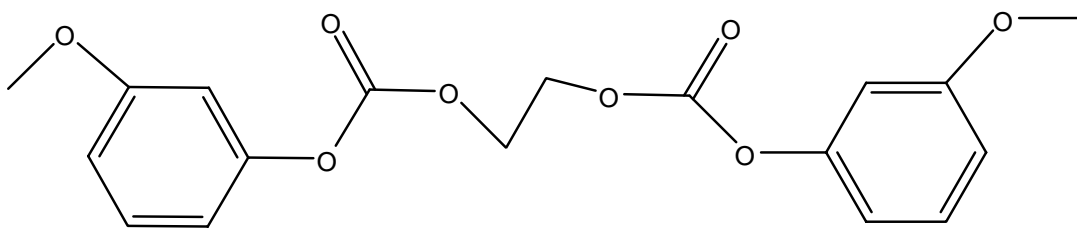
Polyurethane or polycarbamate (6<sup>th</sup> edition, Chapter 29.14, 7<sup>th</sup> edition, same)

Polyurethanes can be formed by the reaction of a diisocyanate compound and a dialcohol. The example below is using toluene diisocyanate and ethylene glycol.



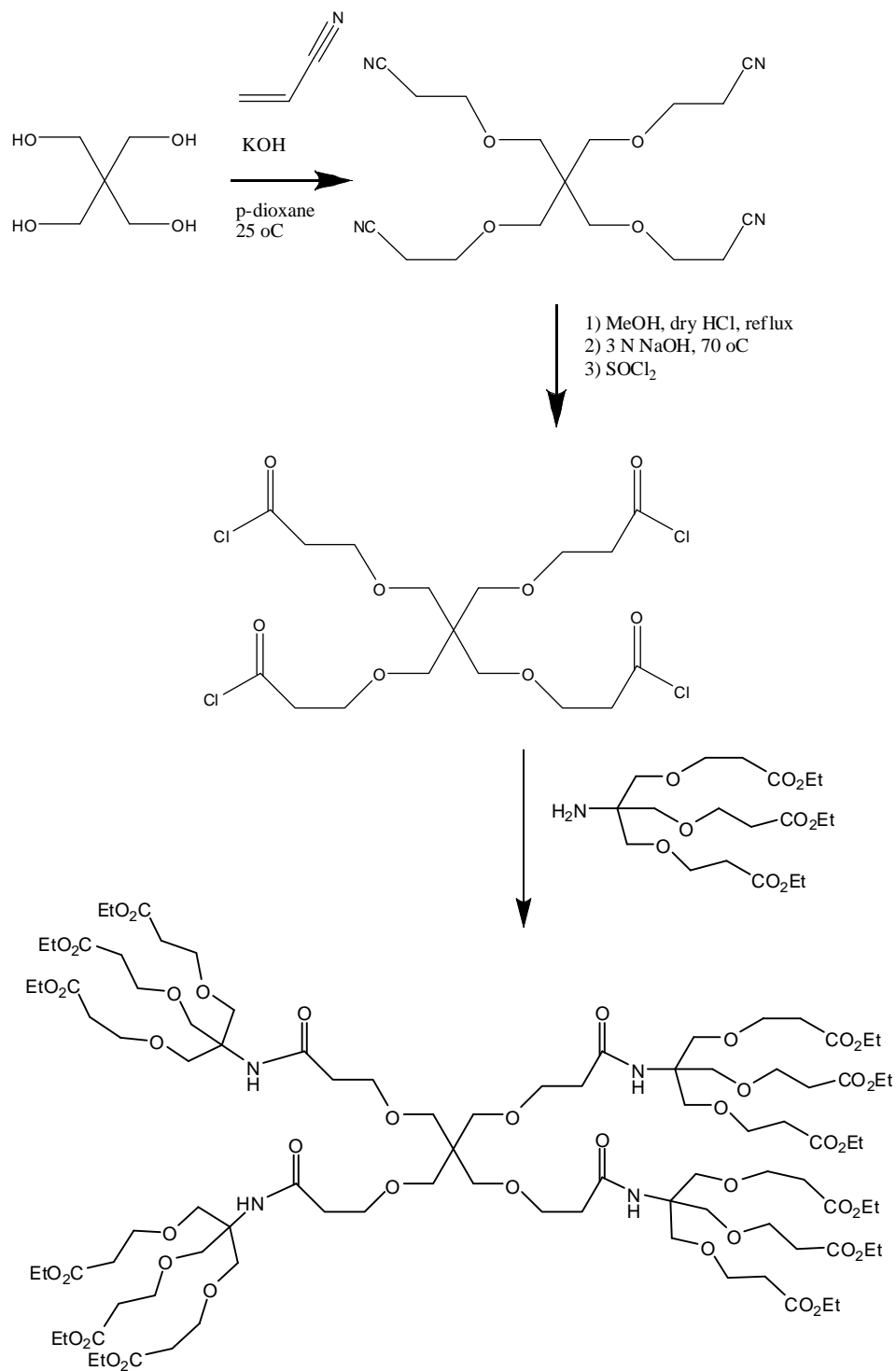
Polycarbonate (6<sup>th</sup> edition, Chapter 29.13, 7<sup>th</sup> edition, same)

Polycarbonates can be formed by the reaction of phosgene with a diol. A polycarbonate is given below.



Cascade or starburst polymers (Not in your book.)

Starburst polymers are high molecular weight, highly symmetrical polymers that start at a central carbon. An example is given below from Solomons, Organic Chemistry, 6<sup>th</sup> Edition, page 856 who took the example from Newkome et al, Macromolecules, 1991, 24, 1443 – 1444). The product of the molecule below is [12]ester. Reaction of [12]ester with another mole of amine makes [36]ester. Reaction of [36]ester with another mole of amine makes [108]ester.



[12]-ester is seen above since it has twelve ester groups on the periphery.

Ester enolates (6<sup>th</sup> edition, Chapter 21, 7<sup>th</sup> edition, same)

We have previously seen enolates from aldehydes and ketones. The pK<sub>a</sub> of the α-proton for aldehydes and ketones differ but are usually more acidic than esters. Why?

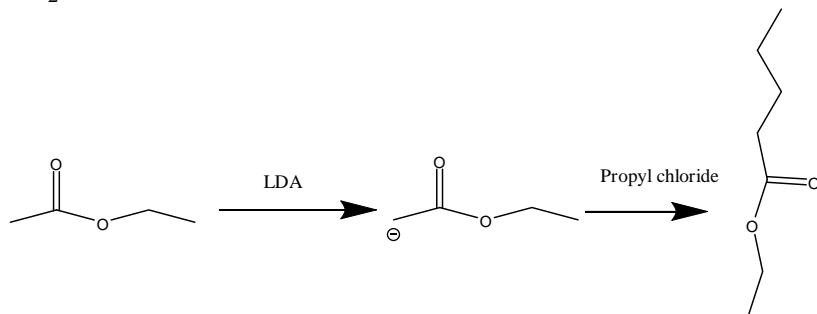
Oxygen (from the ester) donates electrons into the carbonyl making the carbonyl less positive. This makes the alpha-proton less likely to leave. However, enolates can be formed with the appropriate base. We saw that the choice of base was very important in the aldol condensation and it is also very important with esters as well.

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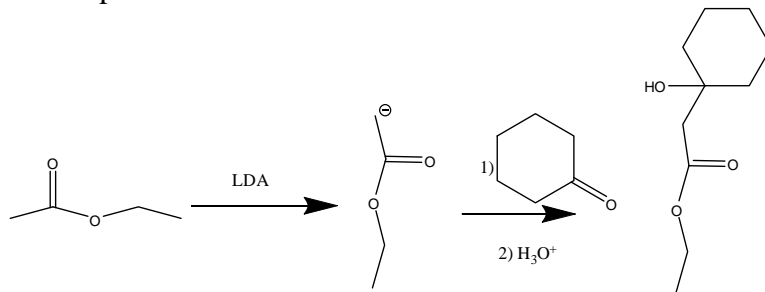
LDA and Esters (Chapter 21.10, 7<sup>th</sup> edition, same)

The choice of bases for forming the enolate from esters will consist of two possibilities in this class. The first choice is LDA. LDA is a bulky base that will not add to the carbonyl group and will provide the enolate in a high yield. Give the product of the reactions below.

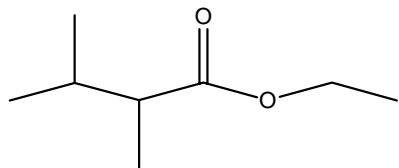
SN<sub>2</sub> reaction



Nucleophilic addition

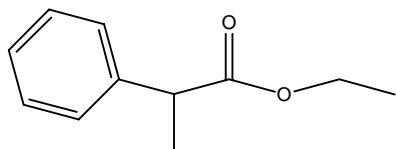
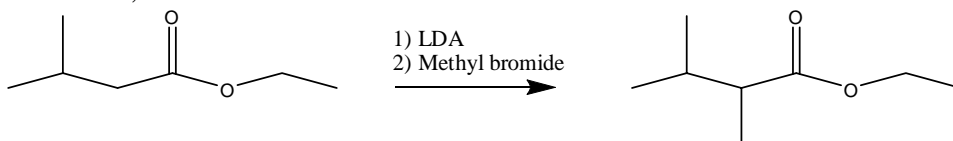


(6<sup>th</sup> edition, Problem 21.11, 7<sup>th</sup> edition, same) Outline efficient syntheses of the following compounds from esters, ketones and alkyl halides.



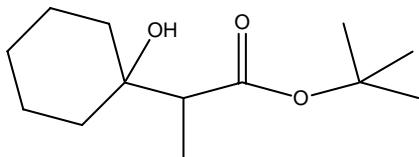
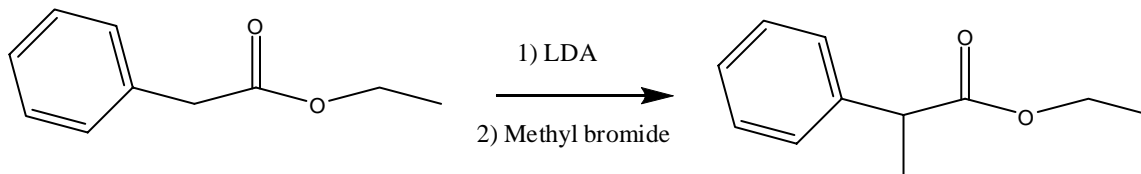
a)

Alkyl halides will undergo  $S_N2$  reactions. The alpha carbon has an isopropyl group and a methyl group. Isopropyl halides will undergo mainly elimination and not substitution. Therefore, we must use the reaction below.



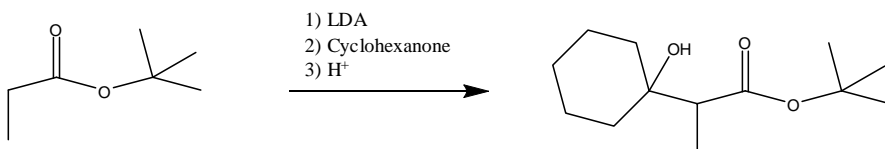
b)

The problem states use alkyl chlorides. Therefore, we can not use bromobenzene in the reaction. Bromobenzene will not undergo an  $S_N2$  reaction. We must use the reaction below.



c)

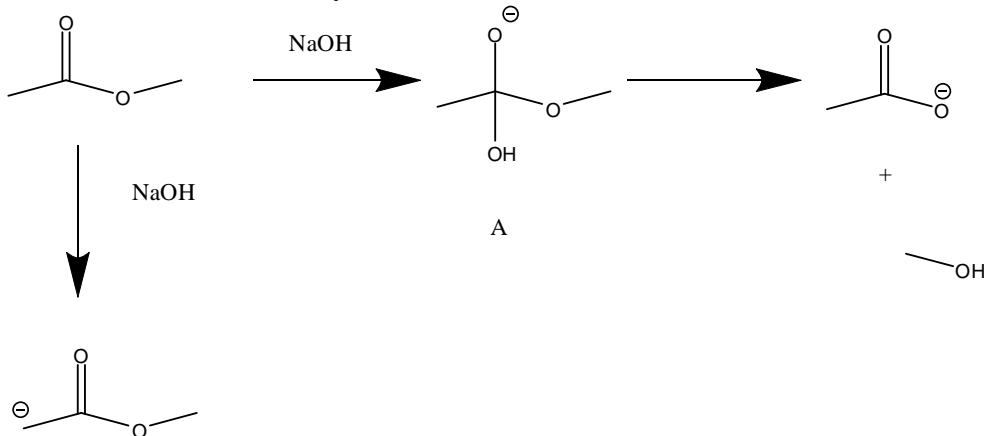
The product contains a tertiary alcohol. This means we must use a ketone. The reaction is given below. The alternate reaction of adding a methyl group will not work due to the acidic proton on the alcohol.



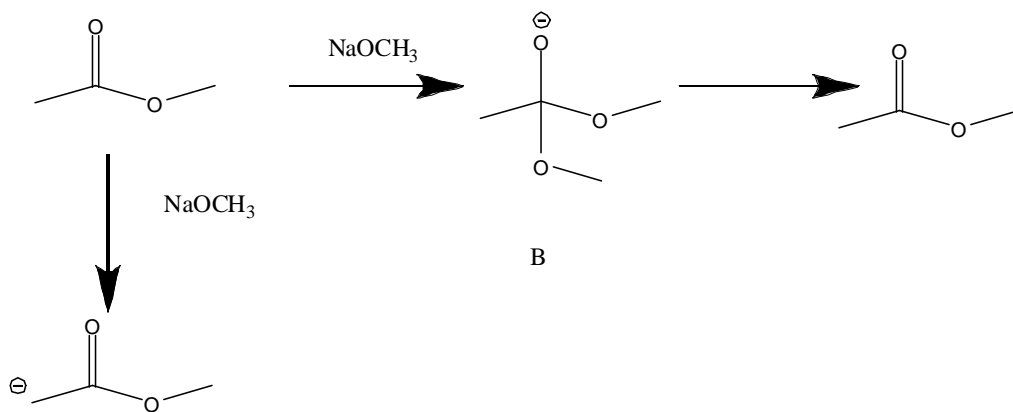
Base is same as ester group (Not in your book.)

The base/nucleophile can also have two possibilities in the reaction with esters. One can be removal of the proton. The other possibility can be addition to the carbonyl.

Give the products of the following reactions showing CLEARLY why you want to use the same base as the ester. For example, if it is a methyl ester, the base must be methoxide. If it is an ethyl ester, the base must be ethoxide.



Complex A can lose either an OH (and return to starting material) or it can lose a methoxide and form the saponification product.



Complex B (with two symmetrical groups) can lose either methoxide group and ONLY return to starting material. Therefore, the base ALWAYS has to be the same as the ester.

Comparison of aldol and Claisen condensation (6<sup>th</sup> edition, Aldol = Chapter 18.2 -3, Claisen = Chapter 21.2 – 4, 7<sup>th</sup> edition, same)

Aldol condensation

Forms  $\beta$ -hydroxycarbonyl  
 Forms condensation product  
 by loss of water  
 Mixed aldol between two aldehydes  
 If mixed, only one component can  
 have alpha protons  
 Can form 5 or 6 membered ring by  
 Intramolecular aldol

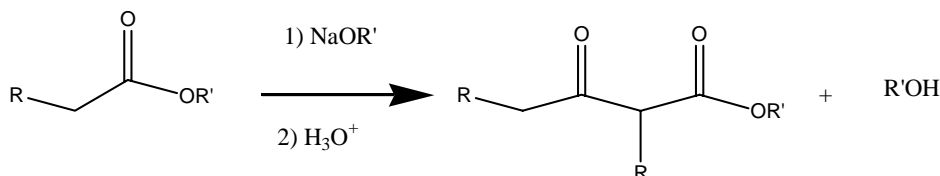
Claisen Condensation

Forms  $\beta$ -ketoester  
 Forms condensation product  
 by loss of alcohol  
 Mixed Claisen between two esters  
 If mixed, only one component can  
 have alpha protons  
 Can form 5 or 6 membered ring by  
 intramolecular Claisen

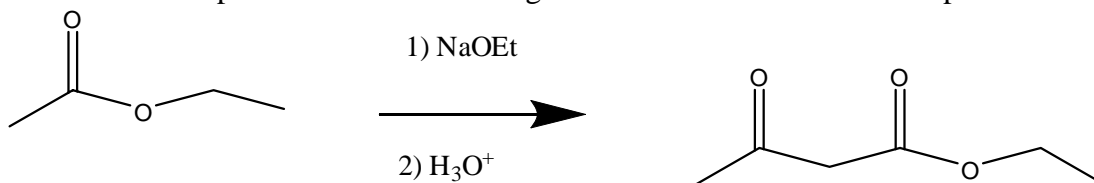
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Claisen condensation (6<sup>th</sup> edition, Chapter 21.2, 7<sup>th</sup> edition, same)

The Claisen condensation is defined by Carey as a “reaction in which a  $\beta$ -ketoester is formed by condensation of two moles of an ester in base.” The example of Carey is given below.



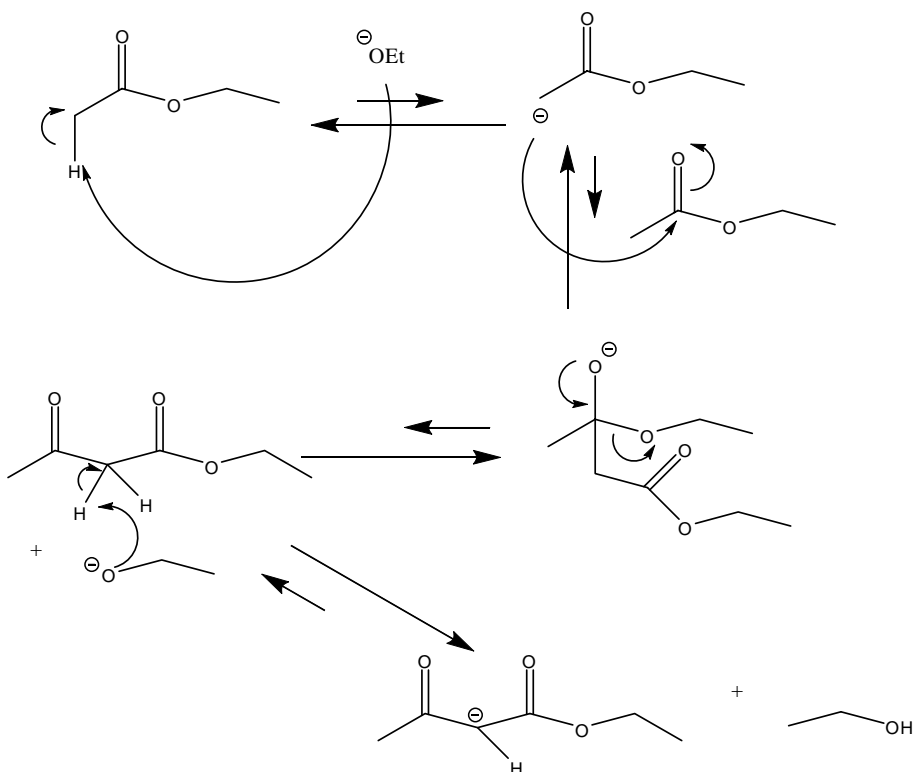
Give the products of the following Claisen reaction and name the product.



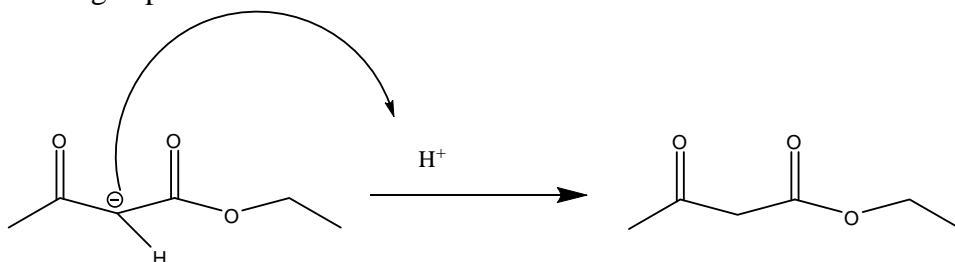
Name # 1: Ethyl 3-oxobutanoate  
 Name # 2: Ethyl acetoacetate  
 (shortened to Ethyl acac)  
 Name # 3: Acetoacetic ester

Claisen mechanism (6<sup>th</sup> edition, Mechanism 21.1, 7<sup>th</sup> edition, same)

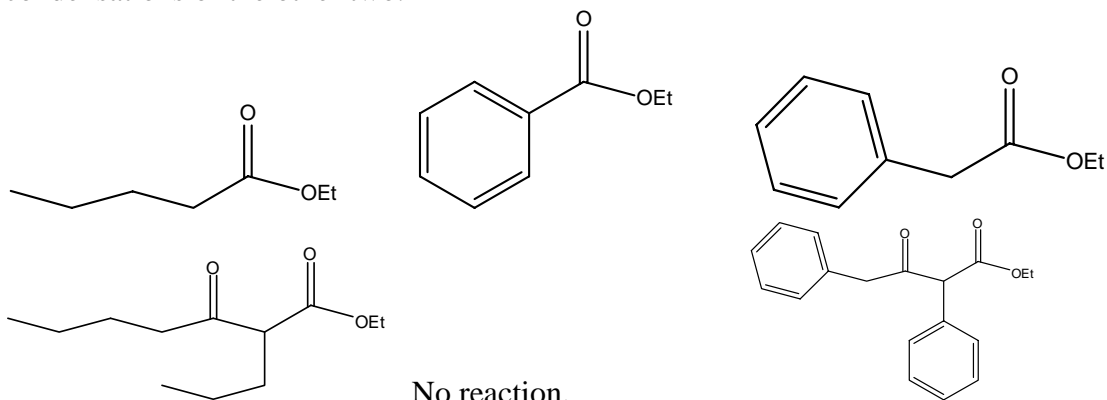
The Claisen mechanism is given below. TWO ALPHA hydrogens are REQUIRED for a Claisen condensation. Why? This can be explained with the mechanism below with ethyl acetate and sodium ethoxide.



There are four steps to the mechanism. Three steps are unfavorable and the last step is favorable. This is why two protons are required for a Claisen condensation. After the four steps of the mechanism have been completed, the last step is to form an uncharged product via an acid/base reaction and this is shown below.

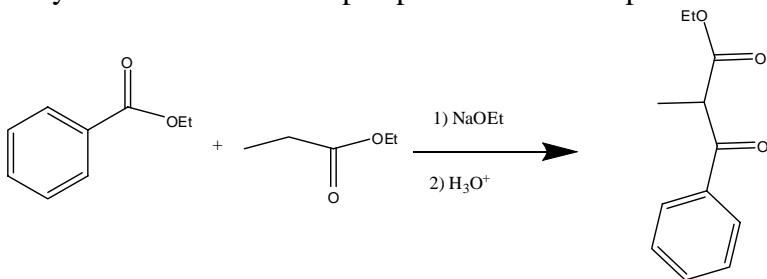


(6<sup>th</sup> edition, Problem 21.1, 7<sup>th</sup> edition, same) One of the following esters cannot undergo the Claisen condensation. Which one? Write structural formulas for the Claisen condensations of the other two.



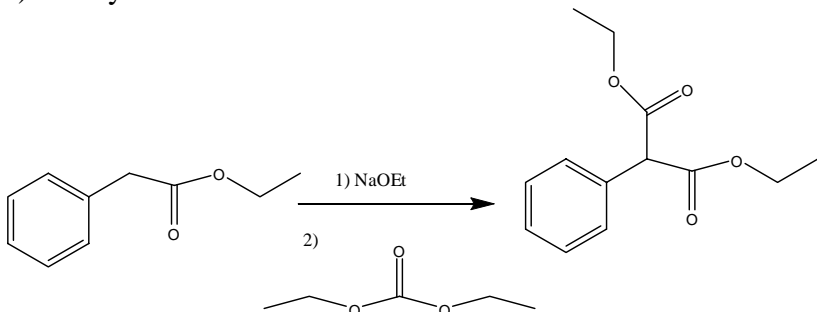
No  $\alpha$ -protons.  
Mixed Claisens (6<sup>th</sup> edition, Chapter 21.4, 7<sup>th</sup> edition, same)

Mixed Claisen reactions can be carried out by the reaction of two different esters. Only one ester can have alpha protons. Give the product of the following reaction.

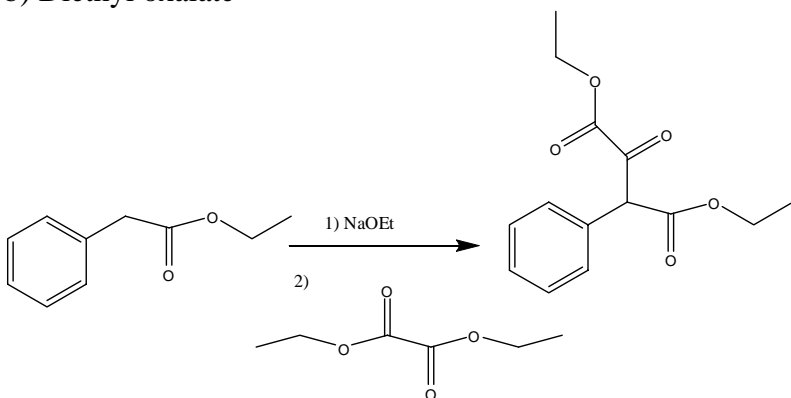


(6<sup>th</sup> edition, Problem 21.3, 7<sup>th</sup> edition, same) Give the structure of the product obtained when ethyl phenylacetate is treated with each of the following esters under conditions of the mixed Claisen condensation:

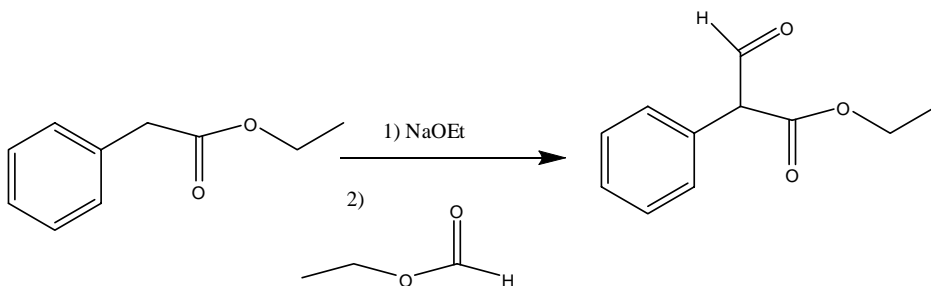
a) Diethyl carbonate



b) Diethyl oxalate

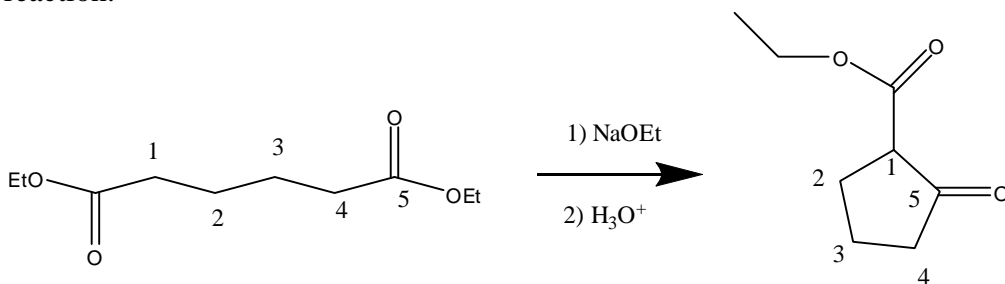


c) Ethyl formate



Dieckmann reaction (6<sup>th</sup> edition, Chapter 21.3, 7<sup>th</sup> edition, same)

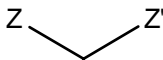
The Dieckmann reaction is an intramolecular Claisen condensation. Formation of 5 or 6 membered rings are seen in this class. Give the product of the following reaction.



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Active hydrogen compound (Not in your book.)

An active hydrogen compound is defined as a methylene group (CH<sub>2</sub>) with two electron drawing groups next to the methylene group. A standard example is shown below.

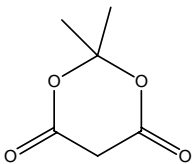


Z and Z' can be the same group or different groups. Some examples of possibilities for Z and Z' are (this list is not complete) some of the following:

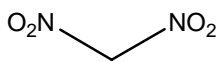
Any carbonyl including ketone    ester    aldehyde

Other groups besides carbonyls nitro cyano

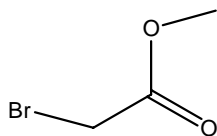
Some examples are shown below.



Meldrum's acid



Dinitromethane



Methyl  $\alpha$ -bromoacetate

How active hydrogen compounds react (Not in your book.)

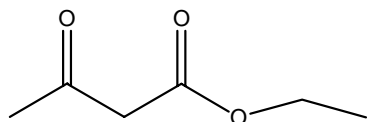
All active hydrogen compounds react at the CH<sub>2</sub> group between the two electron withdrawing groups. The protons on this carbon are very acidic (the pK<sub>a</sub> differs depending on the electron withdrawing groups) and are usually below a pK<sub>a</sub> of 10. Reaction with even a weak base can form appreciable amounts of a nucleophile. A nucleophile can then undergo reactions covered in class including: nucleophilic substitution (S<sub>N</sub>2) of methyl, primary, and some secondary halides, nucleophilic addition to aldehydes and ketones, nucleophilic acyl substitution of carboxylic acid derivatives or nucleophilic conjugate addition (MICHEAL reaction.).

Specific Active Hydrogen compounds

Acetoacetic Ester (6<sup>th</sup> edition, Chapter 21.7, 7<sup>th</sup> edition, same)

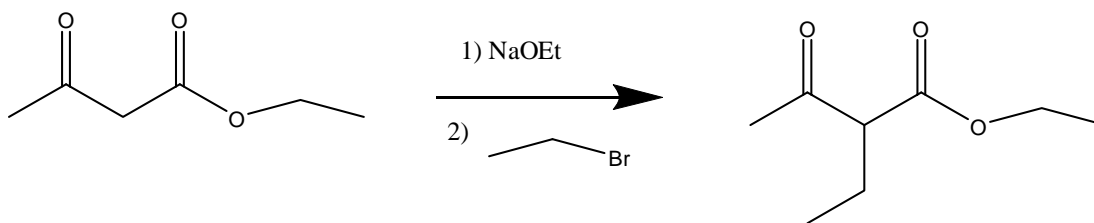
a) One Z group is a ketone and one is an ester

The compound below can be named using three different methods. The first method is to name it acetoacetic ester. It does not influence the reaction if it is a methyl ester, ethyl ester, etc. The second method to name it is to call it ethyl acetoacetate. This names the ethyl ester and an aceto group on an acetate group. This name can be shorted to ethyl acac. Finally, the compound can be called Ethyl 3-oxobutanoate.

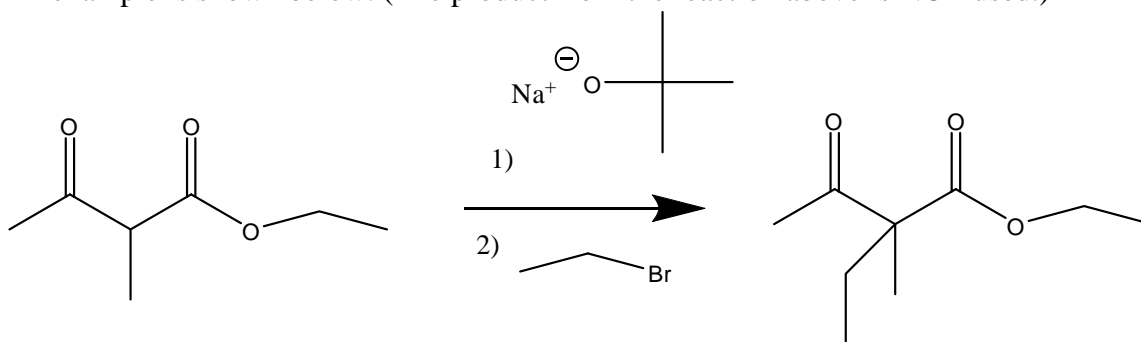


Nucleophilic substitution of Ethyl acac (6<sup>th</sup> edition, pg. 927, 7<sup>th</sup> edition, pg. 890)

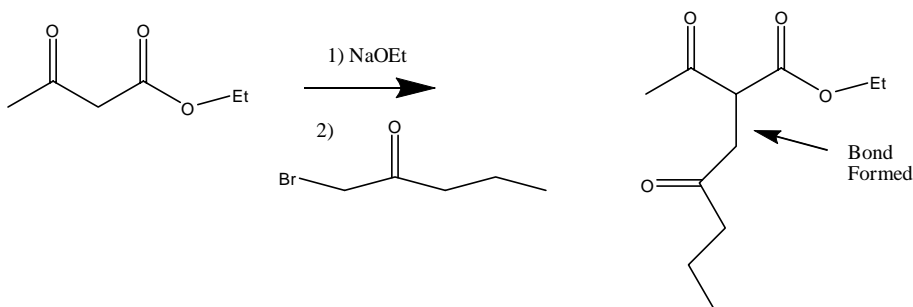
The major use of ethyl acac is to make substituted acetones. Ethyl acac contains four carbons not including the ethyl ester group. Removal of CO<sub>2</sub> from ethyl acac gives acetone. An example of this reaction is shown below.



The same base (sodium ethoxide) as the ester (Ethyl) has to be used to remove the proton in the first step. Use of sodium hydroxide would cleave the ester and can not be used. Once the first group has been added, the proton between the two carbonyls is less acidic and a stronger base must be used. In most cases, the base is sodium or potassium tert-butoxide. Tert-butoxide is a bulky base and will not readily add to either carbonyl. An example is shown below. (The product from the reaction above is NOT used.)



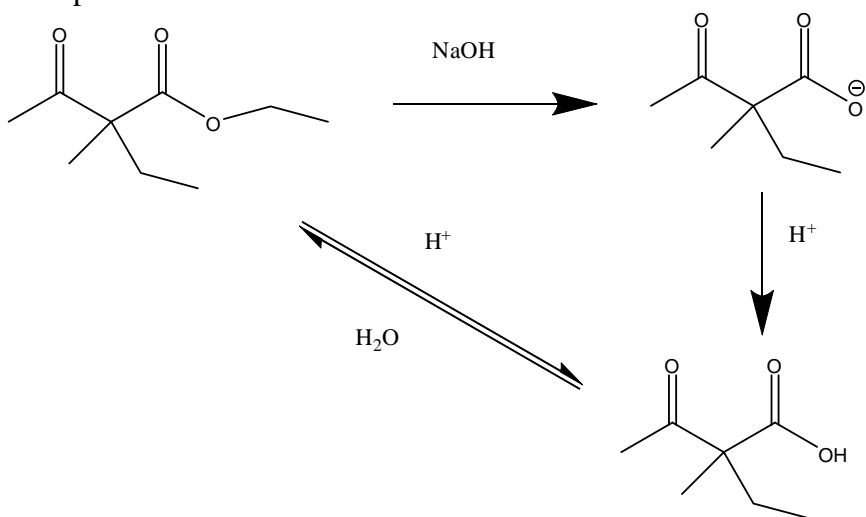
The alkyl halides used for the nucleophilic substitution can be varied to form MANY different products. An example is shown below.



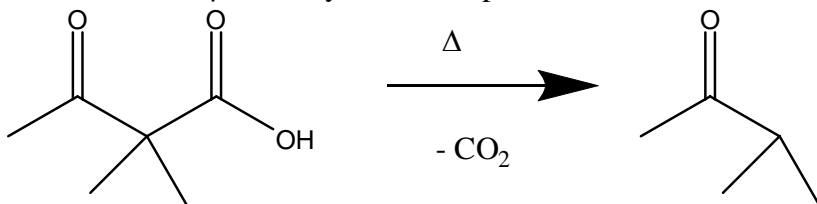
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Removal of the carboxylic acid and conversion to substituted acetones (6<sup>th</sup> edition, pg. 927, 7<sup>th</sup> edition, pg. 890)

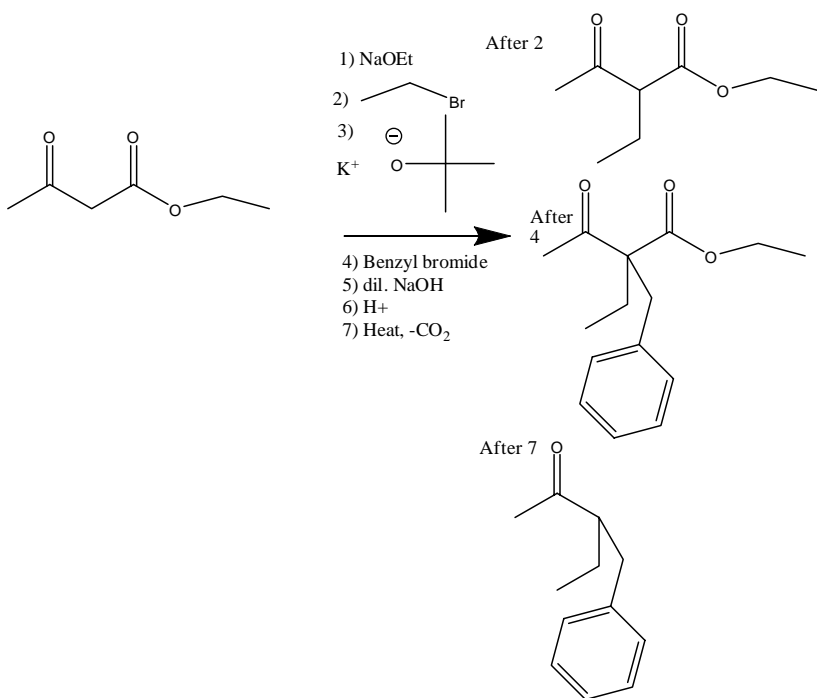
Once one or two groups have been added to the methylene group, the ester group is hydrolyzed. The ester group can be hydrolyzed in one step under acidic conditions or in two steps under basic conditions. Basic conditions, even though it requires two steps, is usually preferred due to not being reversible. Acidic conditions are reversible. An example is shown below.



The final step in the synthesis of substituted acetones from ethyl acac is removal of the carboxylic group as CO<sub>2</sub> by adding heat. The carboxylic acid group can be lost because it has a β-carbonyl. An example is shown below.



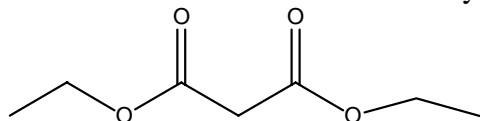
Conversion from ethyl acac to substituted acetones requires SEVEN steps. At first glance, the steps look intimidating. However, take each step separately to form the product. The first, third, and sixth steps are just acid/base reactions. Steps two and four are S<sub>N</sub>2 reactions. Step five is nucleophilic acyl substitution. Finally, step seven is decomposition of the acid to form the product. An example of all seven steps is given below.



Malonic Ester (6<sup>th</sup> edition, Chapter 21.8, 7<sup>th</sup> edition, same)

b) Both Z groups (see above) are ester groups

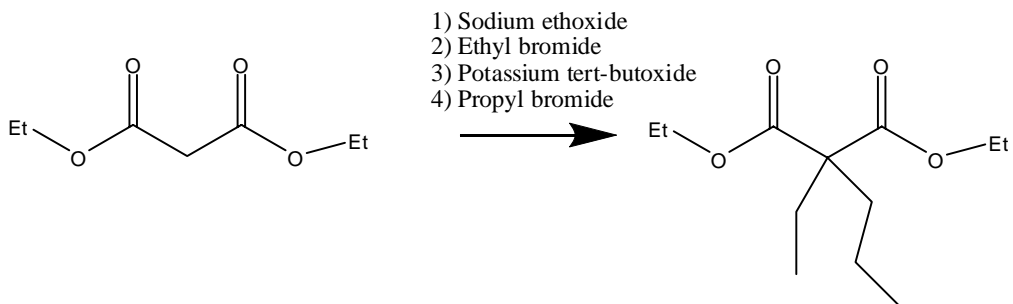
When both electron withdrawing groups on an active hydrogen compound are esters, the compound is called malonate. The reactions of malonate esters are called the malonic ester synthesis. The acetoacetic ester synthesis furnishes substituted acetones while the malonic ester synthesis forms substituted acetic acids. The ester groups do not influence the reaction and can be anything but are most usually ethyl groups.



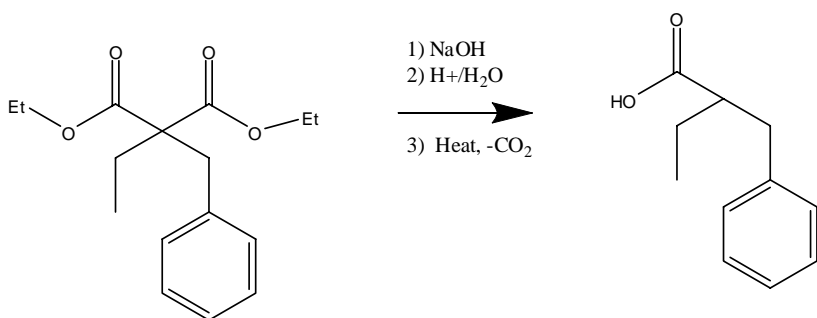
Diethylmalonate

Nucleophilic substitution of diethyl malonate (6<sup>th</sup> edition, pg. 930, 7<sup>th</sup> edition, pg. 892)

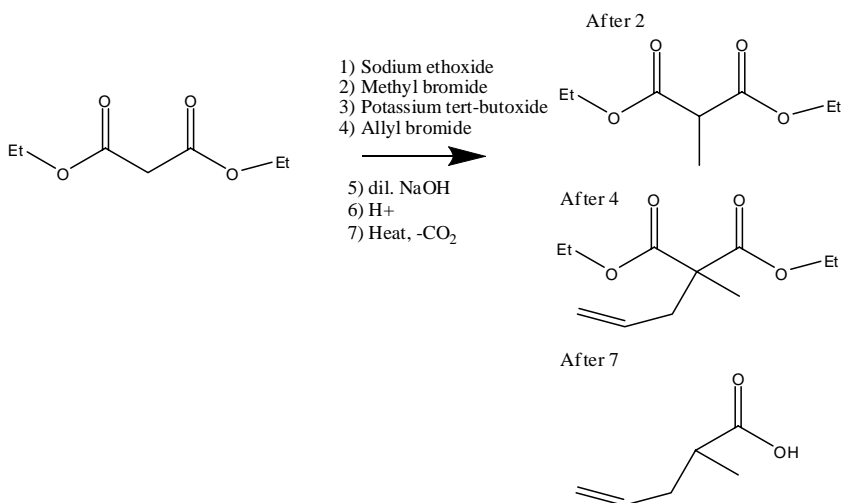
Diethyl malonate will undergo nucleophilic substitution in a fashion similar to Ethyl acac. An example is shown below. Et stands for ethyl.



Removal of the carboxylic acid group and conversion to substituted acetic acids



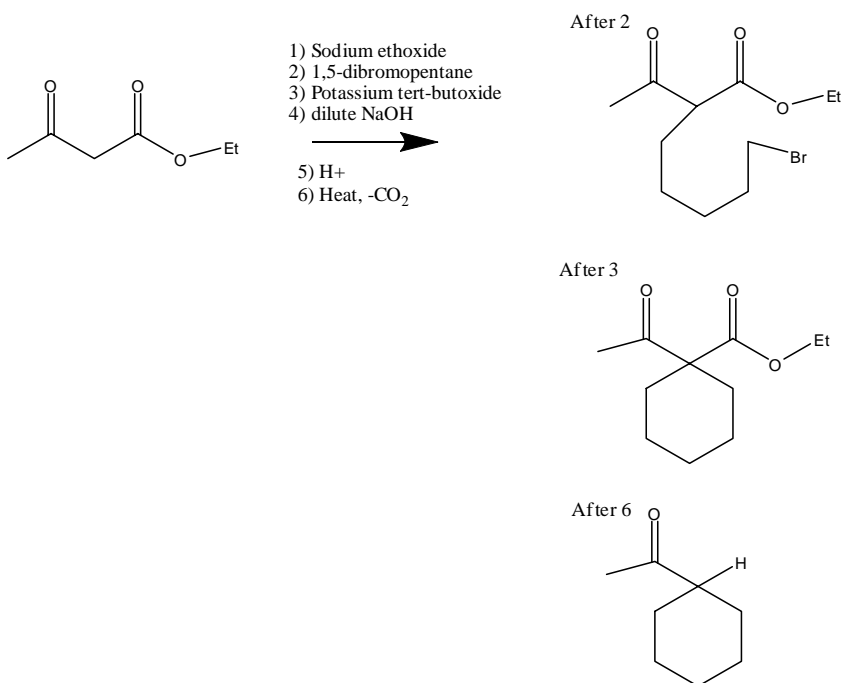
An example with all seven steps using diethyl malonate is given below. Again, take each step separately to form the product.



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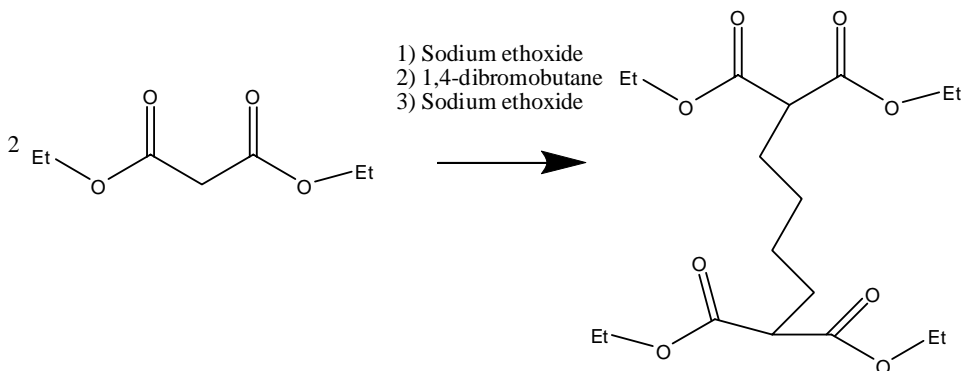
Dinucleophilic substitution using ONE mole of ethyl acac or diethylmalonate (6<sup>th</sup> edition, pg. 931, 7<sup>th</sup> edition, pg. 894)

Nucleophilic substitution can be carried out on a dihalide if ONE mole of ethyl acac is used. A ring is formed with one carbon of the ring coming from the ethyl acac or diethyl malonate. For example, if 1,3-dibromopropane is used, cyclobutane is formed. If 1,4-dibromobutane is used, cyclopentane is formed. An example is shown below with ethyl acac.

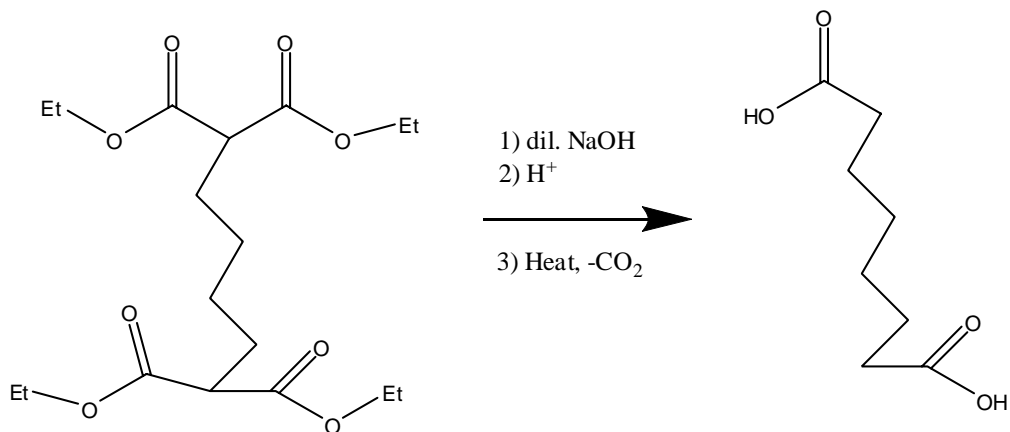


Dinucleophilic substitution with TWO moles of ethyl acac or diethyl malonate (Not in your book.)

Disubstitution with two moles of ethyl acac or diethyl malonate does not form a ring as shown above. It forms a long chain and will allow removal of more than one carboxylic acid group. An example is shown below with diethyl malonate.



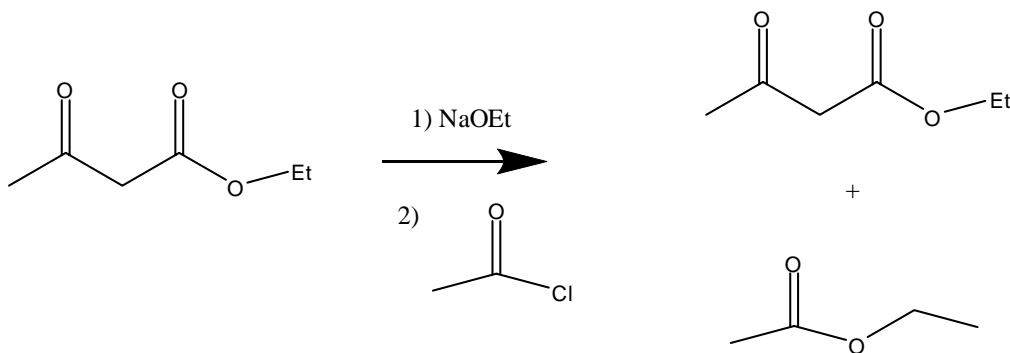
The molecule formed above can then be hydrolyzed with sodium hydroxide, acid, and two moles of carbon dioxide can be lost. The reaction is continued below.



Nucleophilic Acyl substitution with the enolate of Ethyl acac (Not in your book.)

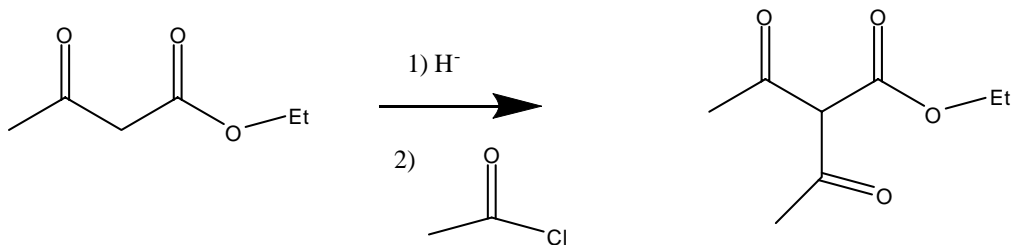
All of the reactions shown so far have used the base that corresponds to the ester. All of the reactions so far have also been nucleophilic substitutions. Enolates can also undergo nucleophilic acyl substitutions but the correct base is **IMPERATIVE**.

Ethyl acac and acetyl chloride with the **WRONG** base



Ethoxide removes the proton and forms ethanol. Ethanol then reacts with the acid chloride to form the ester. Ethyl acetoacetate is recovered unchanged.

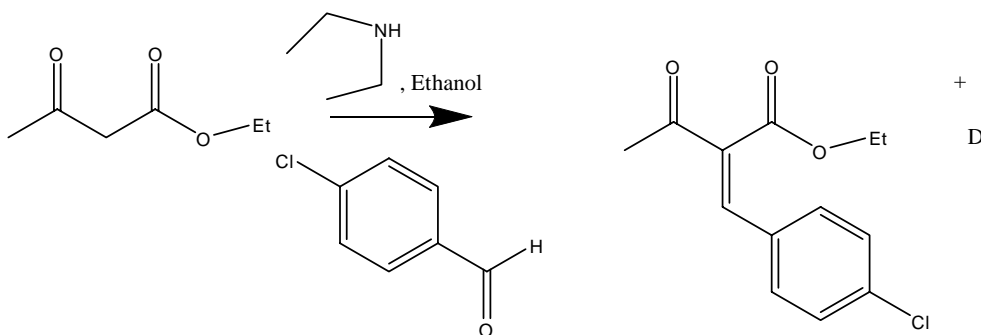
Ethyl acac and acetyl chloride with the **CORRECT** base



Hydride removes the proton and forms  $\text{H}_2$ . This gas then bubbles out of the solution and does not react with the acid chloride (as shown above.)

Nucleophilic addition of active hydrogen compounds with aldehydes or ketones (called a Knoevenagel reaction) (Not in your book.)

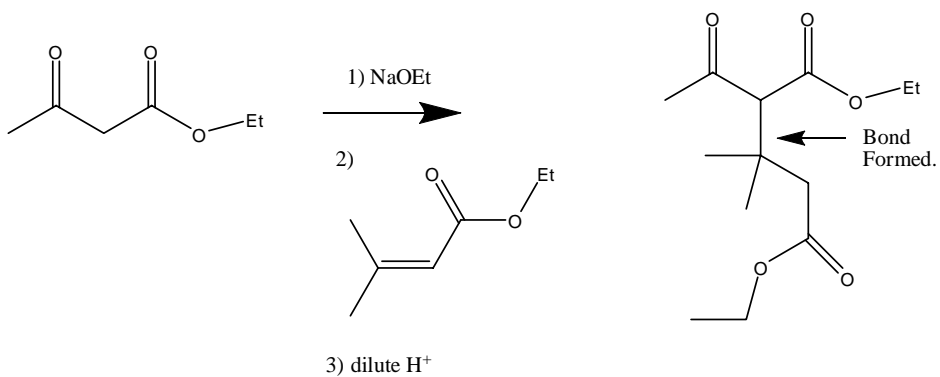
Reaction of an active hydrogen compound with an aldehyde or ketone reacts via a nucleophilic addition mechanism. In most cases, the addition product is not isolated and the condensation product is formed instead. An example is shown below with ethyl acac.



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Michael Additions of Active hydrogen compounds (6<sup>th</sup> edition, Chapter 21.9, 7<sup>th</sup> edition, same)

Active hydrogen compounds can add in conjugate fashion to  $\alpha,\beta$ -unsaturated molecules as shown below.



Reaction of ethyl acac with TWO equivalents of a strong base ( $\text{NH}_2^-$ ) (6<sup>th</sup> edition, not covered, 7<sup>th</sup> edition, pg. 903)

Ethyl acac reacts with two equivalents of a strong base to form a dienolate. The more reactive enolate from the methyl group can do nucleophilic substitution as shown below.

