

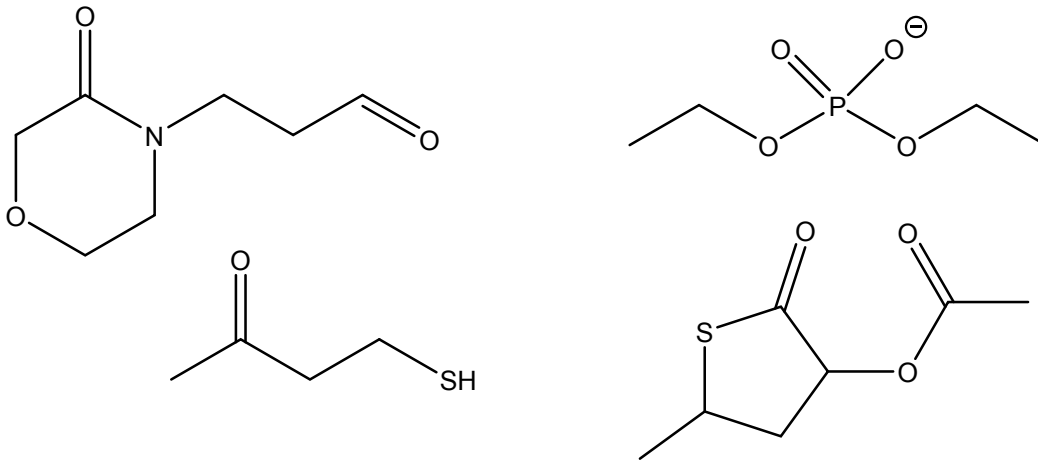
### Discussion Exercise 3: Hydrolysis Reactions

#### Skill 1: Recognize functional groups that are hydrolyzed

- Carboxylic acid derivatives are able to be hydrolyzed under catalytic conditions (acid, base, enzyme). The derivatives common in biochemistry are amides, esters, thioesters, phosphomonoesters, phosphodiester, and phosphoanhydrides.
- Ketone/aldehyde derivatives are able to be hydrolyzed under catalytic conditions (acid, enzyme). The derivatives common in biochemistry are hemiacetals, acetals, and imines.

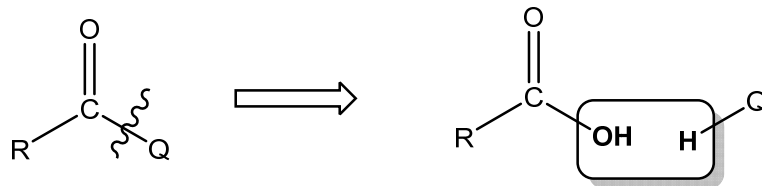
Problem 1: Draw example molecules that contain amide, ester, thioester, phosphodiester, and phosphoanhydride functional groups.

Problem 2: In the molecules below, label all hydrolysable functional groups.

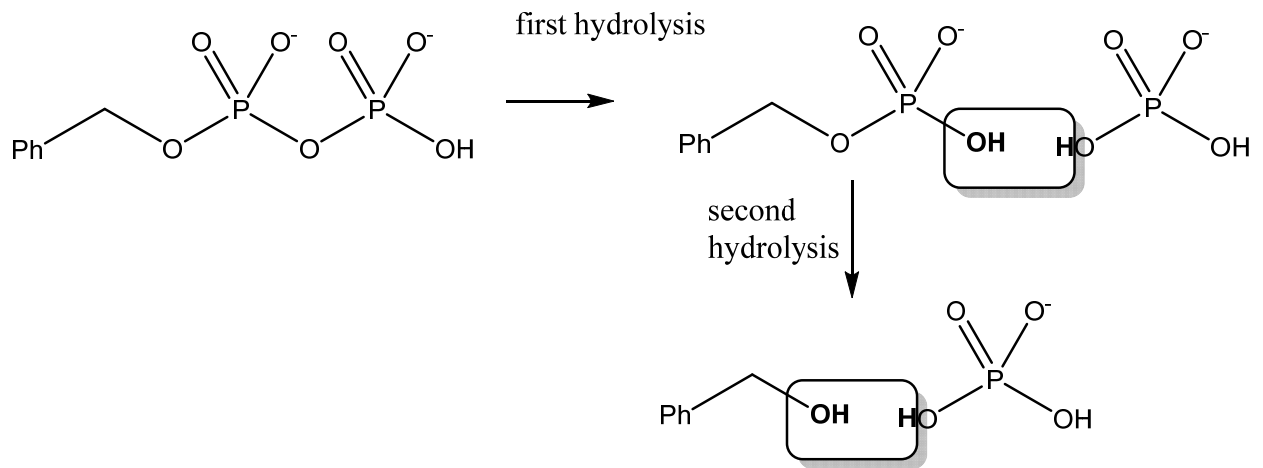
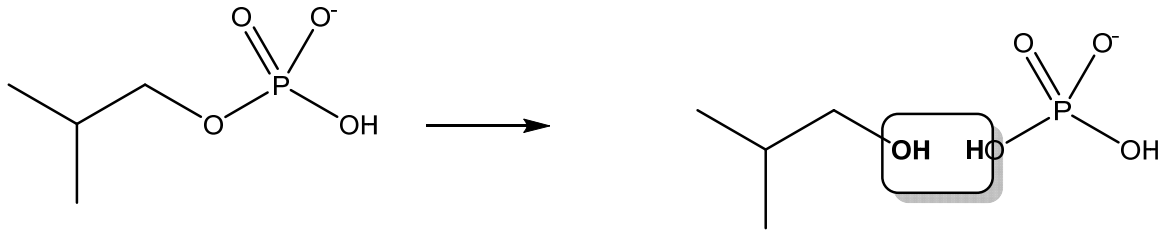


#### Skill 2: Predict the products of the hydrolysis of carboxylic acid derivatives

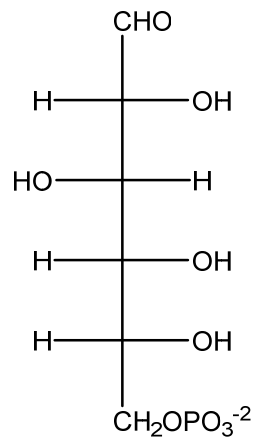
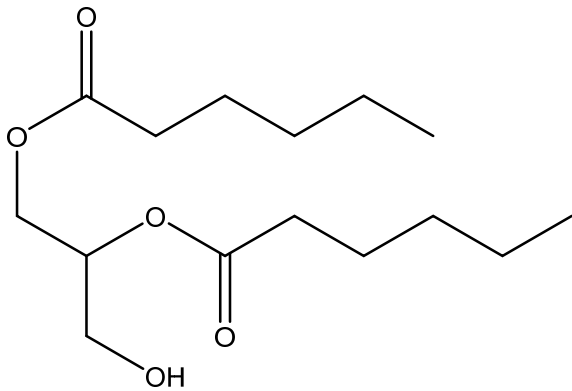
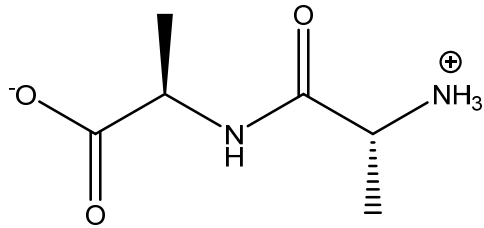
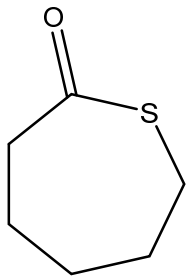
- Hydrolysis is the breaking of a bond with water, so the products have added two hydrogen atoms and an oxygen atom.
- The general form of the reaction is given below. “Q” is the attached heteroatom. For instance, in an amide, Q=N. In a thioester, Q=S. In an ester, Q=O. You can apply this reaction to any carboxylic acid derivative.



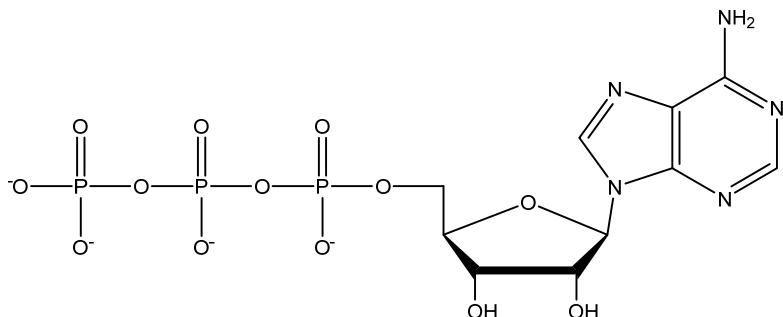
- This also applies to phosphate esters and anhydrides.



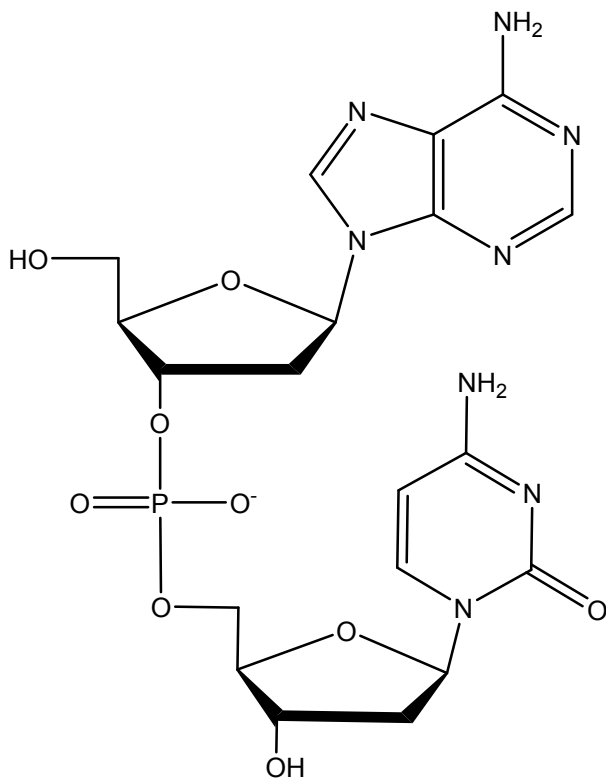
**Problem 3:** Predict the products of these hydrolysis reactions.



**Problem 4:** A phosphoanhydride bond of ATP can be hydrolyzed to give AMP and pyrophosphate. Draw the structure of pyrophosphate in its major ionization state at pH 7. . (pKa values 1-4 for pyrophosphate are 0.91, 2.10, 6.70. and 9.32.)

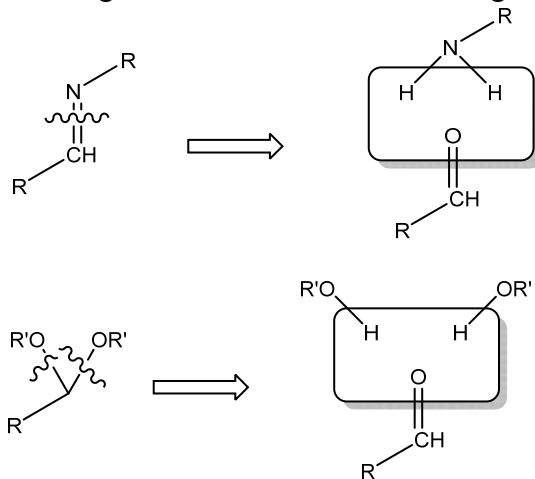


**Problem 5:** Phosphodiesterases can be hydrolyzed on either side of the phosphate functional group to give a phosphate monoester and an alcohol. Draw the two possible products that form when the diester is hydrolyzed.

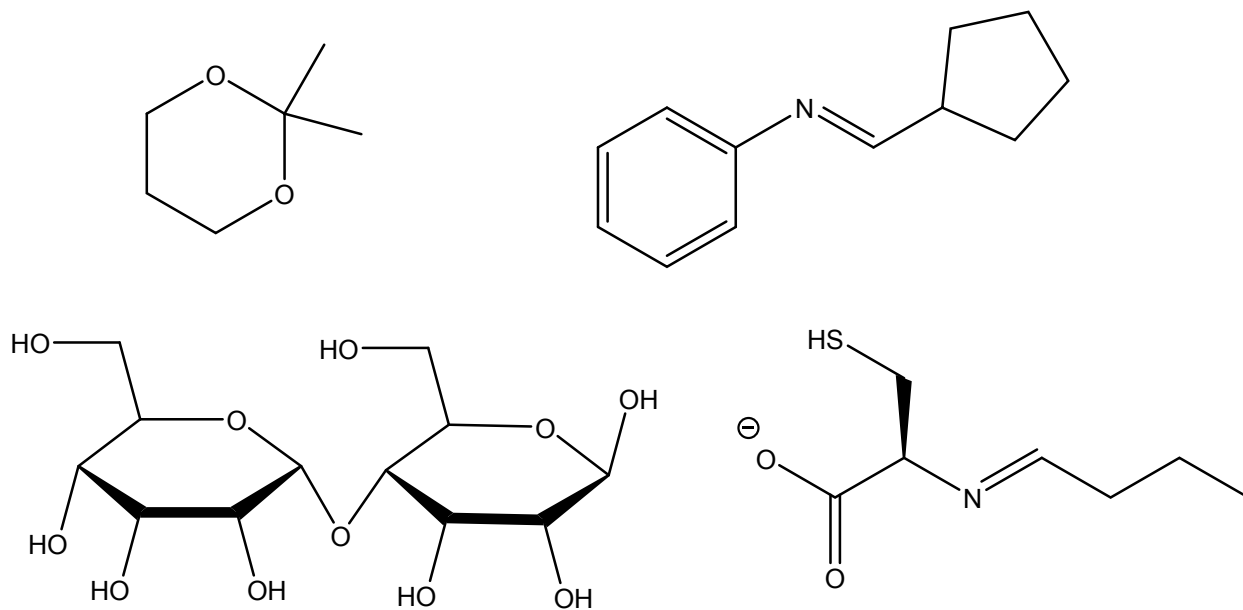


**Skill 3: Predict the products of the hydrolysis of ketone/aldehyde derivatives**

- Hydrolysis is the breaking of a bond with water, so the products have added two hydrogen atoms and an oxygen atom.
- The hydrolysis products of general imines and acetals are given below.



**Problem 6:** Predict the hydrolysis products of each of these compounds.



**Problem 7:** Proteases are enzymes that hydrolyze polypeptides. Trypsin is a protease that specifically hydrolyzes the peptide bond on the carboxy side of positively charged side chains. Draw the full structure of the trypsin hydrolysis products of ASKW.

Problem 8: Nucleases are enzymes that hydrolyze oligonucleotides. Draw the full structures of the hydrolysis products of pApCpUp if the nuclease only cuts the 3' phosphodiester linkage after purines.