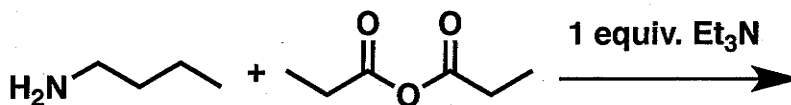


**General Instructions:**

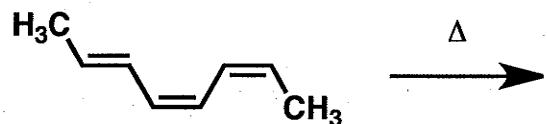
- (i) Use scratch paper at back of exam to work out answers; final answers must be recorded at the proper place on the exam itself for credit.
- (ii) Print your name on each page.

1. (18 points) Show the major product or products expected from each reaction:

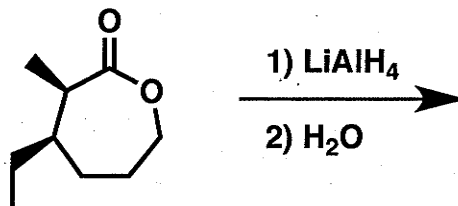
(a)



(b)



(c)

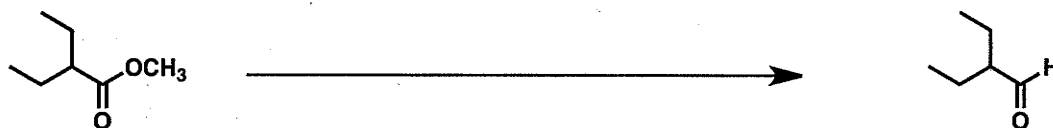


2. (24 points) Show the reagents and other organic molecules required to convert the starting material to the indicated product. Be sure to differentiate clearly between distinct steps by using "1)", "2)", etc.

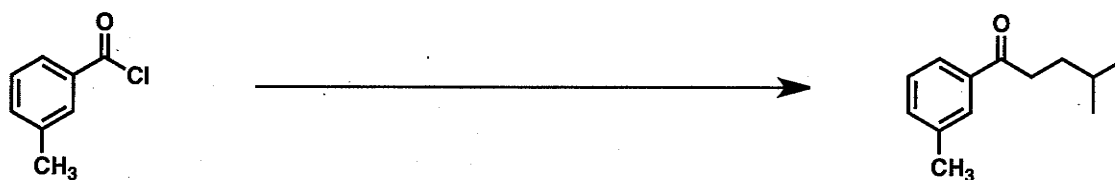
(a)



(b)



(c)

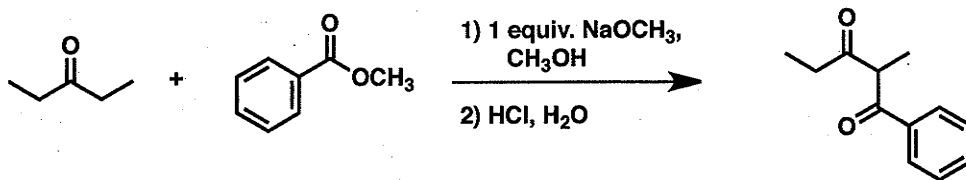


(d)

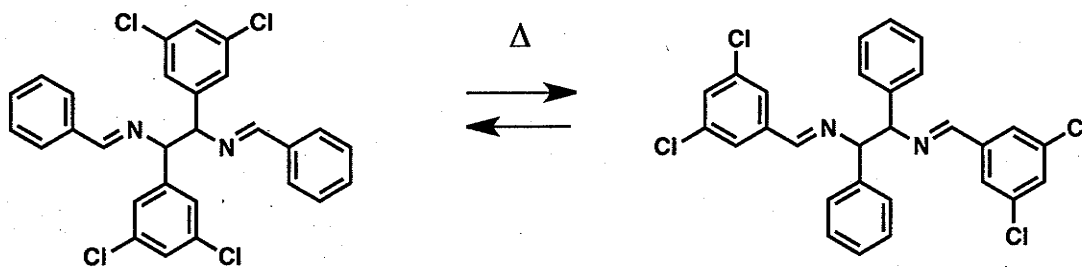


3. (17 points) Draw out a mechanism ("curved arrows") for each reaction shown below. Be sure to show all important resonance structures in intermediates.

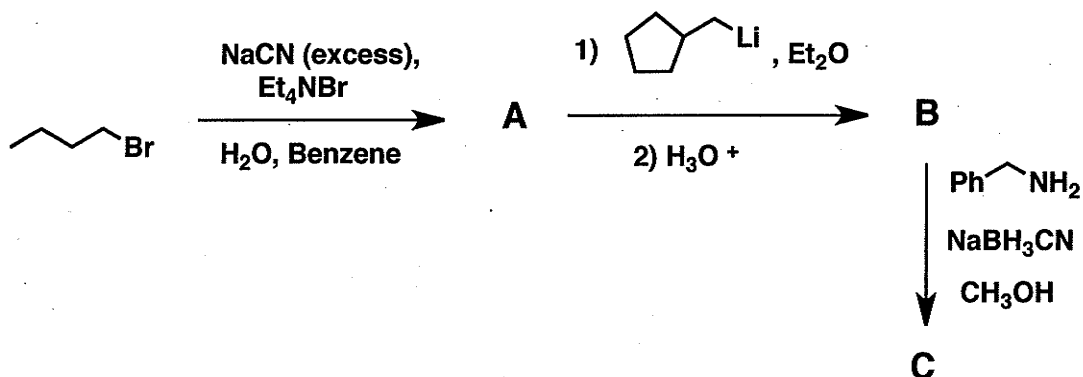
(a)



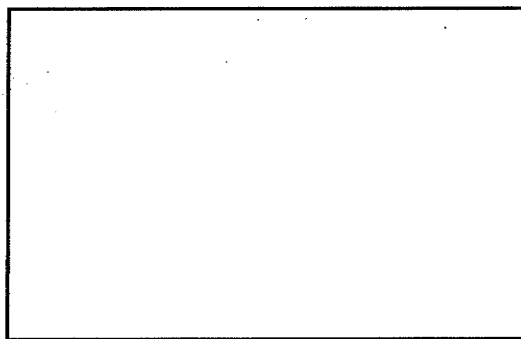
(b)



4. (21 points) Consider the reaction sequence below. Give the structures of compounds A, B and C in the appropriate boxes.

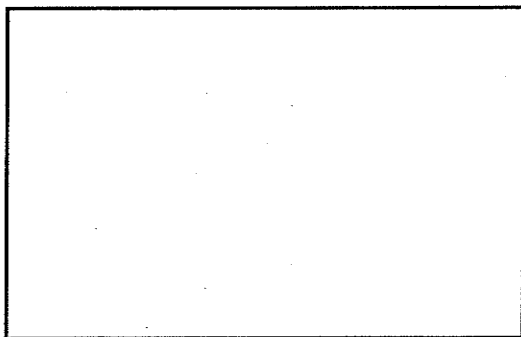


A =



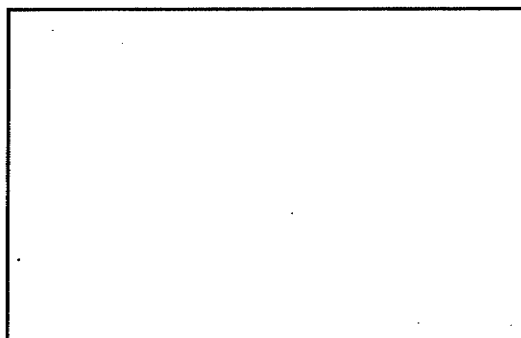
Strong IR signal  
at  $2240\text{ cm}^{-1}$

B =



Strong IR signal  
at  $1725\text{ cm}^{-1}$

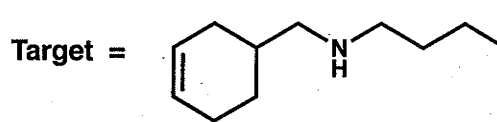
C =



Moderate IR signal  
at  $3350\text{ cm}^{-1}$

In each case, circle  
the functional group  
that gives rise to the  
indicated IR signal.

5. (20 points) Propose an efficient synthetic route from starting material to target. You may use any other starting materials containing 4 or fewer carbons.



<u>Problem #</u>	<u>Score</u>
1	/ 18
2	/ 24
3	/ 17
4	/ 21
5	/ 20

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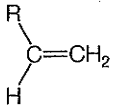
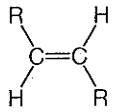
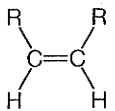
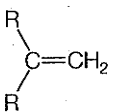
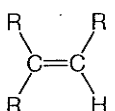
**Total:**

**/ 100**

Although this complexity may seem confusing at first, it is usually possible to gain a lot of information about the groups present in a molecule, even if we cannot assign all the bands, or draw a complete structure of the sample molecule. It is a great help in structure assignment to know what types of bonds are present in a molecule. There is also an important side benefit to these complicated IR spectra. The very complexity of the spectrum means that IR spectra of quite similar molecules are different. Each spectrum serves as a fingerprint of the molecule. If two IR spectra are identical (not similar—my old boss insisted on there being no difference greater than the width of the pen line drawn by the recorder) the compounds must be the same.

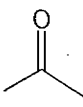
Table 15.3 gives the general positions of absorptions of a variety of functional groups, and once again we come to the question of memorization. Should one learn this chart by heart? Personally, I think not. It is important to know that this kind of general correlation exists, and you should have a rough idea of where some important functional groups absorb. If you come to use IR often you will automatically learn the relevant details of the chart, as you work out what the signals in your IR spectra tell you.

**TABLE 15.3** Typical Infrared Absorptions of Functional Groups<sup>a</sup>

Functional Group	Position (cm <sup>-1</sup> )	Intensity <sup>b</sup>
Alkanes		
C-H	2980-2850	m-s (stretch)
C-C	1480-1420	m (bend)
Alkenes		
=C-H	3150-3000	m (stretch)
C=C	1680-1620	m-w (stretch)
(conj) C=C	1630-1600	m-w (stretch)
	995-985 915-905	s (out-of-plane bend)
	980-960	s (out-of-plane bend)
	730-665	s (out-of-plane bend) (br, variable)
	895-885	s (out-of-plane bend)
	840-790	m (out-of-plane bend)

(continued)

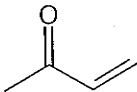
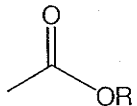
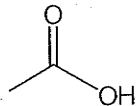
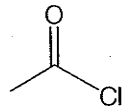
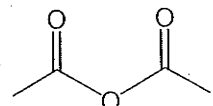
TABLE 15.3 Typical Infrared Absorptions of Functional Groups<sup>a</sup> (Continued)

Functional Group	Position (cm <sup>-1</sup> )	Intensity <sup>b</sup>
Alkynes		
≡C-H	3350-3300	s (stretch)
C≡C	2260-2100	m-w (stretch)
Alcohols		
O-H		
free	3650-3580	m (stretch)
hydrogen bonded	3550-3300	br, s (stretch)
C-O	1260-1000 1150-1050	s (stretch)
Amines		
N-H	3500-3100 (two bands for primary amines, one band for secondary amines)	br, m (stretch)
C-N	~1200	m (stretch)
Aromatic compounds		
=C-H	3080-3020	m-w (stretch)
C=C	1600-1580	m-w (stretch)
C-H		
mono	770-730 710-690	s (out of plane bend)
ortho	770-735	s (out-of-plane bend)
meta	900-860 810-750	m (out of plane bend) s (out-of-plane bend)
para	725-680 860-800	m (out-of-plane bend) s (out-of-plane bend)
Carbonyl compounds aldehydes, ketones		
	C=O	1730-1700 (higher in strained cyclic molecules)
		s (stretch)

(continued)



TABLE 15.3 Typical Infrared Absorptions of Functional Groups<sup>a</sup> (Continued)

Functional Group	Position (cm <sup>-1</sup> )	Intensity <sup>b</sup>
Carbonyl compounds aldehydes, ketones		
	1680–1660	s (stretch)
C–H (aldehydes)	2900–2700 (two bands)	w (stretch)
Esters		
	1750–1735 1300–1000	s (C=O) (stretch) s (C–O) (stretch)
Acids		
	1730–1700 3200–2800	s (C=O) (stretch) s, br (O–H) (stretch)
Acid chlorides		
	1820–1770	s (C=O) (stretch)
Anhydrides		
	1820–1750 (two bands) 1150–1000	s (C=O) (stretch) s (C–O) (stretch)
Imines		
C=N	1680–1640	m (stretch)
Cyanides (nitriles)		
C≡N	~2250	s (stretch)

<sup>a</sup>CAUTION! There certainly is some subjectivity in this table, and the values represent average positions for "normal" compounds. Conjugation generally lowers double-bond stretching vibrations by about 20 cm<sup>-1</sup>.

<sup>b</sup>Medium = m, strong = s, weak = w, broad = br.



