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Selected Organic Chemistry Problems with Answers, Part 1.

2017

Problem 1

0.1776 g of compound **1** (C₄H₁₀O₃) reacts with excess methylmagnesium iodide in diethyl ether. In the reaction 84.1 cm³ of methane is formed.

- How many acidic hydrogens does compound **1** possess?
- The IR spectrum of **1** does not show carbonyl absorption and the ¹H NMR spectrum contains three peaks with integral ratio of 1:2:2. What is the structure of **1**?

Solution:

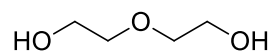
- Molecular weight of **1**: 106 g/mol (calculated on the basis of the formula given).

$$0.1776 \text{ g } \mathbf{1} = 1.67 \text{ mmol of } \mathbf{1}$$

$$V(\text{CH}_4) = 0.0841 \text{ dm}^3 \rightarrow 3.433 \text{ mmol CH}_4$$

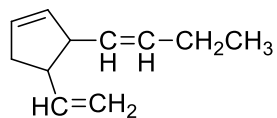
$$\text{Number of active hydrogen atoms} = n(\text{CH}_4)/n(\mathbf{1}) = 3.433 / 1.67 = 2$$

- The structure of **1**:



Problem 2

Structure of multifidene is shown below.



- How many stereoisomers of multifidene can exist?
- How many stereoisomers are possible given that the molecule has a *cis* relationship between alkenyl substituents?
- Given that the butenyl group has the *Z* configuration, and that the above mentioned *cis* relationship is valid, how many stereoisomers of multifidene are possible.
- Draw the structures which are fulfilling both criterions b) and c).
- Identify the relationship between the stereoisomers of point d).

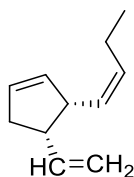
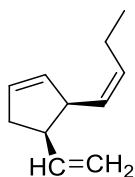
Solution:

a) 8

b) 4

c) 2

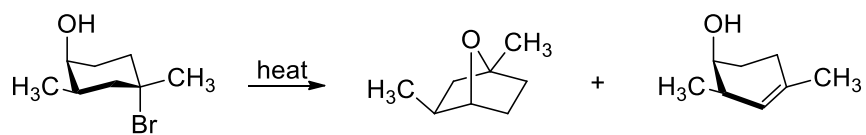
d)



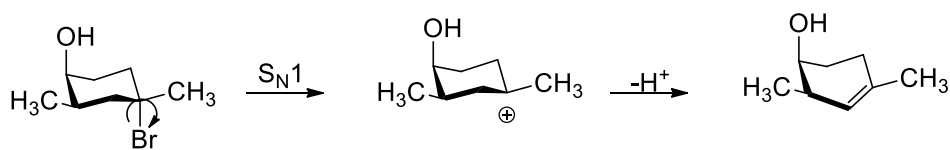
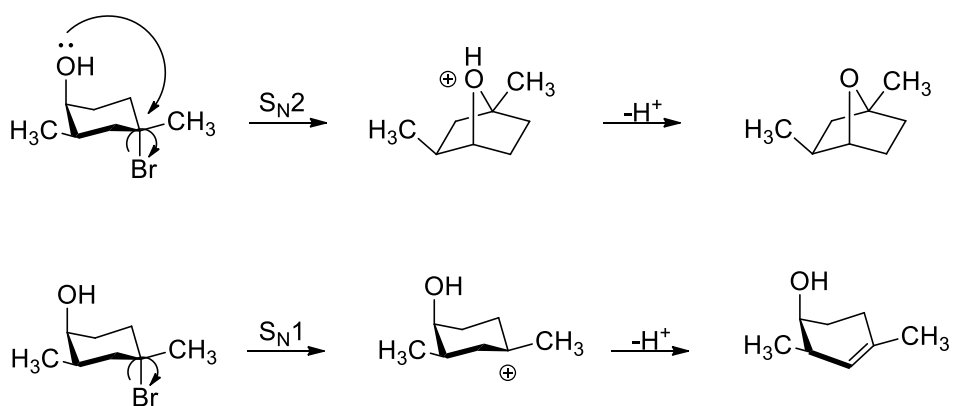
e) Enantiomers.

Problem 3

Provide a plausible mechanism for the following reaction. Show all the elementary steps using the curved arrow presentation.

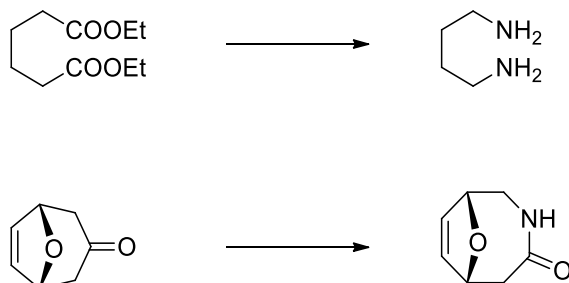


Solution:



Problem 4

The following transformations occur in 1-3 steps. Choose correct reagent combination for both reactions from options a)-d).



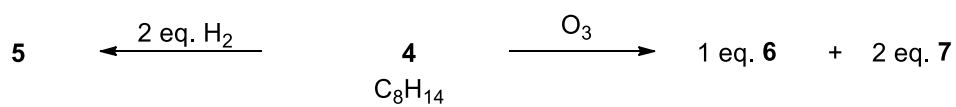
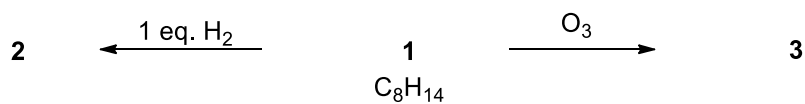
- a) 1. $\text{C}_6\text{H}_5\text{COOOH}$, CH_2Cl_2 ; 2. LiAlH_4 , diethyl ether; 3. H_2O
- b) 1. NH_2OH ; 2. strong acid or PCl_5
- c) NH_4OH , NH_4Cl , H_2O , reflux
- d) 1. N_2H_4 (excess); 2. HNO_2 , H_3O^+ , $5\text{ }^\circ\text{C}$

Solution:

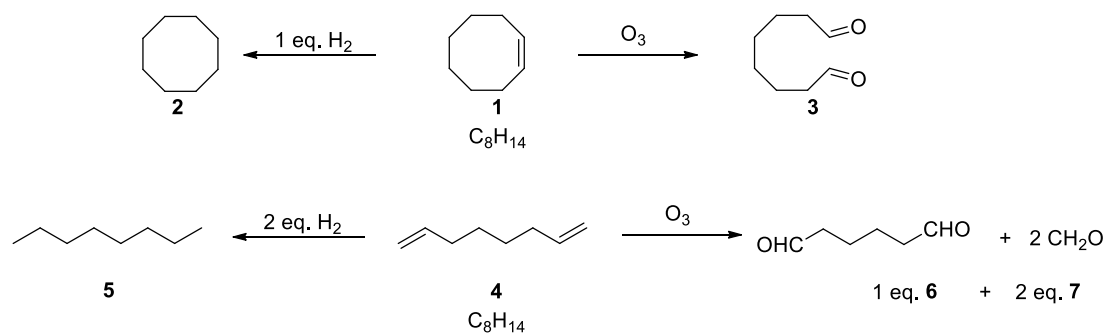
d, b

Problem 5

Deduce the identity of the missing compounds (1-7) in the following reaction sequences.



Solution:



Problem 6

Gramicidine S is a polipeptide with a molecular weight of approximate 1300 Da.

The hydrolysis products (cc HCl, 6 h) of the peptide are L-Leu, L-Orn, D-Phe, L-Pro, L-Val. [L-Ornithine (Orn) is a rare amino acid of formula

$^+H_3NCH_2CH_2CH_2CH(NH_2)COO^-$.] Partial hydrolysis of the peptide results in the following fragments: Leu-Phe, Phe-Pro, Orn-Leu, Val-Orn, Phe-Pro-Val, Val-Orn-Leu, Pro-Val-Orn.

End group analysis for the C terminus is negative; identification of the N terminus using DNFB gives only one product: DNP-NH-CH₂CH₂CH₂CH(NH₃⁺)COO⁻.

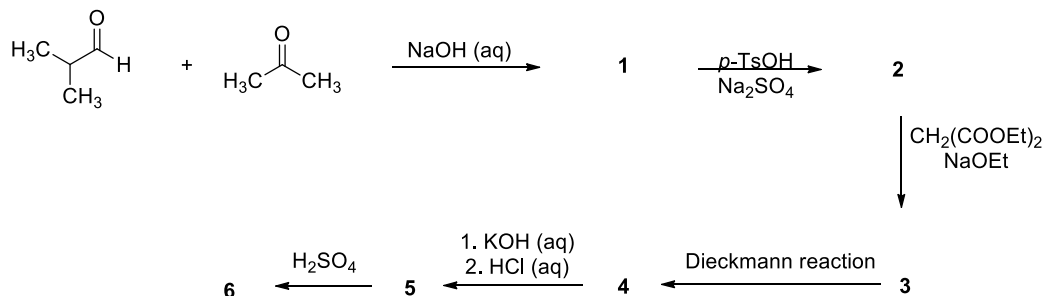
Determine the amino acid sequence of Gramicidine S.

Solution:

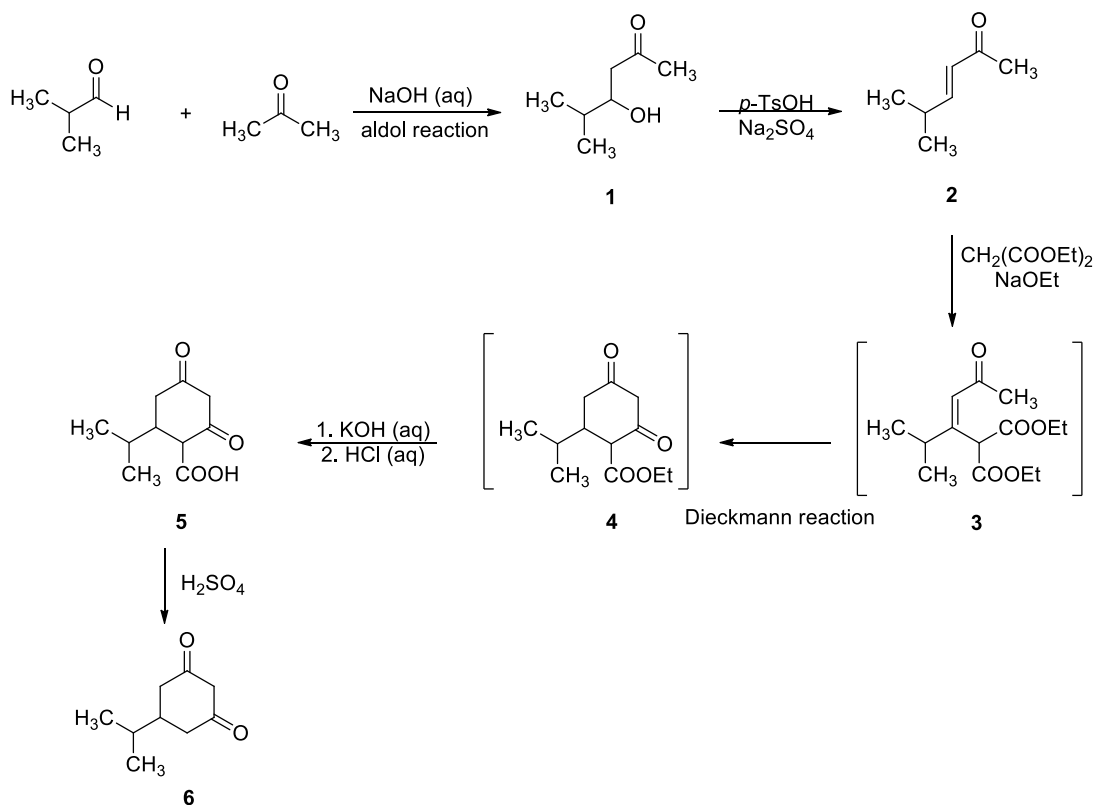
-cyclo(Leu-Phe-Pro-Val-Lys-Leu-Phe-Pro-Val-Lys)-

Problem 7

Deduce the structure of the missing compounds (1-6) in the following reaction sequences.

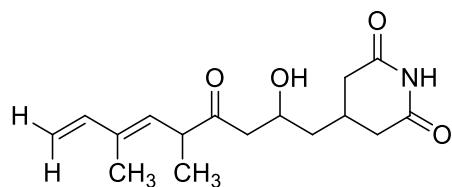


Solution:



Problem 8

Constitutional formula of streptimidone is shown below.

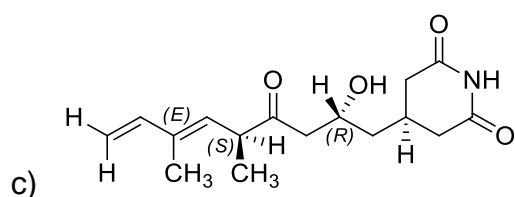


- How many diastereomers of streptimidone are possible?
- How many enantiomers?
- Draw the stereoisomer, in which the double bond has an *E* configuration, the absolute configuration of the chiral carbon atom near the double bond is *S*, and the other chiral carbon has *R* absolute configuration.

Solution:

a) 8

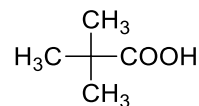
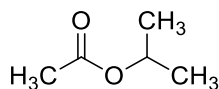
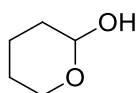
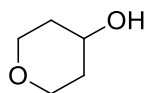
b) 4



Problem 9

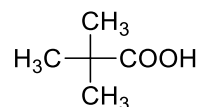
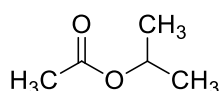
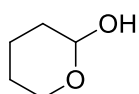
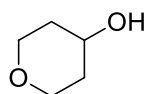
The four constitutional isomers shown below 1-4 were treated with three reagents. The test results are indicated in the table below the formulas.

Pair the numbers with the structure.



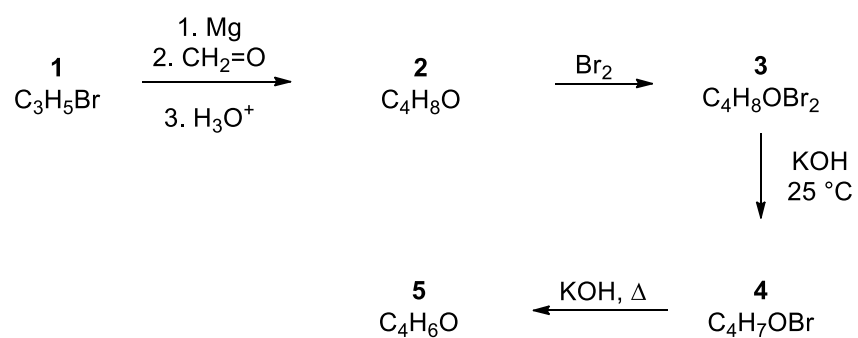
	5 % NaHCO ₃ (aq)	Tollens` reagent (AgNO ₃ in NH ₄ OH)	Jones` reagent (CrO ₃ in H ₃ O ⁺)
1	No change	No change	No change
2	No change	Precipitation of elementar silver. ("silver mirror")	The color of the reagent changes to green.
3	Gas evolves, which makes the Ca(OH) ₂ solution opalescent.	No change	No change
4	No change	No change	The color of the reagent changes to green.

Solution:



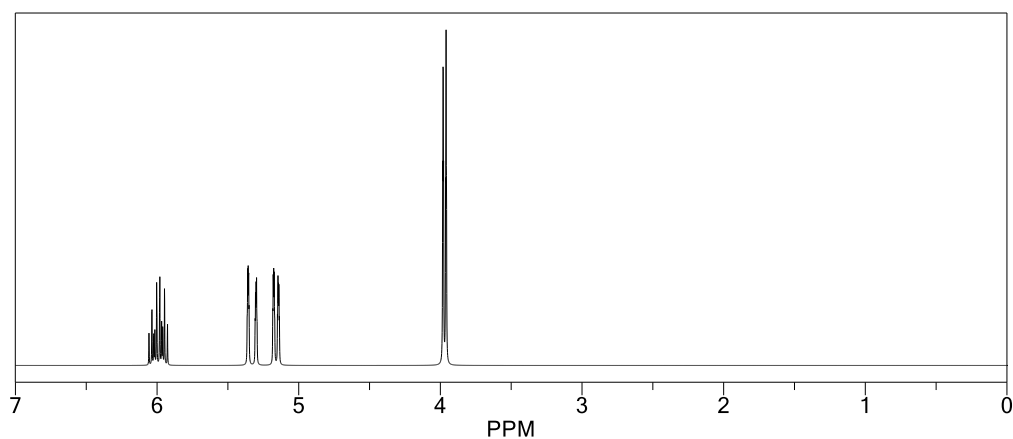
Problem 10

What is the structure of compounds **1-5** in the following scheme?

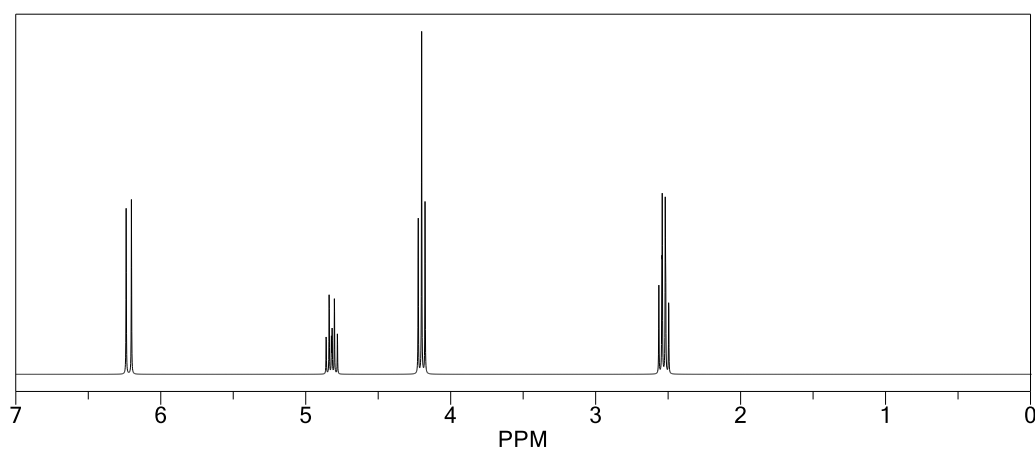


Based on the ^1H NMR spectra match the hydrogen atoms to the corresponding ^1H NMR peak.

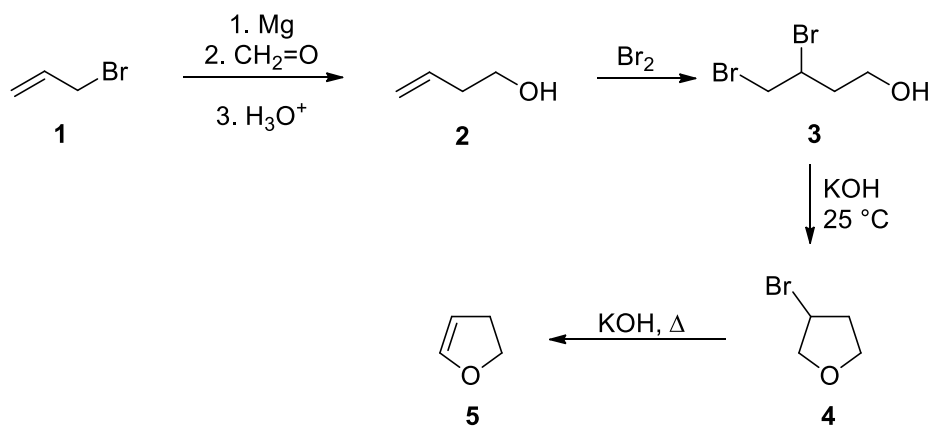
^1H NMR spectrum of **1**:



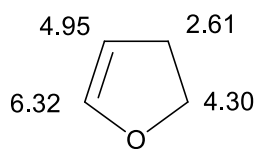
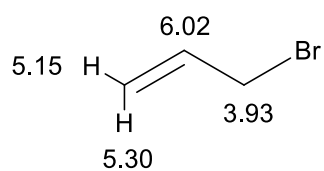
^1H NMR spectrum of **5**:



Solution:

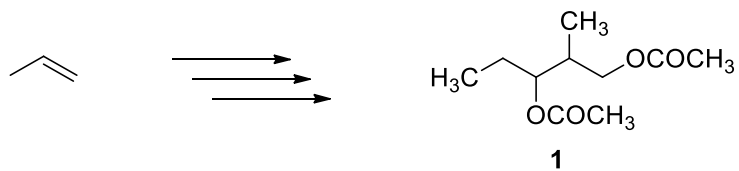


NMR assignments:

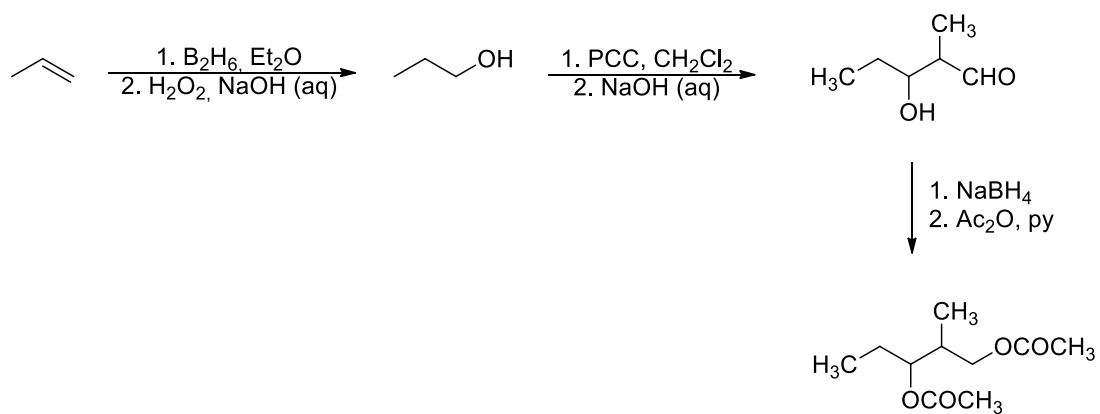


Problem 11

Propose a synthetic route to the molecule **1**. Use propene as starting material.

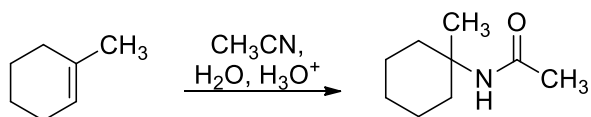


Solution:

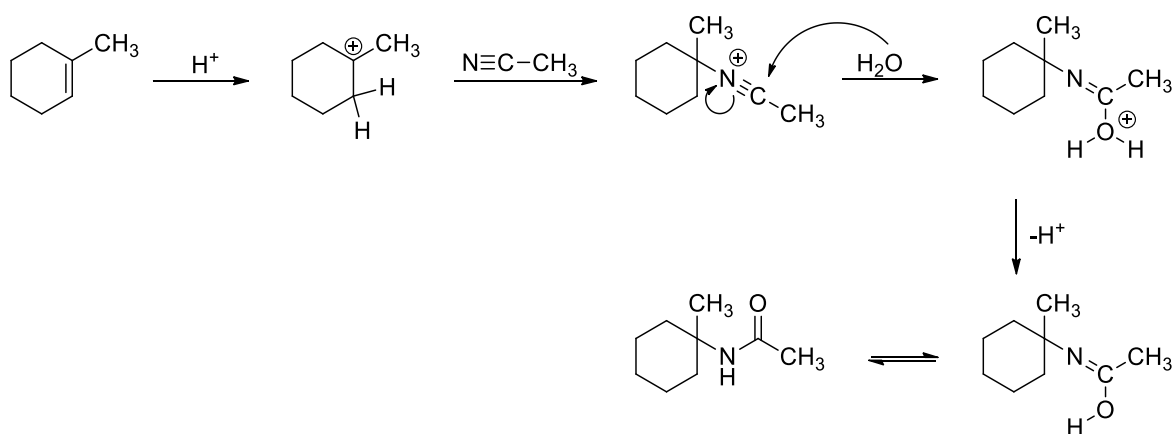


Problem 12

Provide a plausible mechanism for the following reaction. Show all the elementary steps using the curved arrow presentation.



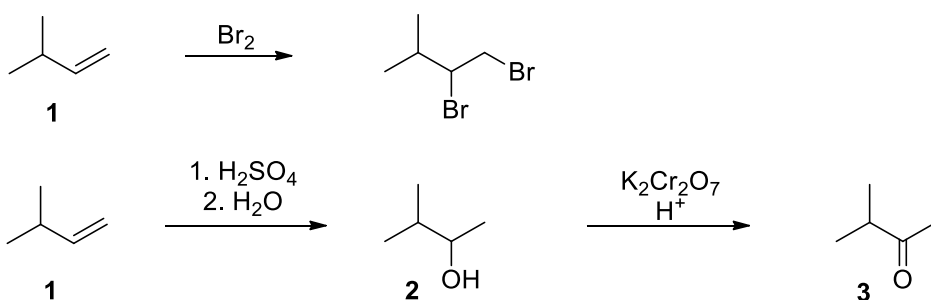
Solution:



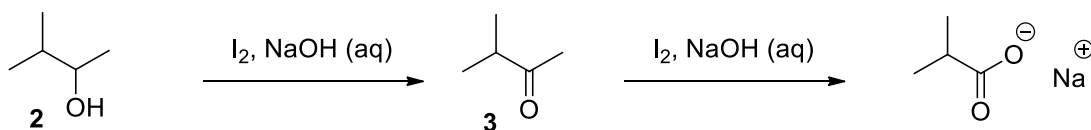
Problem 13

Compound **1** (C₅H₁₀) reacts with 1 equivalent of bromine in CCl₄. **1** also reacts with conc H₂SO₄ and after heating with water (aqueous work-up) it gives **2** (C₅H₁₂O). **2** is treated with chromic acid (H₂Cr₂O₇) to yield **3** (C₅H₁₀O). Both **2** and **3** give positive iodoform tests, forming isobutyric acid (C₄H₈O₂). Propose the structure of **1**, **2** and **3**.

Solution:



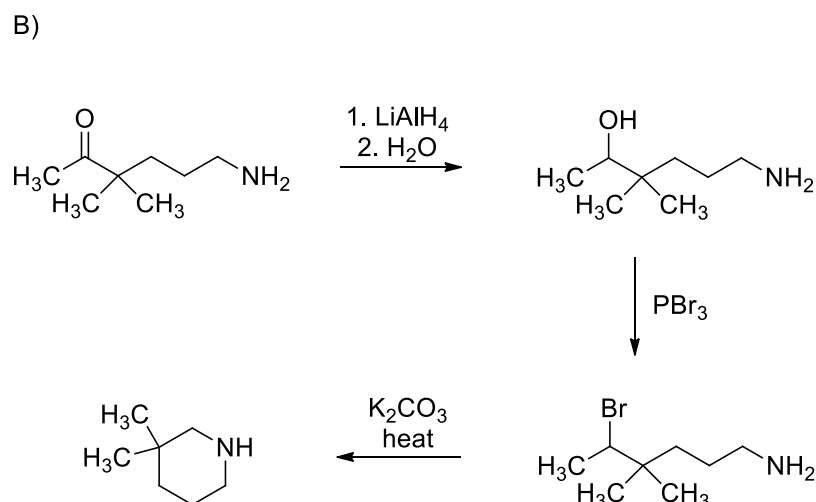
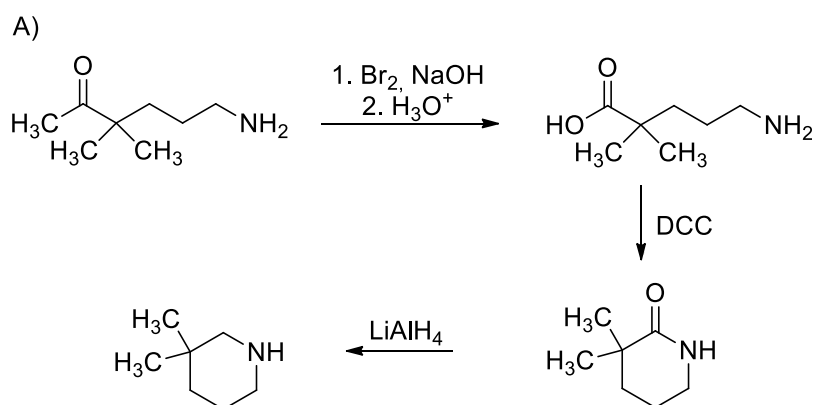
Iodoform test:



Problem 14

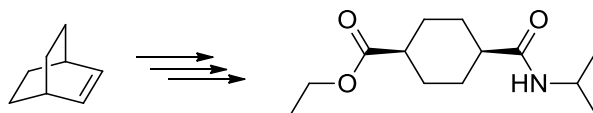
Propose a synthetic route to 3,3-dimethylpiperidine using 6-amino-3,3-dimethylhexane-2-on as a starting material along with any solvents and reagents.

Solution:

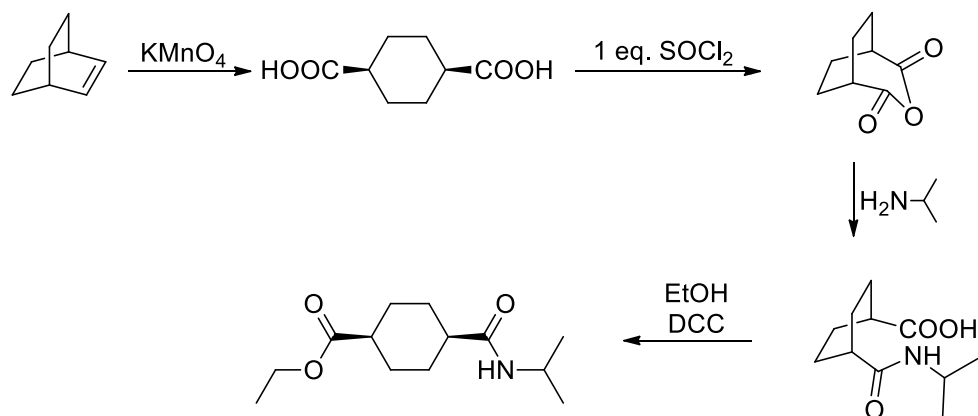


Problem 15

Propose a synthetic route for the following transformation starting from [2.2.2]-bicyclooctene. The target molecule can be achieved in four steps.



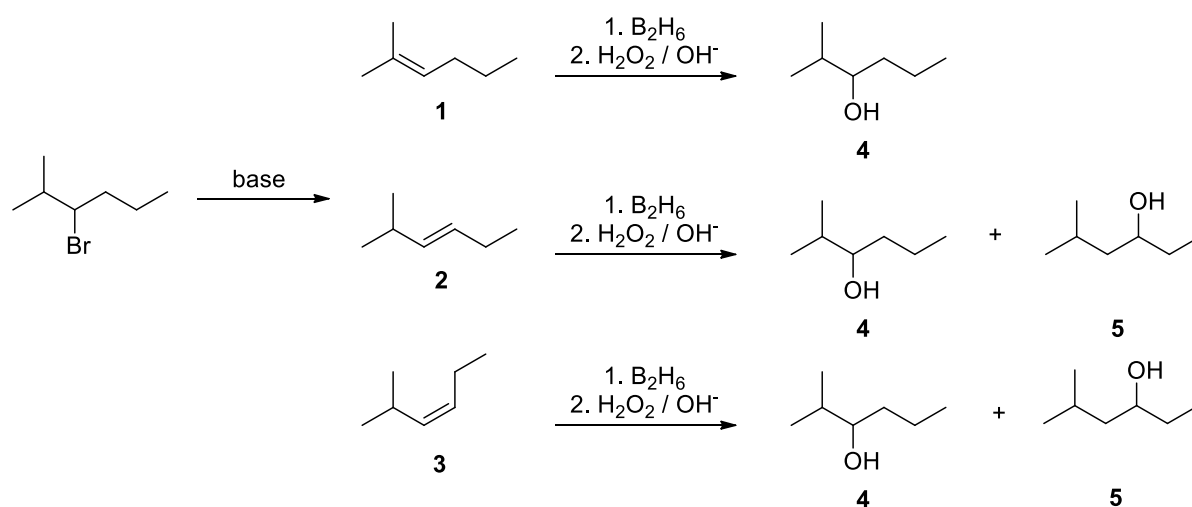
Solution:



Problem 16

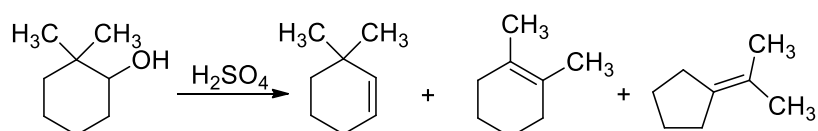
Three compounds (**1**, **2**, **3**) with a formula C_7H_{14} are formed when $C_7H_{15}Br$ is treated with a strong base. Catalytic hydrogenation of the above compounds (**1-3**) gives 2-methylhexane. Treatment of **1** with borane (B_2H_6), then oxidative work-up (H_2O_2/H_2O) affords mostly an alcohol (**4**). Similar reaction of **2** and **3** give a mixture of the alcohol **4**, and the isomeric alcohol **5**, in approximately equal amounts. Determine the structure of molecules **1-5**.

Solution:

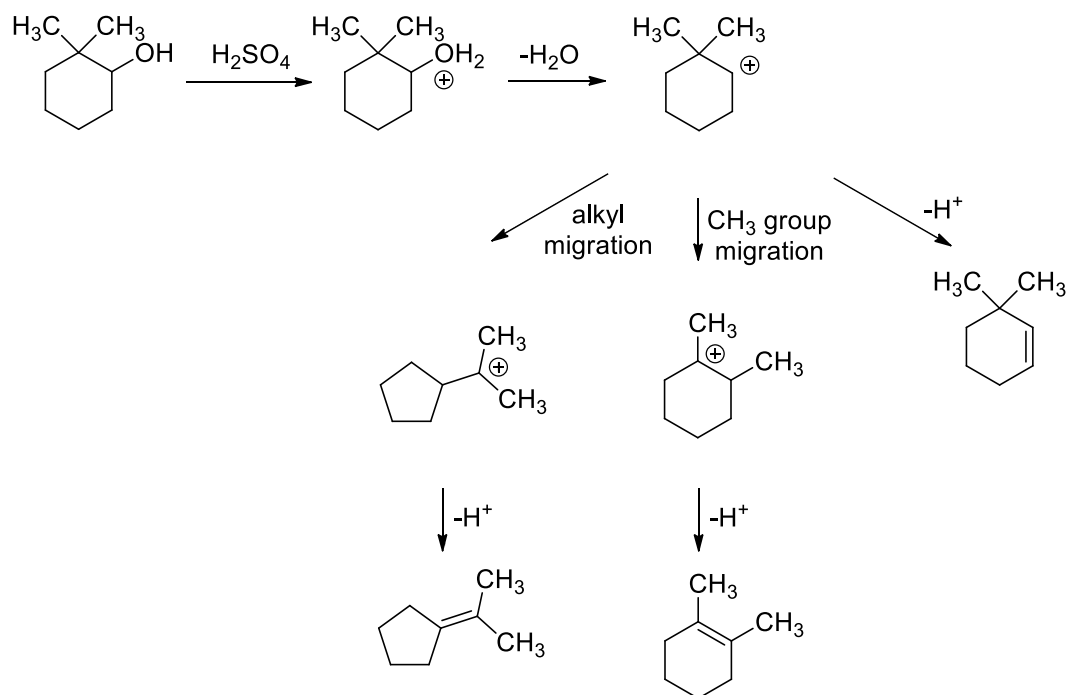


Problem 17

Provide a plausible mechanism for this transformation. Show all the elementary steps using the curved arrow presentation.



Solution:



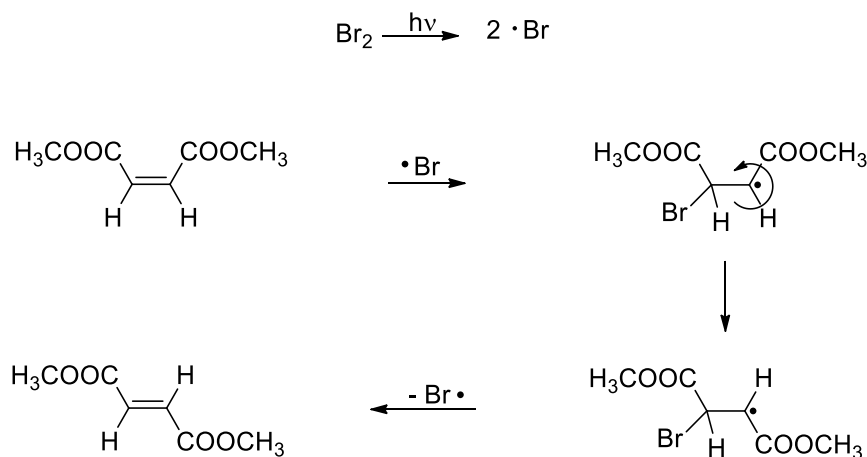
Problem 19

When dimethyl maleate (mp 137-140 °C) is heated with a trace of bromine in the presence of light, a compound of molecular formula $C_6H_8O_4$ with a melting point of 298-300 °C forms. Name the formed compound and explain its formation. Is this reaction reversible or not?

Solution:

a) Dimethyl fumarate

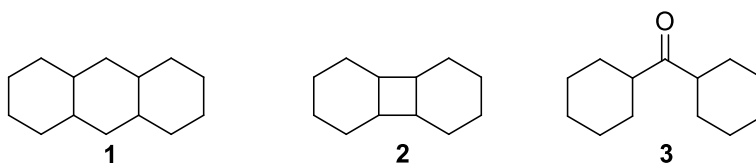
b)



c) The reaction is irreversible, because the formed fumarate is the thermodynamically favored product.

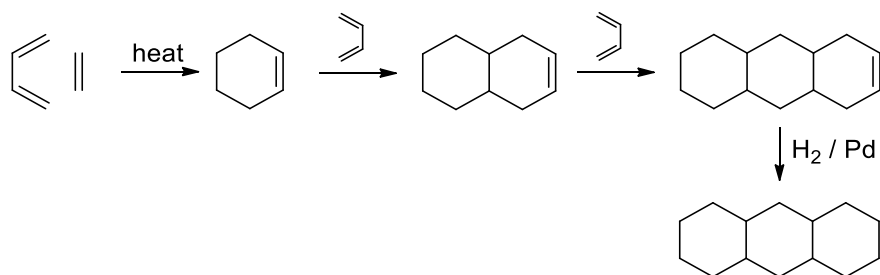
Problem 20

Propose synthetic route for compounds **1-3** using starting materials containing up to four carbon atoms along with any solvents and reagents.

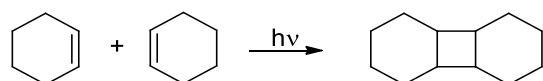


Solution:

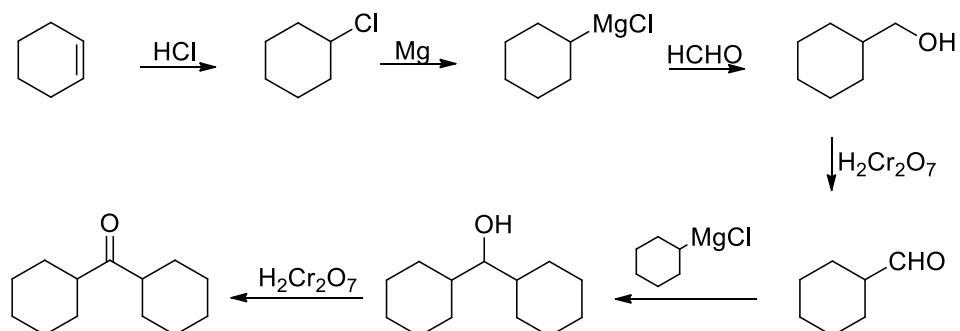
a)



b)

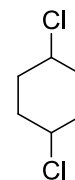
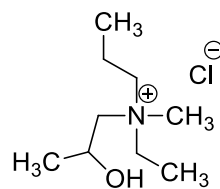
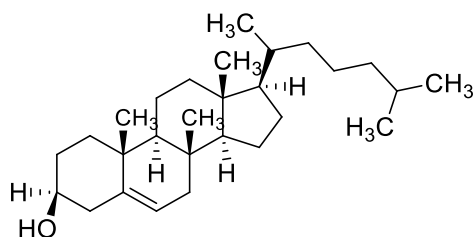


c)

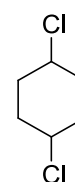
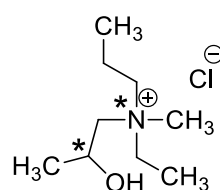
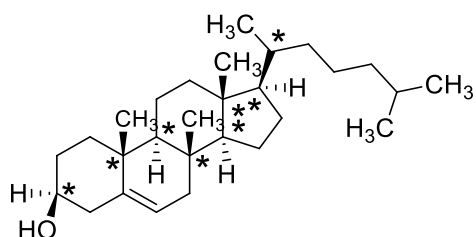


Problem 21

Mark the chiral centers in the following molecules.

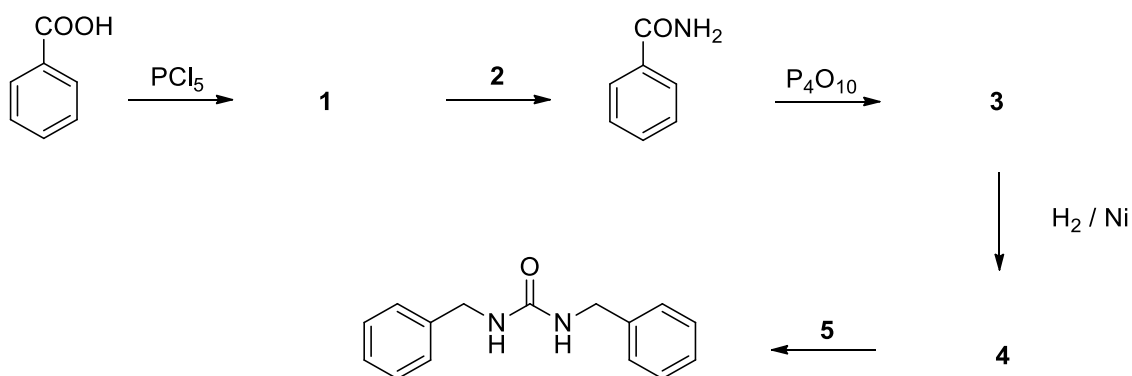


Solution:

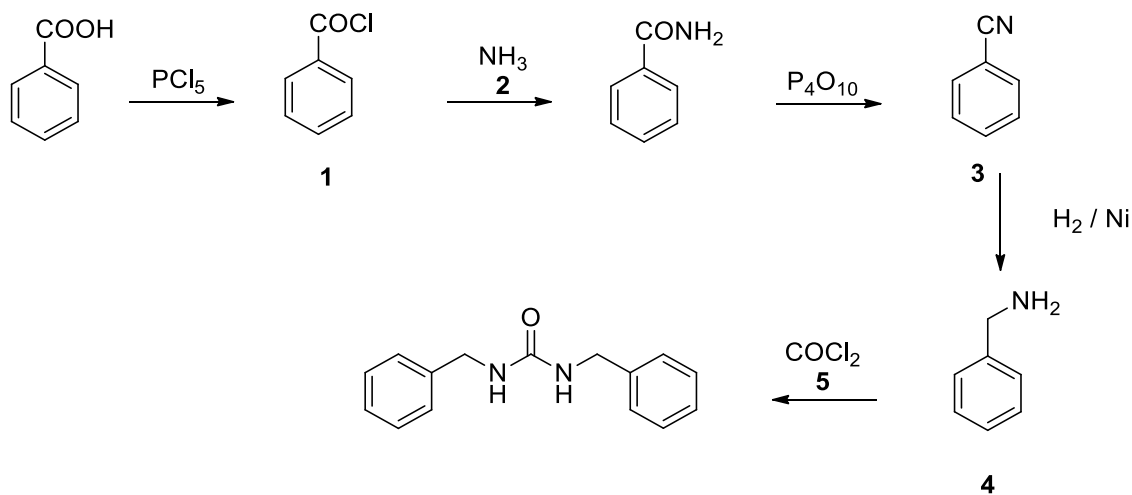


Problem 22

Determine the structure of the compounds **1-5**, based on the information given in the following scheme.



Solution:



Problem 23

What is the structure of the products (a, b, c, d), when compounds **1-4** react with aqueous NaOH?

1: 2-bromobutanoic acid (then the initially formed salt is acidified)

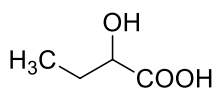
2: 3-bromobutanoic acid (then the initially formed salt is acidified)

3: 4-bromobutanoic acid

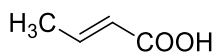
4: 5-bromopentanoic acid

Solution:

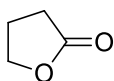
a)



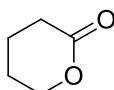
b)



c)

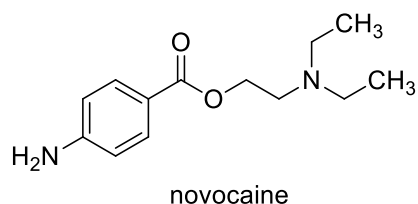


d)

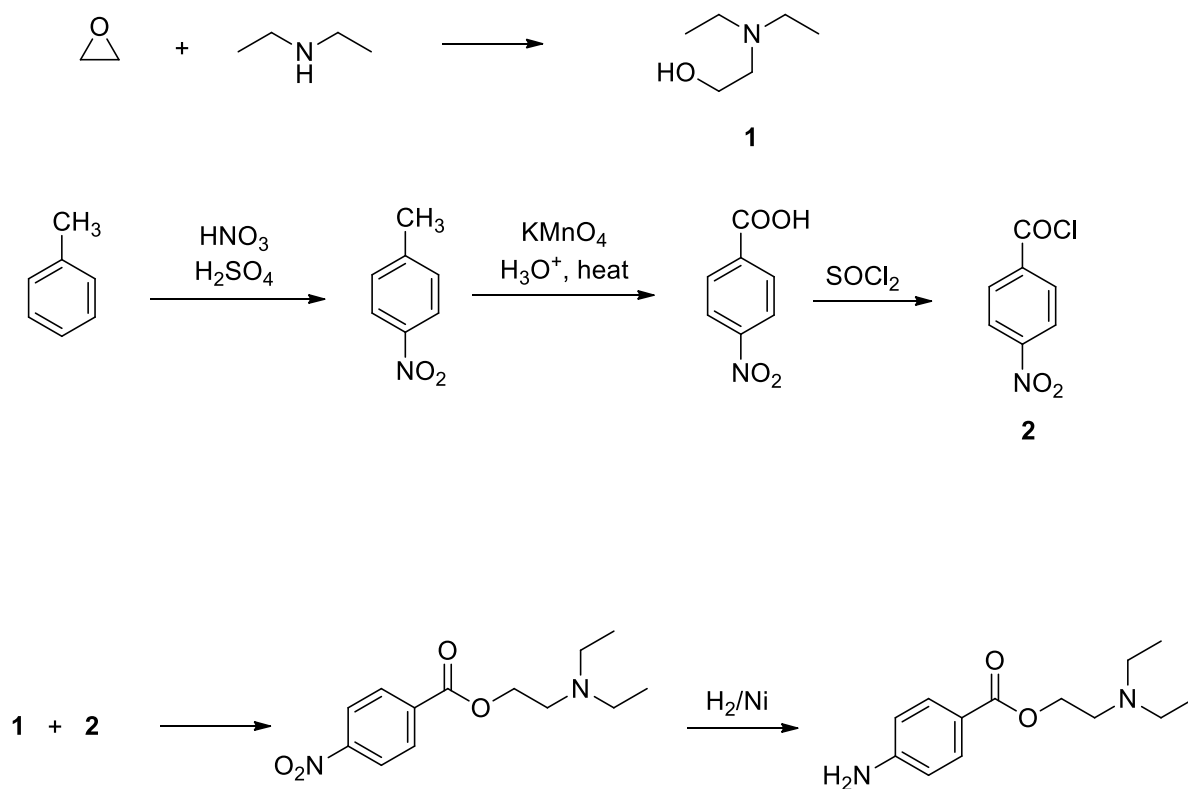


Problem 24

Propose a synthetic route to novocaine shown below. Use toluene and any organic molecule with less than four carbon atoms as starting material. Indicate the solvent and all the reagents for each step in the reaction sequence.

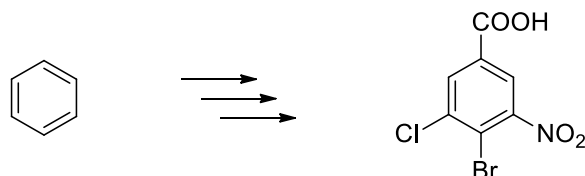


Solution:



Problem 25

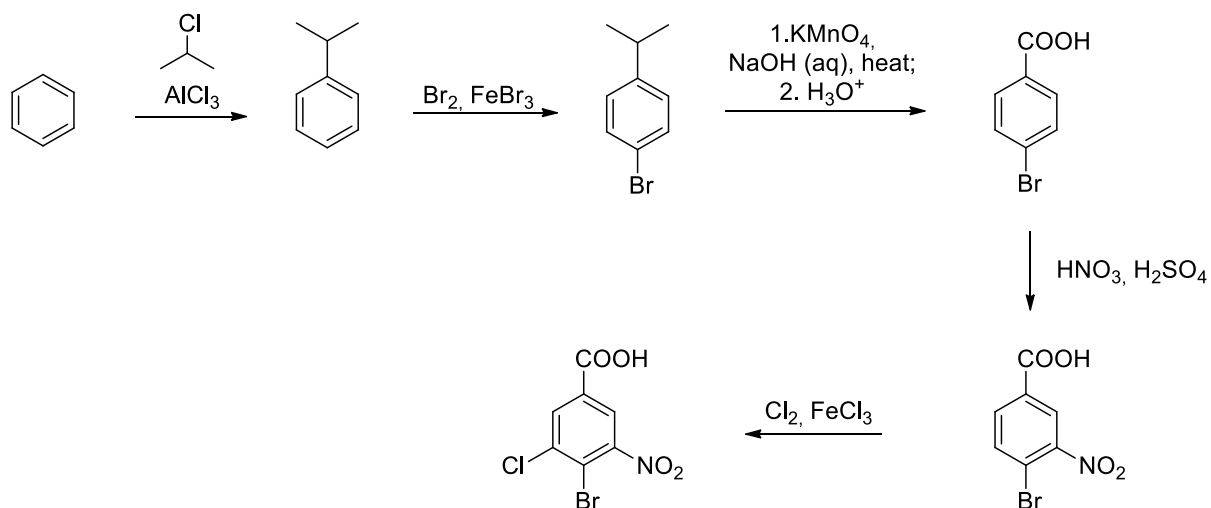
The following transformation can be carried out in five steps. From the list of a)-h), place the correct reagents in the correct sequence to carry out the indicated synthesis.



Reagents:

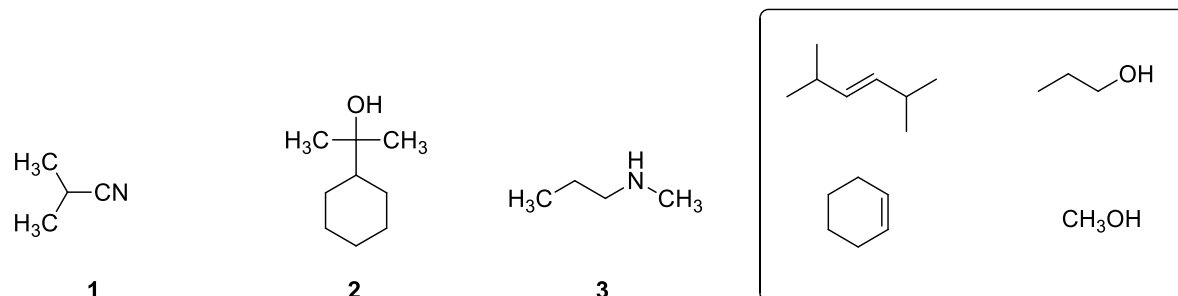
- a) $\text{Br}_2, \text{AlBr}_3$
- b) $\text{HNO}_3, \text{H}_2\text{SO}_4$
- c) 2-chloropropane, AlCl_3
- d) $\text{NaNO}_2, \text{HCl (aq)}$
- e) $\text{KMnO}_4, \text{NaOH}$, heat; acidic work-up
- f) $\text{Cl}_2, \text{FeCl}_3$
- g) $\text{Zn/Hg}, \text{HCl (aq)}$
- h) $\text{CrO}_3, \text{H}_2\text{SO}_4 \text{ (aq)}$

Solution:

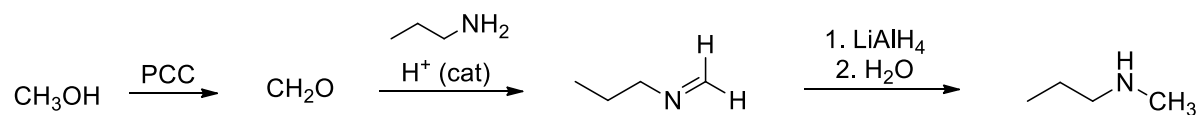
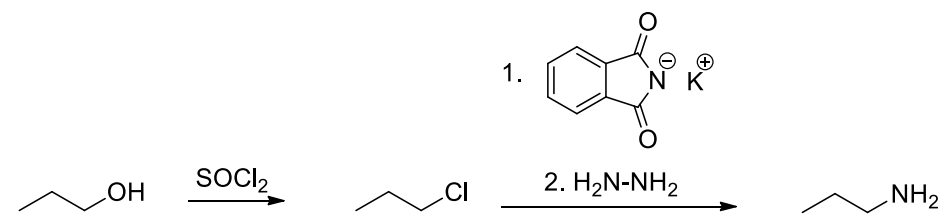
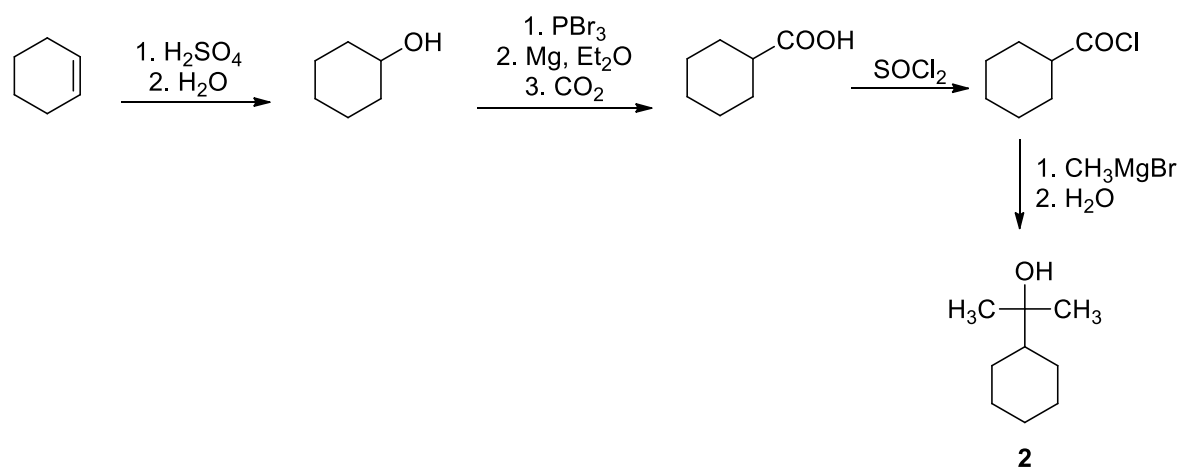
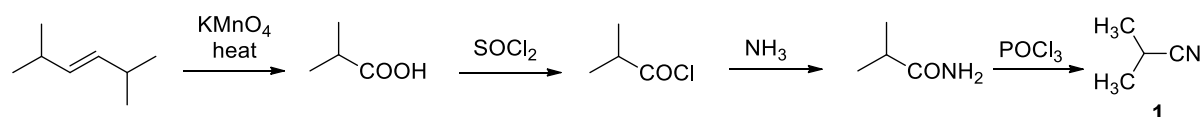


Problem 26

Propose a synthetic route to the molecules **1-3** shown below. Use only the molecules in the box as starting materials and any solvents and reagents.

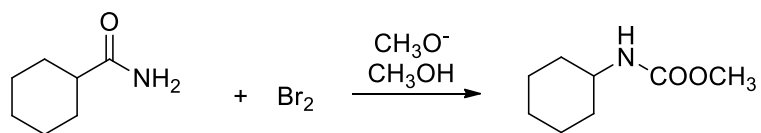


Solution:



Problem 27

Provide a plausible mechanism for the following reaction. Show all the elementary steps using the curved arrow presentation.



Solution:

