Final Exam Worksheet

Types of bonds

Ionic Bonding:

- Attraction of two oppositely charged ion
- typically a metal + non-metal

Covalent Bonding:

- atoms share electrons
- non-metal / non-metal

Polar Covalent:

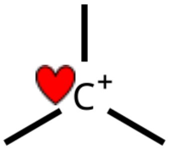
- Atom are non-metals but differ in polarity

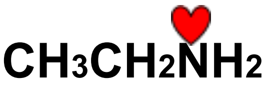
What is the bonding type of each molecule below?

NaOH	HI	NH_3	H_2
ionic	Polar covalent	Polar covalent	covalent

Hybridization

Determine the hybridization of the hearted element:





$CH_3CH_2NH_2$

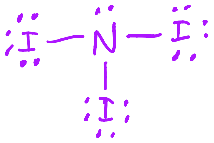
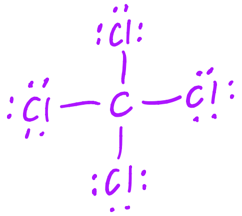
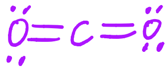
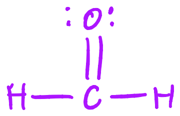
SP_2

Sp

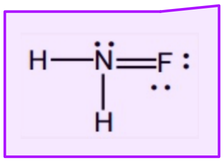
SP_3

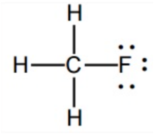
Lewis Structures

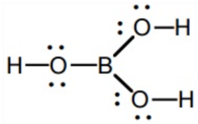
Draw the Lewis structure of the following compounds:

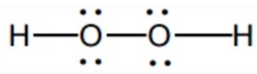
NI_3	CCl_4	CO_2	H_2CO
			

Which of the Lewis structures is wrong?





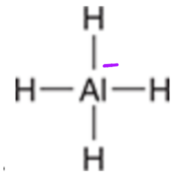




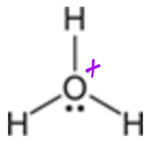
Formal Charge

Assign each molecule a formal charge (if applicable)

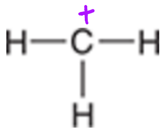
Remember the equation: $FC = (VE) - [\text{lone pairs} + (1/2)\text{ bonding } e^-]$



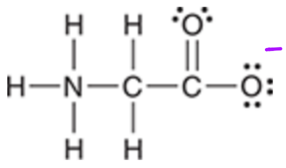
−1



+1



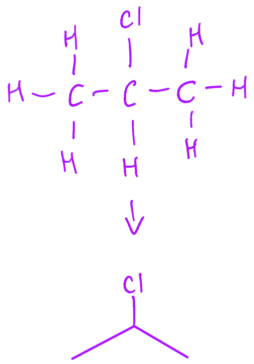
+1

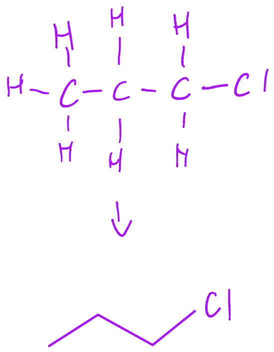


−1

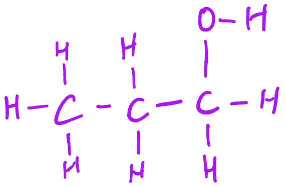
Constitutional Isomers

Draw all possible isomers of C_3H_7Cl

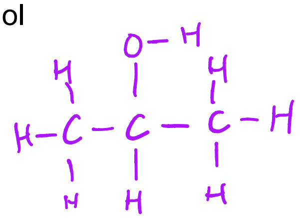


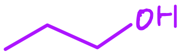


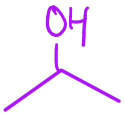
Draw all of the possible isomers of propanol



C_3H_8O

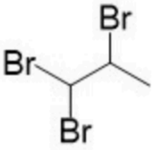




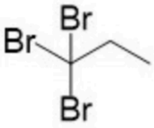


Identify the constitutional isomers of Molecule A

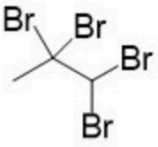
a)



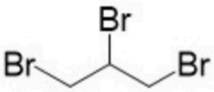
b)



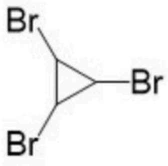
c)



d)



e)



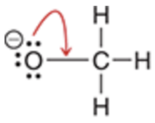
f)

Resonance

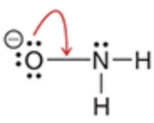
Rules

1. Avoid breaking a single bond

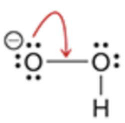
2. Never exceed an octet for second-row elements (C, N, O, F)



Bad arrow



Bad arrow

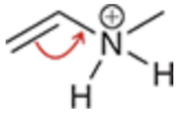


Bad arrow

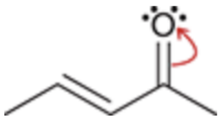
3. Less than the octet is okay

This carbon atom
does not have an octet

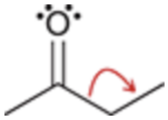
Do the following resonance arrows violate the octet rule? Are there any other rules being violated in the structures below?



yes!



nope

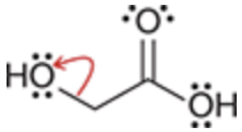


yes!

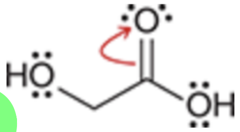
- also breaking the pi bond rule

Which of the following arrows is valid?

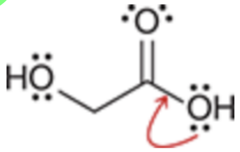
a.



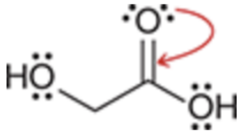
[✓ b.]



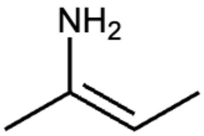
c.

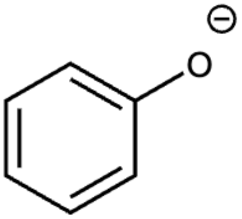


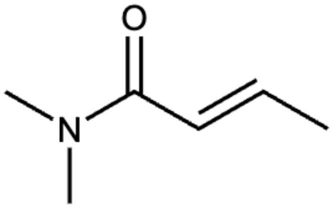
d.

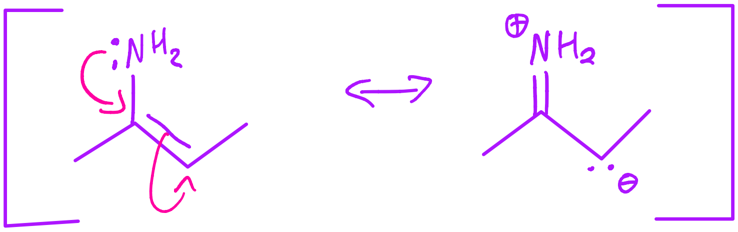


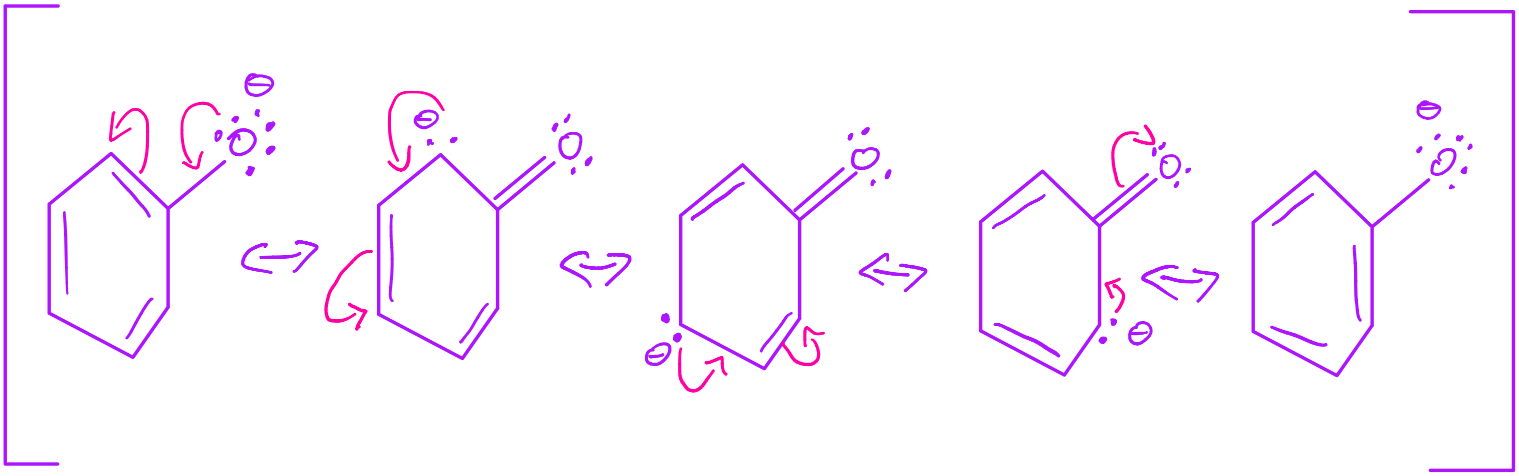
Draw all possible resonance structures in the following compounds:

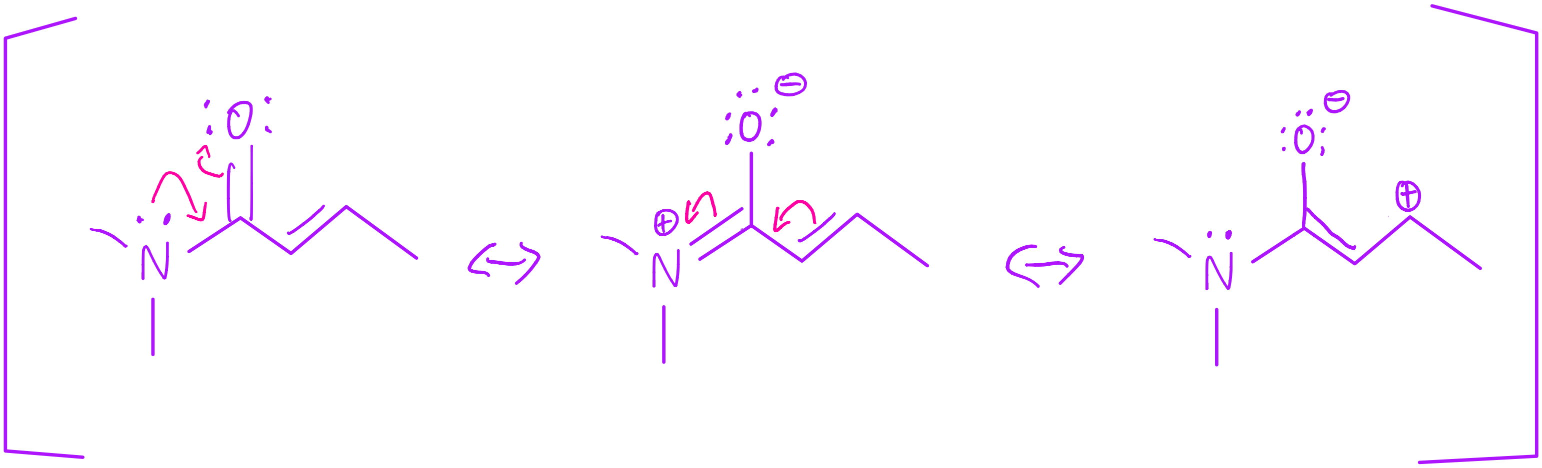




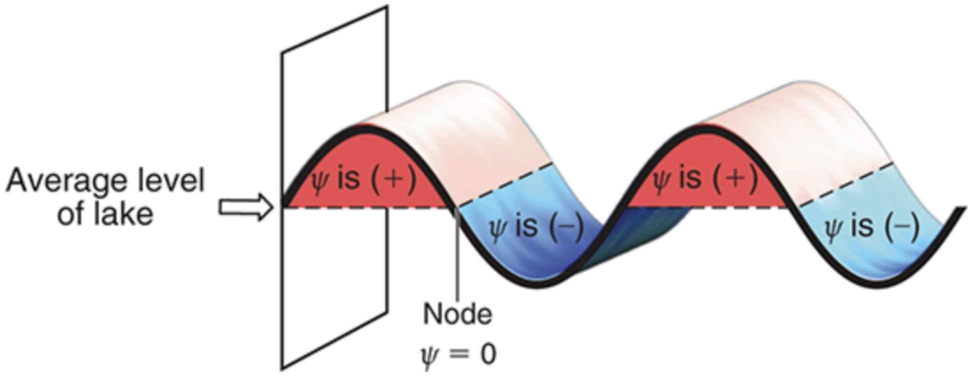








MO theory/Quantum Mechanics



Follow these three principles of filling electron orbitals:

Aufbau's:

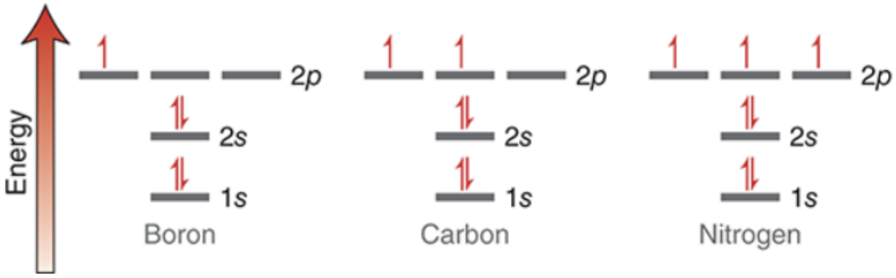
- lowest energy orbitals are filled first

Pauli Exclusion:

- each orbital can accommodate max 2 electons of opposite spin

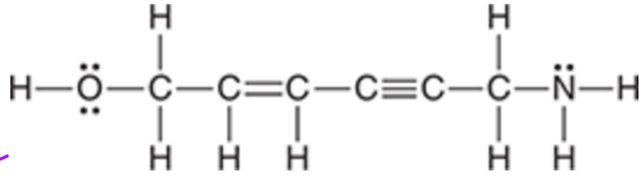
Hund's Rule:

- one electron is placed in each p orbital first, and are then paired up



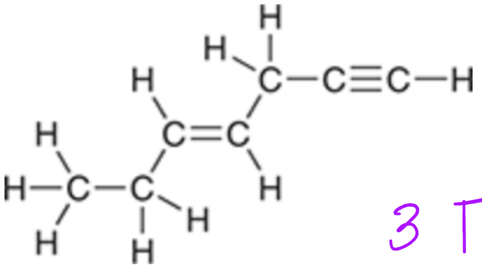
Bonding

How many sigma and pi bonds are in the following molecules?



3π

16 σ



3 π

16 σ

Which of the compounds has the longest and shortest carbon-carbon bond? CH_3CH_3 and HCCH

/ longest

≡ shortest

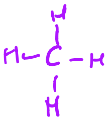
Order the compounds below in decreasing bond length: HI, HF, and HBr

HI > HBr > HF

Do the compounds below have an overall dipole moment?

CH_4

no



NH_3

yes

H_2O

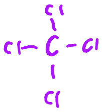
yes

CO_2

no

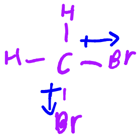
CCl_4

no

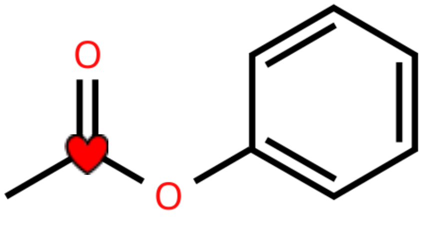


CH_2Br_2

yes



What is the carbon atom's Hybridization state, molecular geometry, and bond angle in the compound below?



sp2

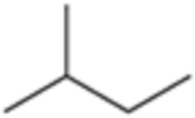
trigonal planar

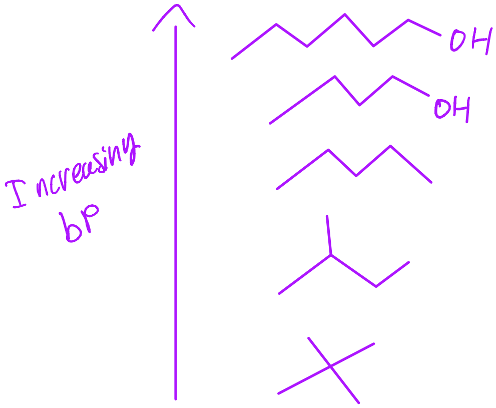
120°

bonus What are the functional groups here?

Ester and aromatic ring

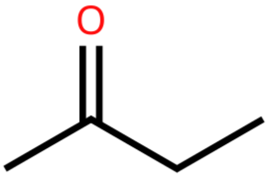
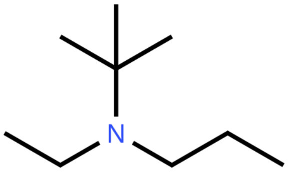
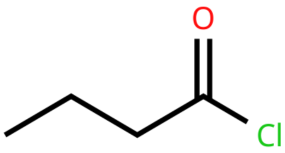
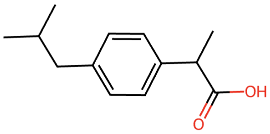
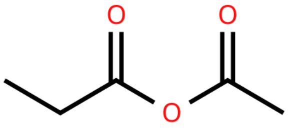
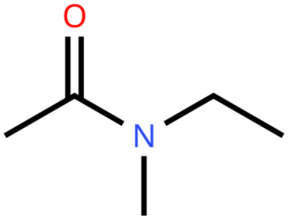
Order the compounds in increasing boiling point:





Functional Groups

Identify the functional groups in the compounds (there can be more than 1):

	Ketone		• tert-butyl • propyl • ethyl
	Acid chloride		• benzene • carboxylic acid • isobutyl
	Anhydride		• Amide

Of the intermolecular forces listed, which is stronger? Weaker?

a. London-Dispersion weaker
b. Dipole-Dipole
c. Hydrogen Bonding stronger

What intermolecular force is present among all molecules?

London-Dispersion

Acids and Bases

Define Bronsted-Lowry acids/bases:

Proton donor/acceptor

Define Lewis acids/bases:

e^- acceptor/e^- donors

Identify the acid, base, conj. acid, and conj. base of the reactions below:

$$\underset{\text{acid}}{HCl} + \underset{\text{base}}{NH_3} \rightarrow \underset{\text{conj. acid}}{NH_4^+} + \underset{\text{conj. base}}{Cl^-}$$

$$\underset{\text{base}}{OH\text{-}} + \underset{\text{acid}}{HCN} \rightarrow \underset{\text{conj. acid}}{H_2O} + \underset{\text{conj. base}}{CN\text{-}}$$

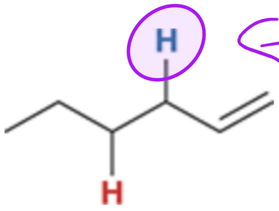
The lower the pKa value, the stronger the acid!

Rank the compounds in increasing order of basicity:

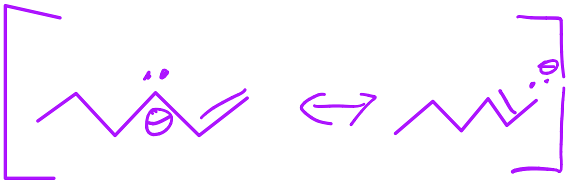
CH_3O^-, H_2O, NH_3, H_2N^-

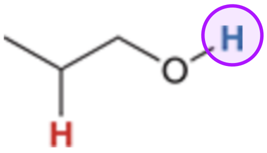
$H_2O < NH_3 < CH_3O^- < H_2N^-$

Circle the most acidic hydrogen:



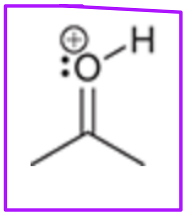
removing this proton provides resonance stability

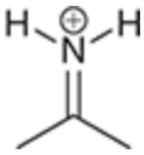




The conj. base of this has a stabilize ⊖ charge on the oxygen, making this proton more acidic

Which of the compounds is more acidic? Why?

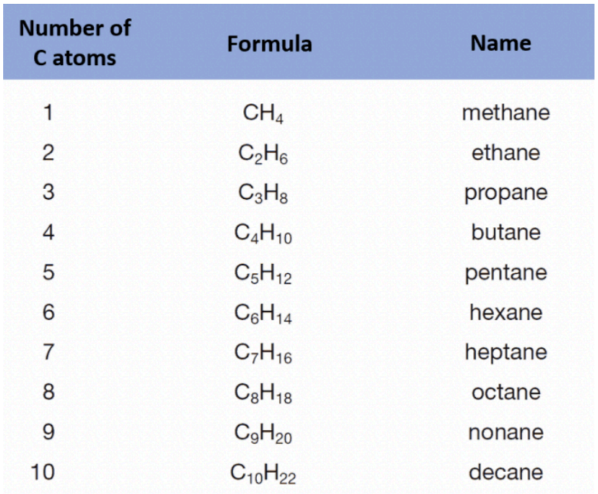




Nitrogen can better stabilize a ⊕ charge, making it weak

Nomenclature 101

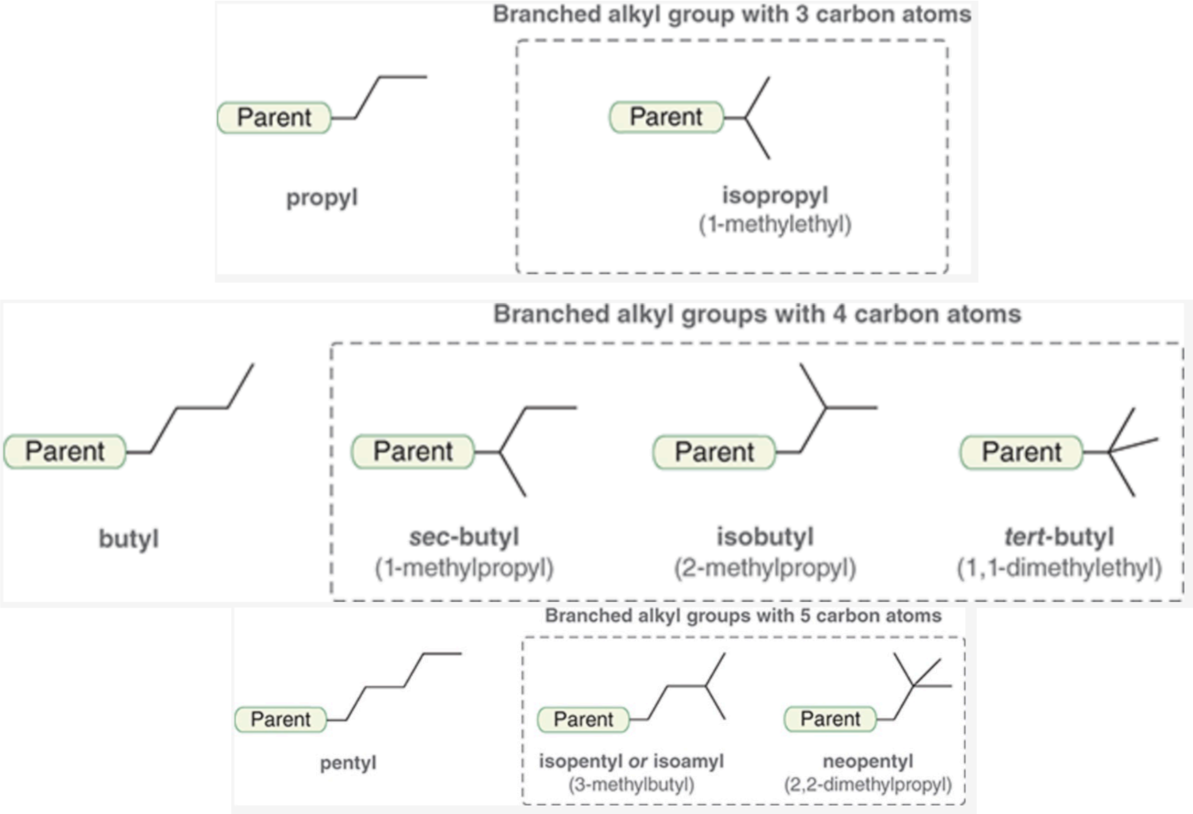
Naming Alkanes:



Number of C atoms	Formula	Name
1	CH_4	methane
2	C_2H_6	ethane
3	C_3H_8	propane
4	C_4H_{10}	butane
5	C_5H_{12}	pentane
6	C_6H_{14}	hexane
7	C_7H_{16}	heptane
8	C_8H_{18}	octane
9	C_9H_{20}	nonane
10	$C_{10}H_{22}$	decane

1. If there is a competition of numbering chains of an equal length, number so that you get the lowest amount of substituents
2. Use cyclo- to indicate a ring
3. To name alkyl substituents prefix + yl
4. Number the parent chain and assign substituents the lowest number possible according to IUPAC rules
5. To put names together, alphabetize substituents and combine using , and -

Common names of alkyl groups (memorize)



When a substituent appears more than once in a molecule:

# of functional groups:	Prefix:
2	Di-
3	Tri-
4	Tetra-
5	Penta-
6	Hexa-

Naming Alkyl Halides

1. Halogen is treated as a Substituent

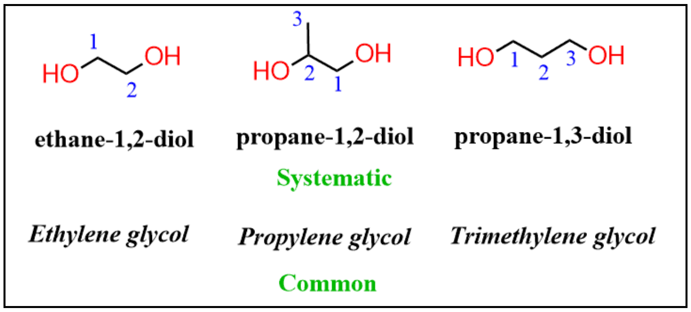
Naming Alcohols

1. Number the chain that includes the hydroxyl group
2. Ends in -ol

3. Alcohol gets priority (for the purposes of this class)

Naming Diols

1. Similar to alcohols just make sure you indicate the prefix of multiple alcohols
2. Remember the common names of basic diols



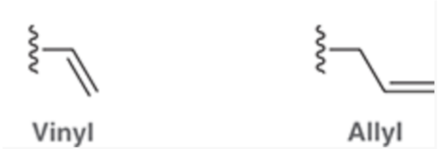
Bicyclic Compounds

1. Find total # carbons cyclized
2. Use “bicyclo”
3. Find bridgeheads / paths
4. Order paths going largest → smallest #

Naming Alkenes

1. Ends in -ene
2. Use the longest chain that includes =
3. Pi bond is assigned lowest #

Allyl and Vinyl groups



Naming Alkynes

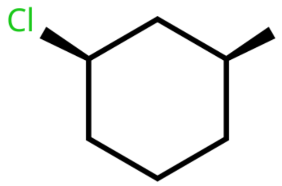
1. Use -yne
2. The triple bond should be assigned lowest #

Alkenes and Alkynes: Which Takes Priority?

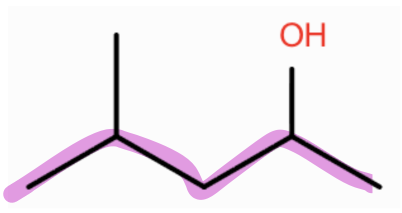
A molecule containing an alkene and alkyne with *no* higher-ranking substituents

- will be **numbered** so as to provide the lowest set of locants
- will be **named** so as to arrange the ene/yne **alphabetically**

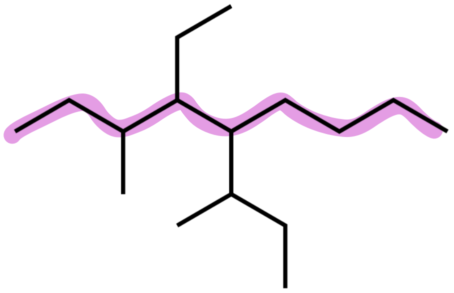
Name the compounds:



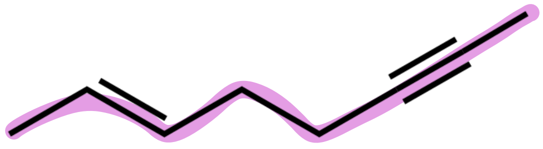
cis-1,3-dichlorocyclohexane



4-methyl-2-pentanol



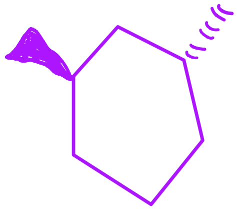
5-sec-butyl-4-ethyl-3-methylnonane



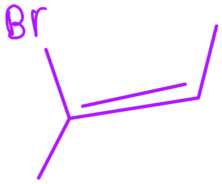
oct-2-en-6-yne

Draw the compound based on the name:

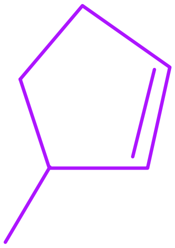
Trans-1,3-dimethylcyclohexane



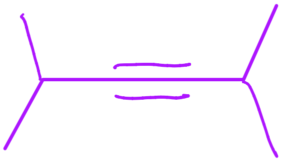
(Z)- 2-bromo-2-butene



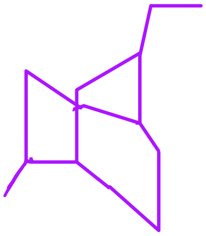
3-methylcyclopentene



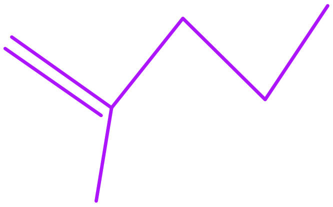
2,5-dimethyl-3-hexyne



10-ethyl-2-methylbicyclo[3.3.2]decane

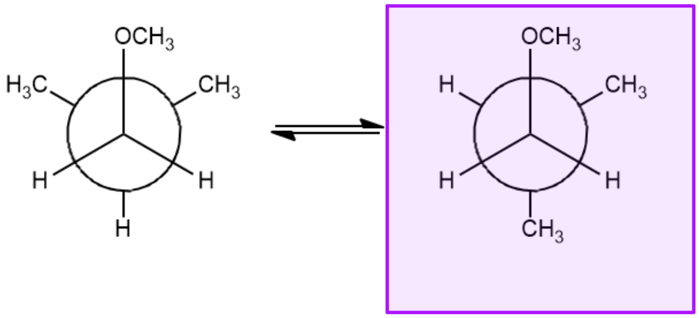


2-methylpentene

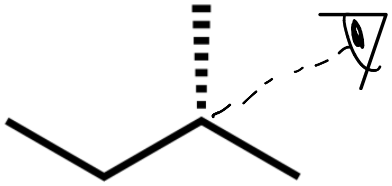


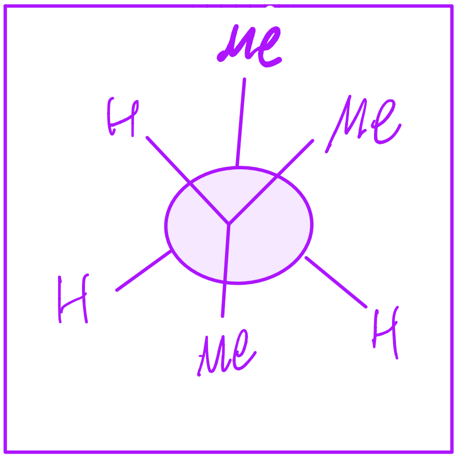
Conformational Analysis

Identify the <u>most stable</u> Newman projection of the molecule below:

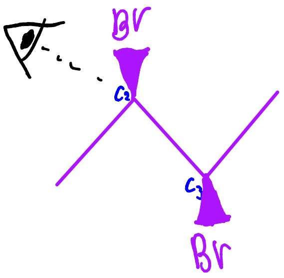


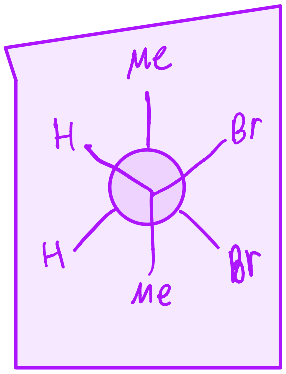
Draw the Newman projections:



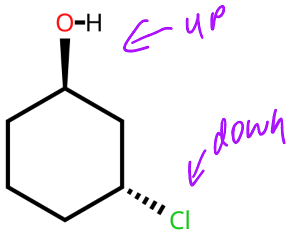


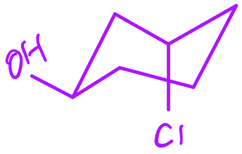
2,3-dibromobutane looking down the C2-C3 bond:



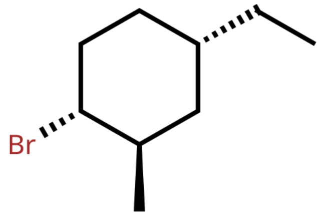


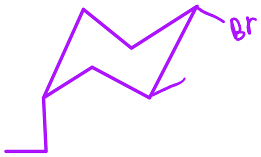
Draw the chair conformation of the compounds below:

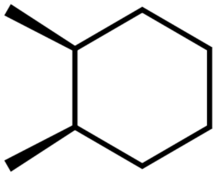


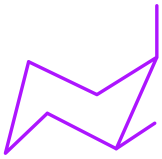


You can draw these in multiple ways

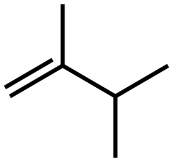




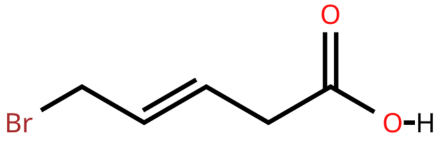




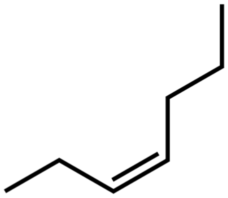
Label the compounds as cis, trans, or non-isomeric



non-isomeric

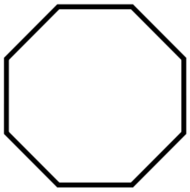


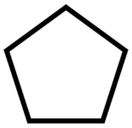
trans



cis

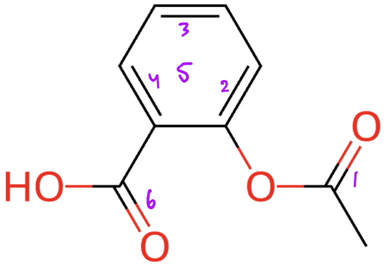
Which of the compounds has the greatest amount of ring strain:

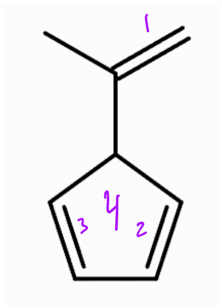




What is the hydrogen deficiency index of the compounds below:

$$\textbf{Degrees of Unsaturation} = \frac{(2 \times \#\text{carbons}) + 2 + \#\text{nitrogens} - \#\text{hydrogens} - \#\text{halogens}}{2}$$

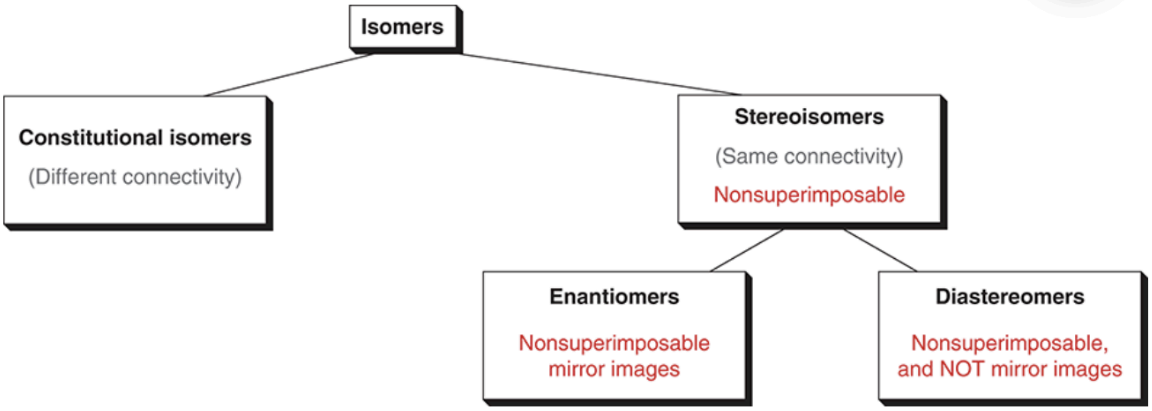




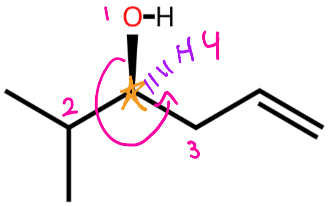
6

4

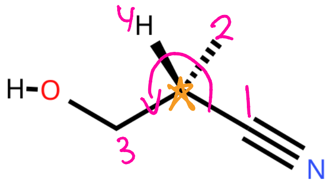
Stereochemistry



Designate the configuration on the following compounds:

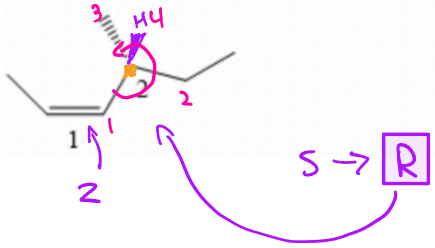


S

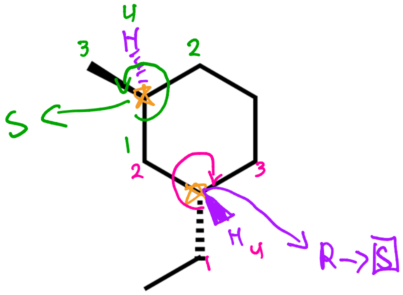


S → R

Designate sequentially (1,2) the stereochemistry at the numbered sites in the molecule shown below:



Name the compound with the R & S configuration:



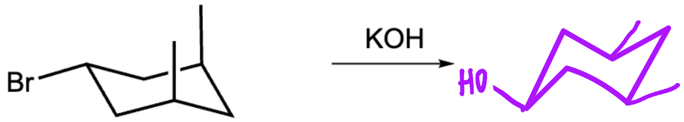
(1S, 3S)-1-ethyl-3-methylcyclohexane

Substitution and Elimination Reactions

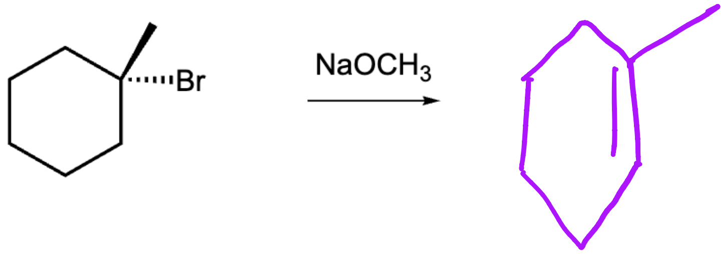
MEMORIZE THIS TABLE!!!

	Strong Base/ Weak Nucleophile	Strong base/ Strong Nucleophile	Weak base/ Strong Nucleophiles	Weak base/ Weak nucleophile
1°	E2	E2 Sn2	Sn2	
2°	E2	E2 Sn2	Sn2	
3°	E2	E2	Sn1	Sn1 E1

Predict the products of the following reactions and identify what kind of reaction is happening:



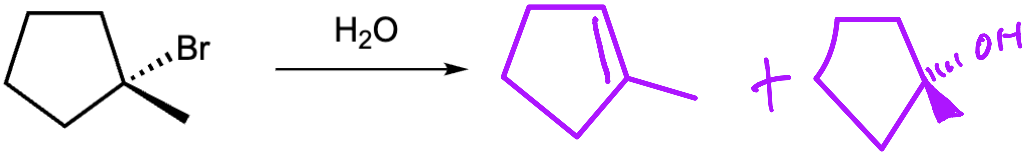
Sn2



E2

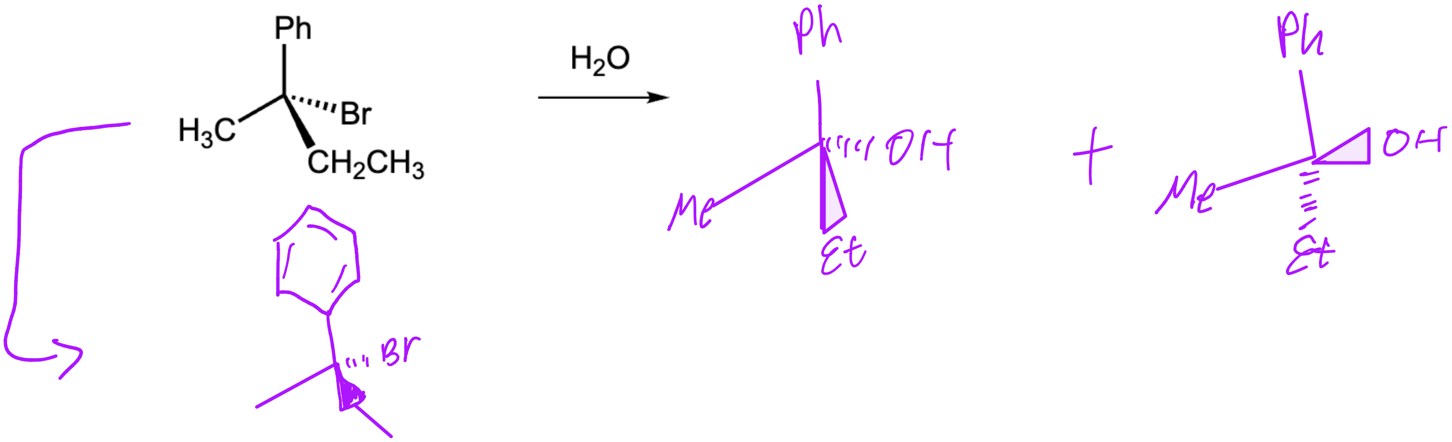
E1

Sn1

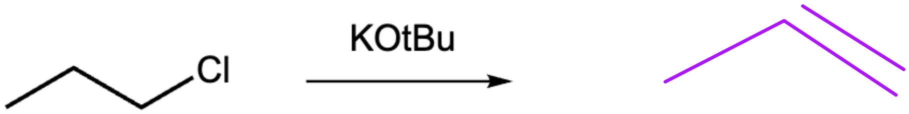


+ EN

Sn1

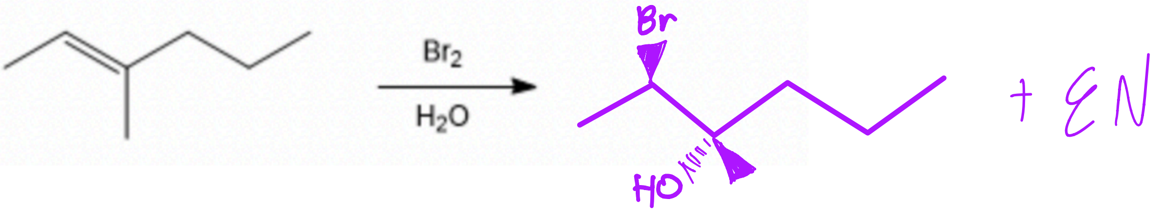


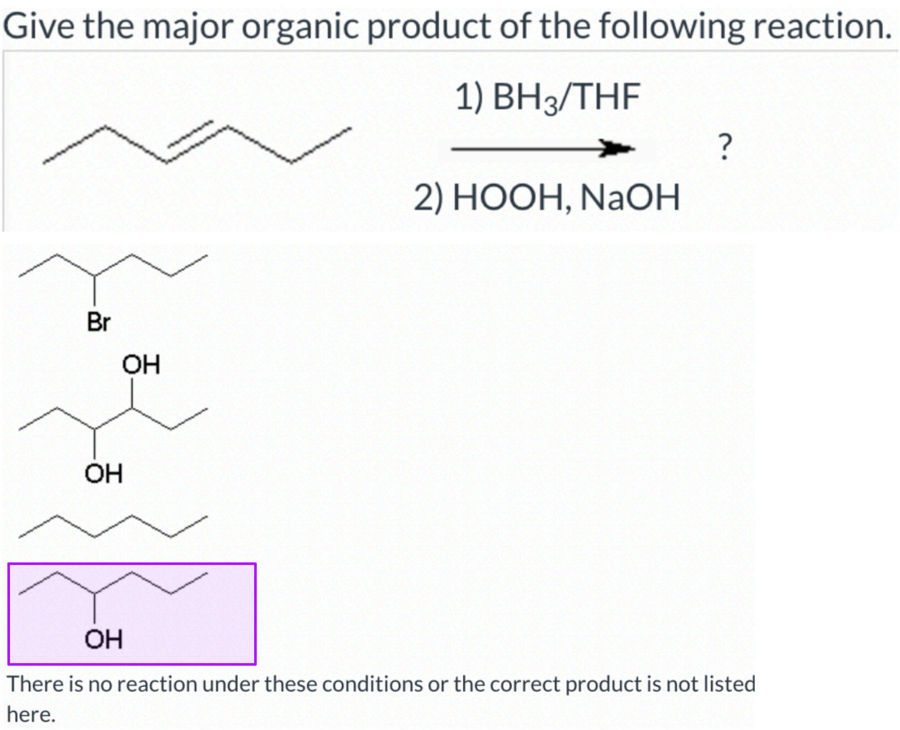
E2



Reactions of Alkenes and Alkynes

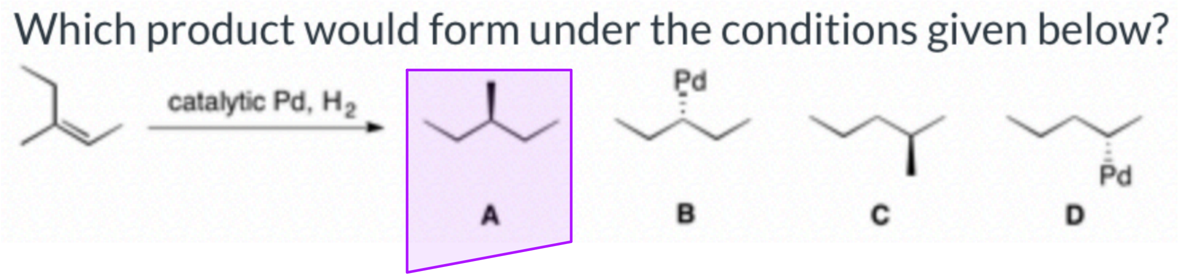
Predict the major product of the following reaction.





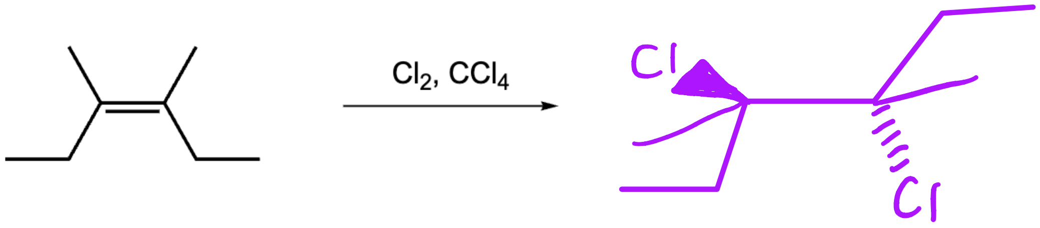
Give the major organic product of the following reaction.

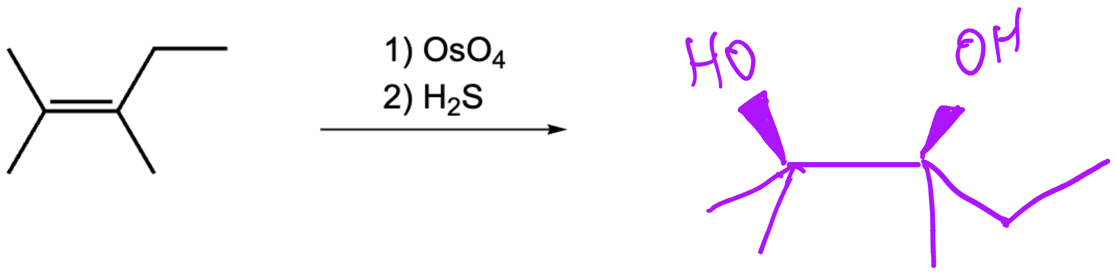
There is no reaction under these conditions or the correct product is not listed here.



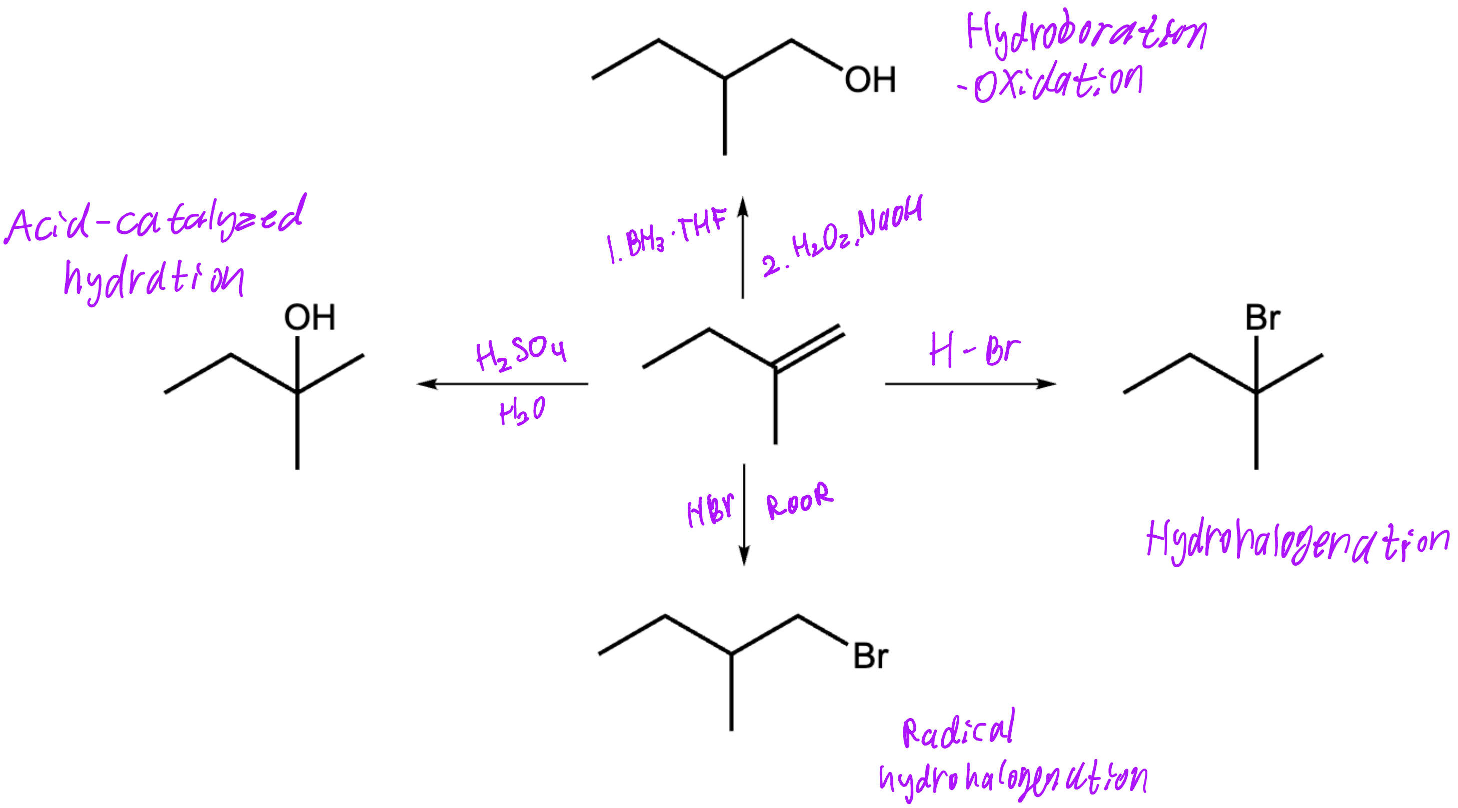
Which product would form under the conditions given below?

Give the major product in the reactions below:

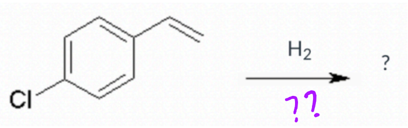




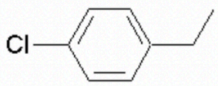
Fill in the missing reagents and identify the reaction being done:

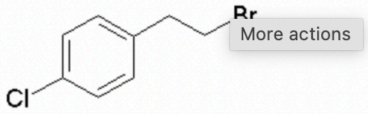


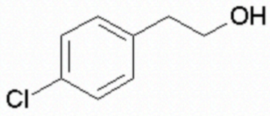
Circle the major product:

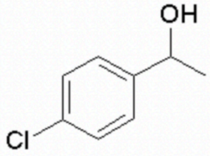


no metal catalyst



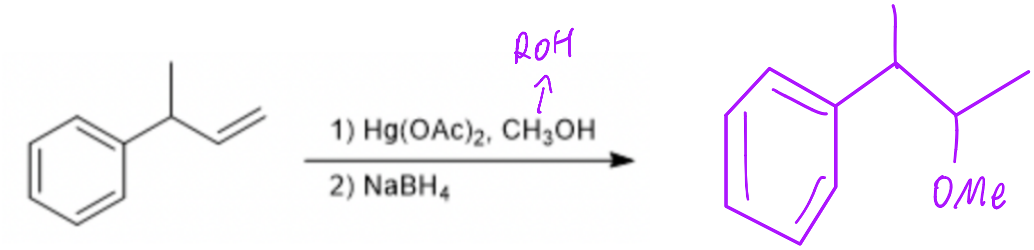


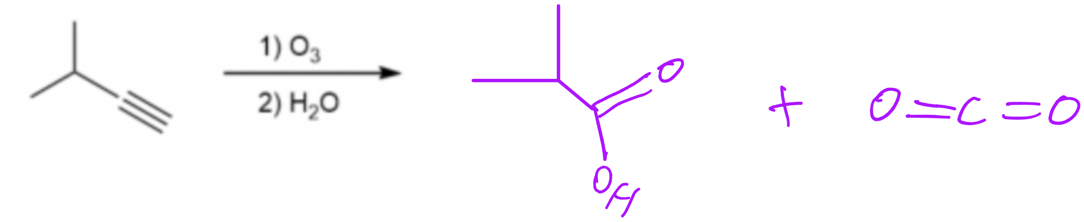


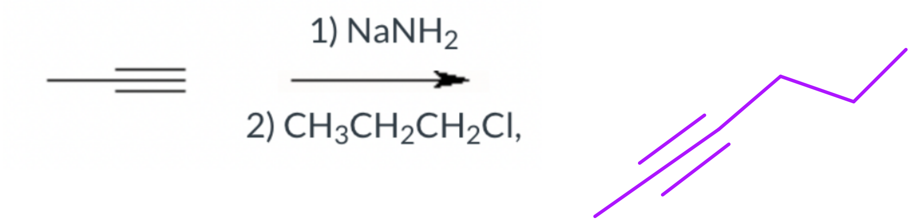


[✓ There is no reaction under these conditions or the correct product is not listed here.]

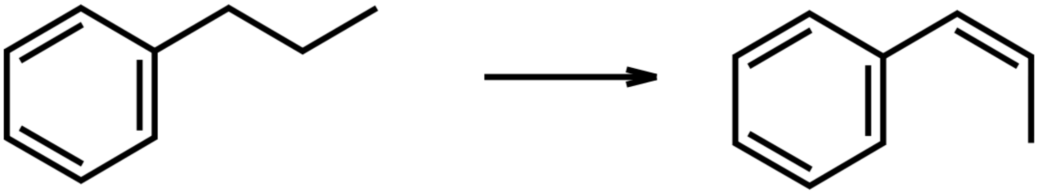
Predict the products:

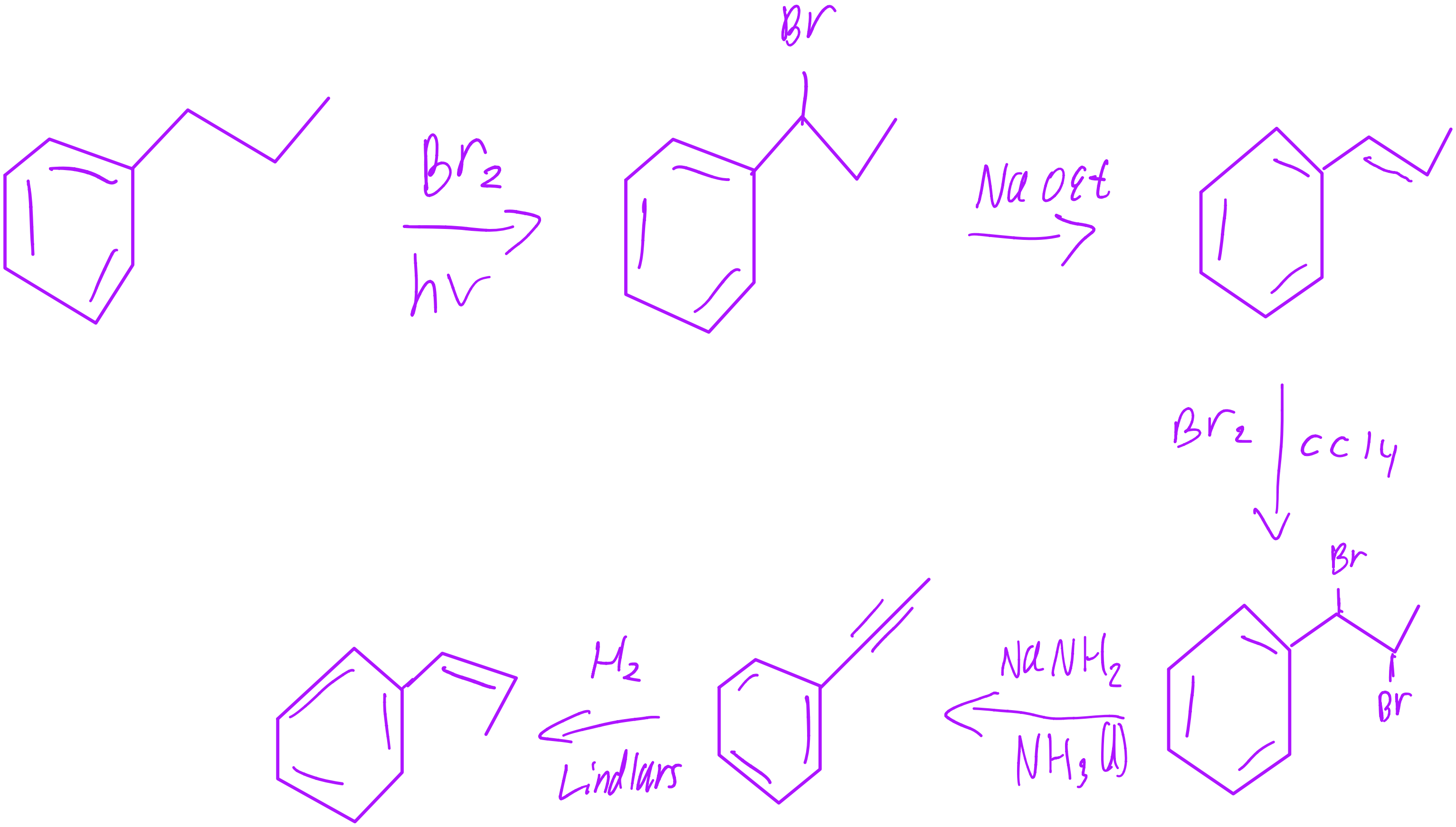




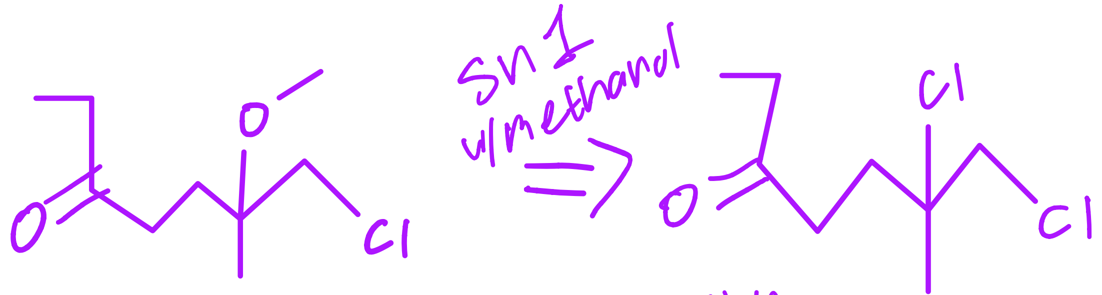


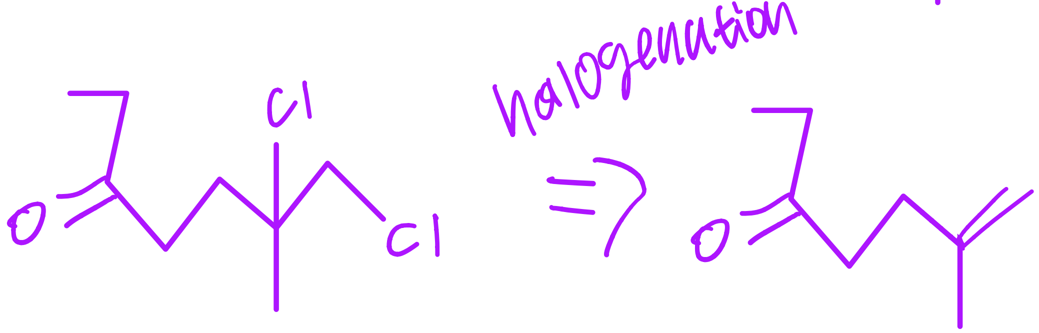
Multi-step Synthesis

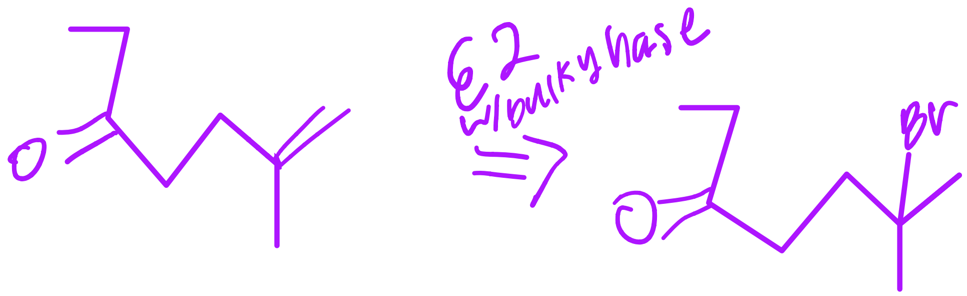


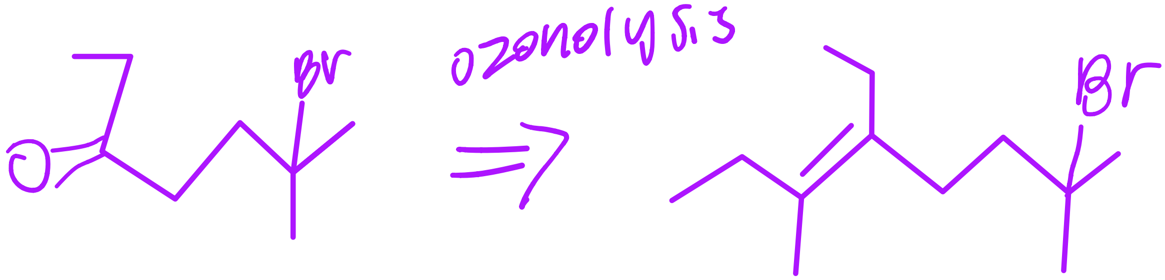


Retrosythesis







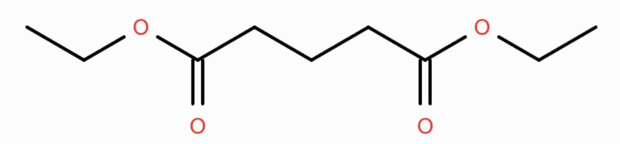


1. O_3/DMS
2. t-buOK/t-butOH
3. Cl_2/CCl_4 →
4. MeOH

NMR

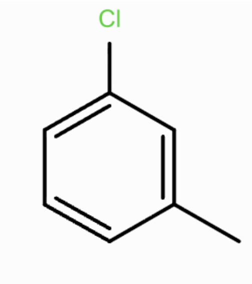
How many H NMR peaks will you expect to see in the compounds below?

1.



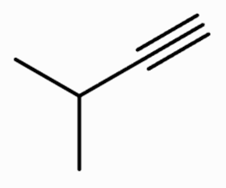
A) 7
B) 3
C) 1
[✓ D)] 4
E) 5

2.



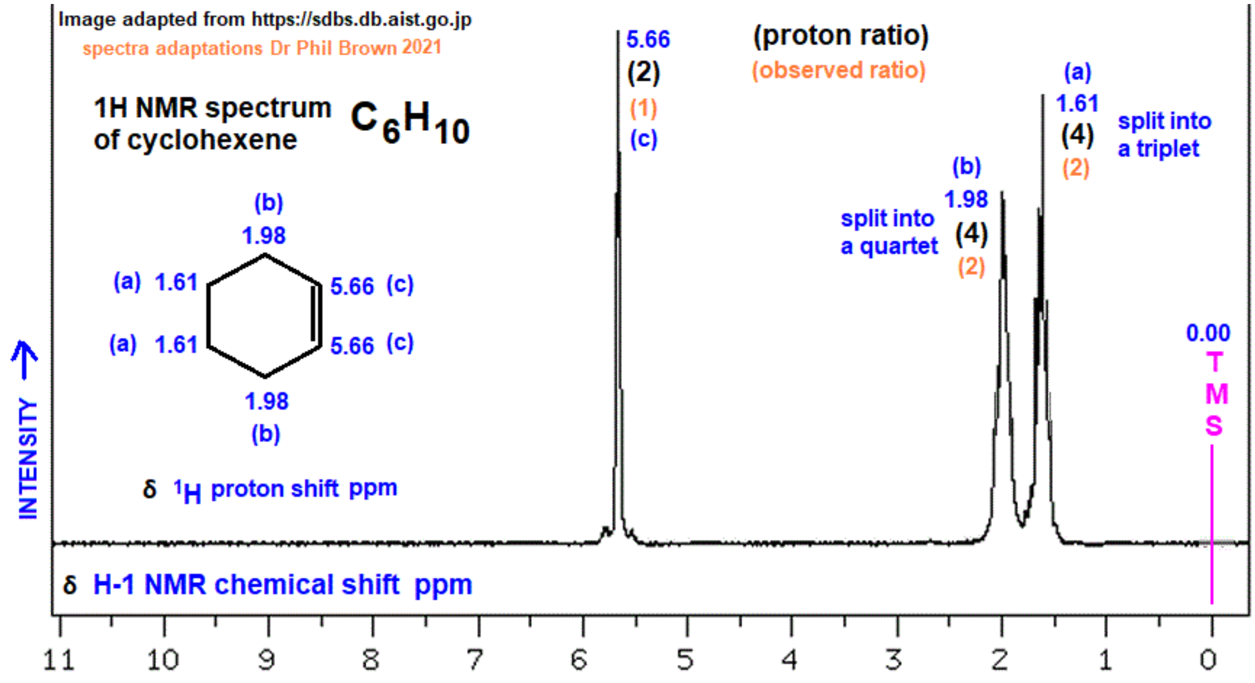
A) 4
B) 2
[✓ C)] 5
D) 1
E) 3

3.



A) 1
B) 2
[✓ C)] 3
D) 4
E) 5

Integration explained a little more for molecules with complete symmetry:

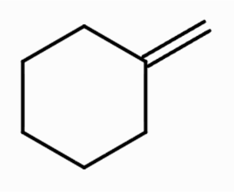


- Integration is a <u>ratio</u>

- Typically, a symmetrical molecule will have lower integration values than the molecular formula

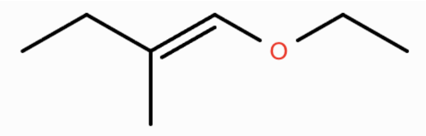
How many C NMR peaks will you see in the compounds below?

1.



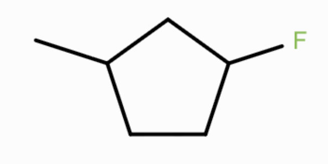
A) 1
[✓ B) 5]
C) 4
D) 2
E) 6

2.



A) 6
B) 12
C) 4
D) 2
[✓ E) 7]

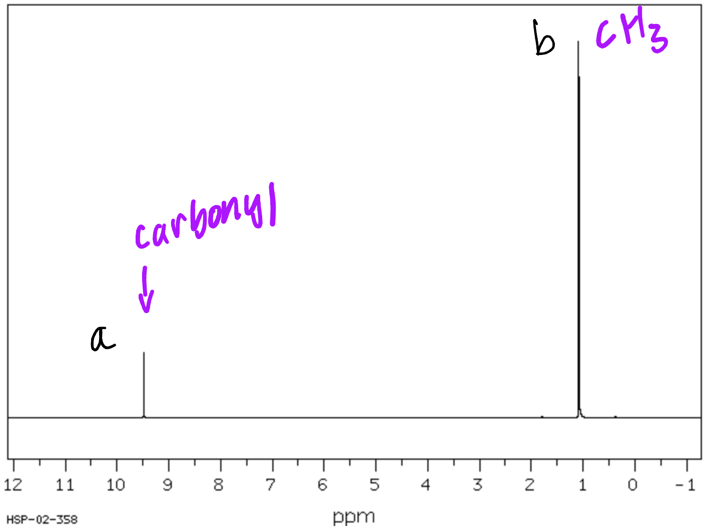
3.

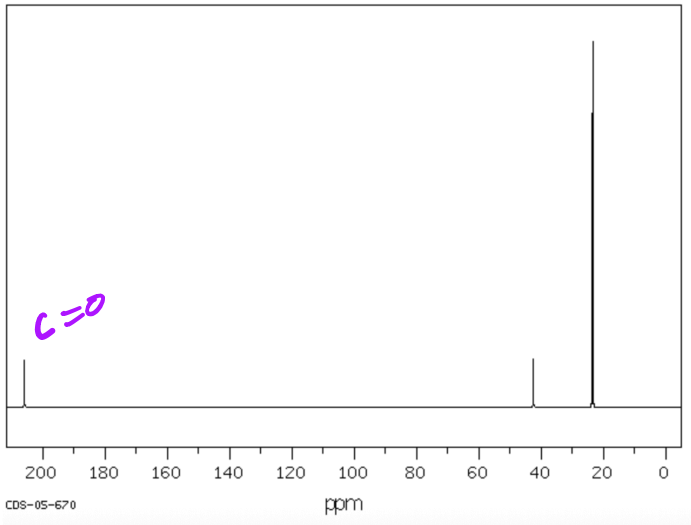


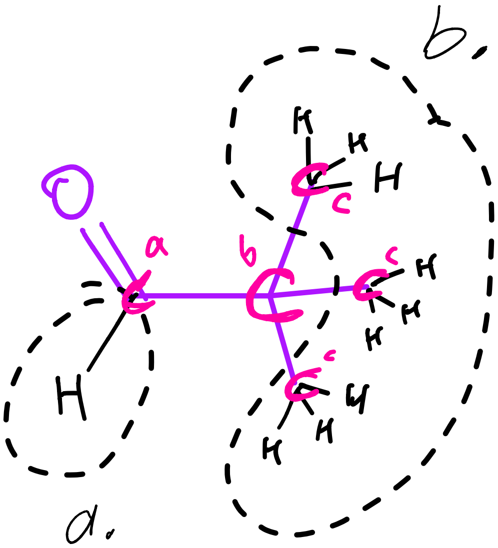
A) 5
B) 3
C) 1
[✓ D) 6]
E) 2

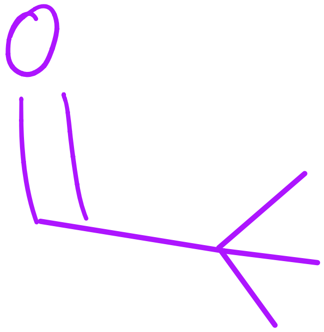
Given the molecular formula, H NMR and C NMR, propose a structure:

$C_5H_{10}O$



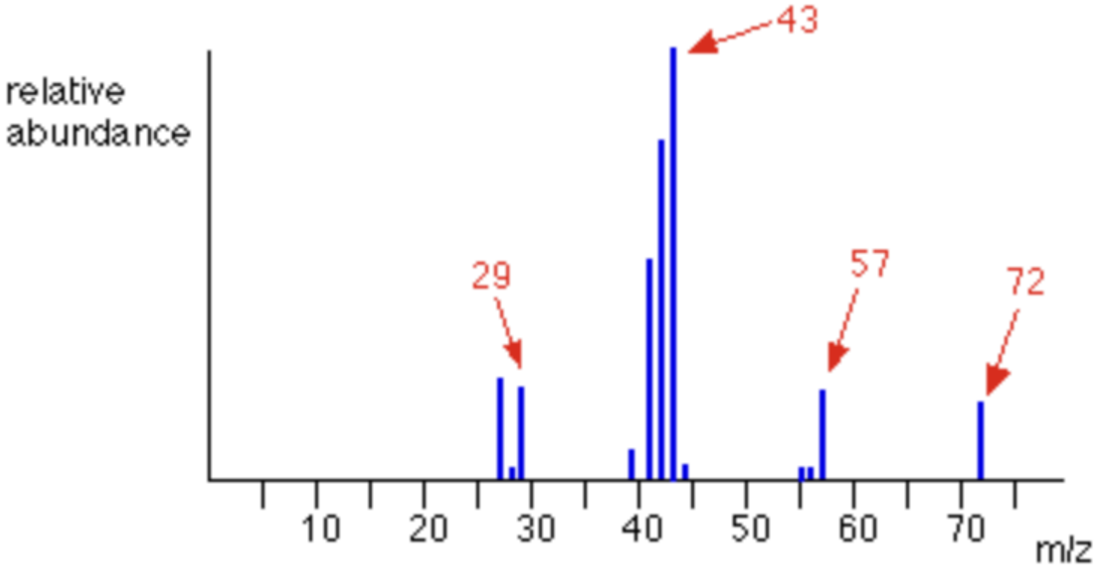






Mass Spectrometry

Given the mass spec of pentane and its prominent peaks, determine the base peak and molecular ion peak.



1. A prominent (M•-18) peak suggests that the compound might be a(n):

   A) Alkane
   [✓ B) Alcohol]
   C) Ether
   D) Ketone
   E) Primary amine

2. Mass spectrometry detects:

   I. Radicals
   II. Radicals and radical cations
   III. Radical cations
   IV. Cations and Anions

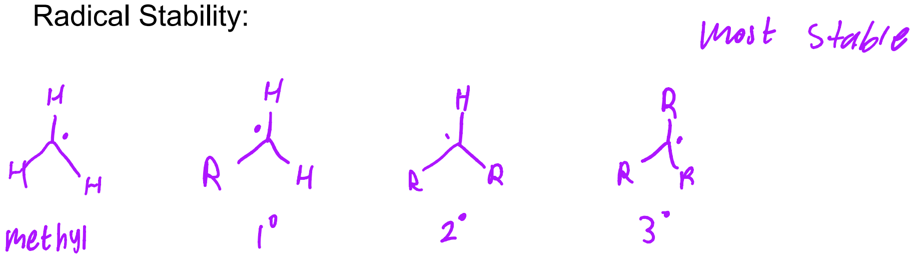
   A) I and II
   [✓ B) III only]
   C) IV only
   D) I, II, and III
   E) II and IV

3. What is the criterion for using mass spectrometry?

A) To find the composition of the sample
[✓ B)] To find the relative mass of atoms
C) To find the concentration of elements in the sample
D) To find the properties of the sample

Radical Reactions

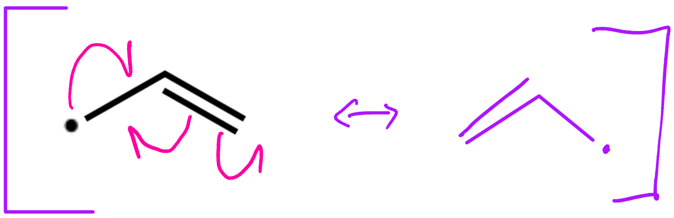
Radical Stability:

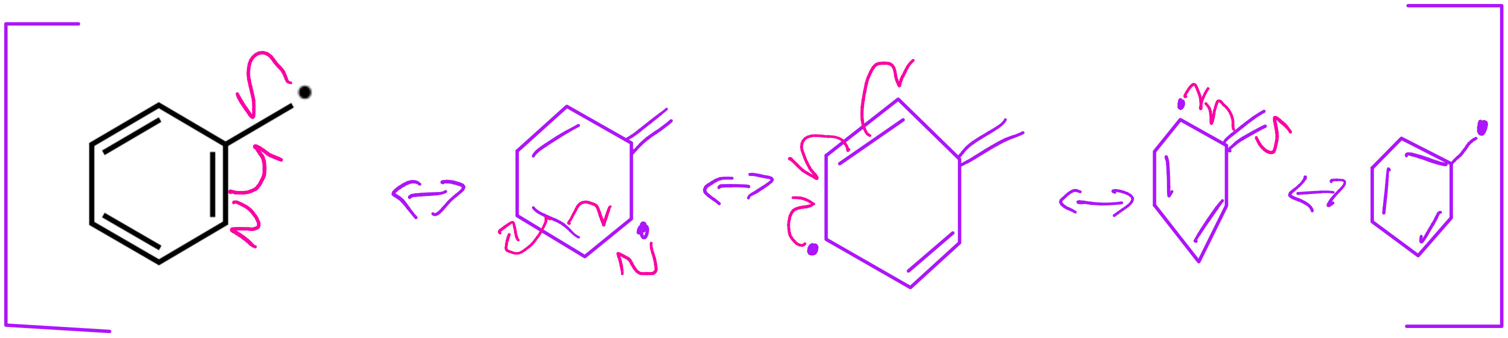


The more alkyl groups the better Stabilized the radical

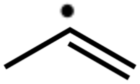
Resonance in radicals:

Allylic radicals ~~are~~ have ___resonance___ and are more stable





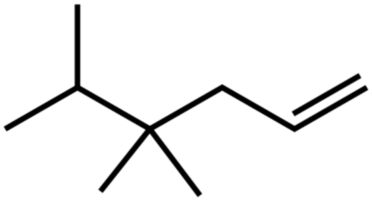
Vinylic radicals have no resonance and are less stable

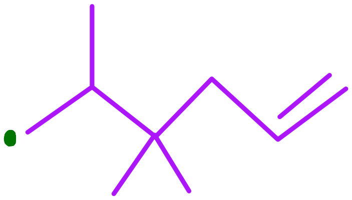


Identifying the weakest bond:

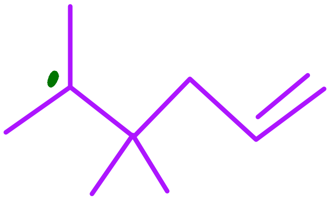
The weakest C-H bond comes from the most stable radical

Start by drawing all possible radicals and compare stability:

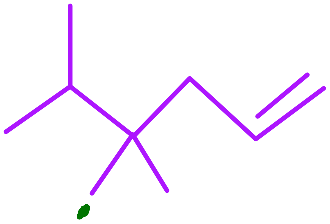




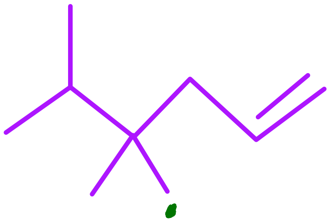
1°



3°

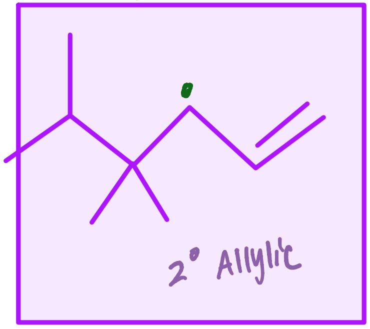


1°

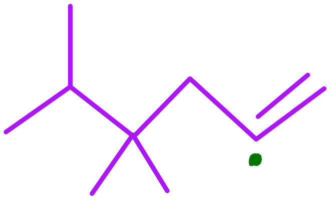


1°

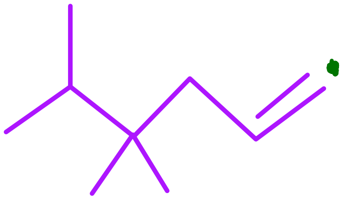
has resonance!



2° Allylic



2° vinylic



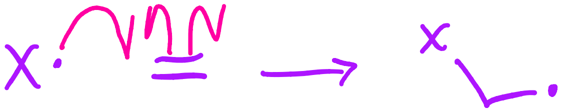
1° vinylic

least stable

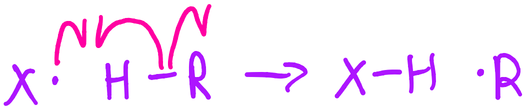
The radical mechanism patterns:

1. Homolytic cleavage

2. Addition to a pi bond

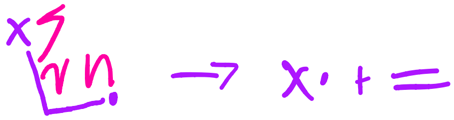


3. Hydrogen Abstraction



4. Halogen Abstraction

5. Elimination



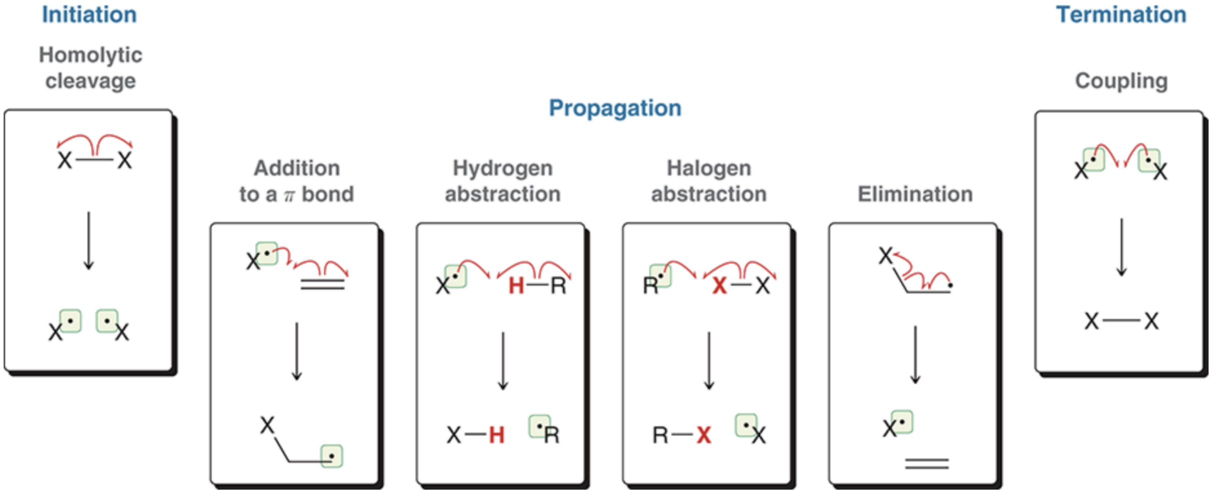
opposite of addition to pi bond

6. Coupling

Name the radical mechanism and draw the arrow pushing:

Halogen Abstraction

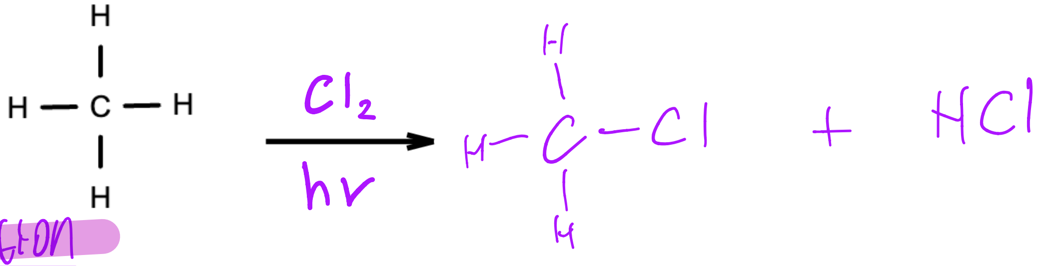
Patterns can be grouped into 3 categories, Initiation, Propagation, Termination



When doing radical reactions remember: when a new chiral center is formed or when adding to an existing chiral center, a racemic mixture will form!

Chlorination is Non-selective while bromination is Selective

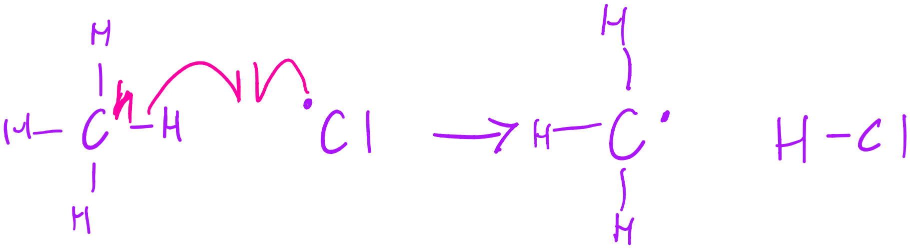
Draw the radical mechanism below, and name the mechanism being used in each step:



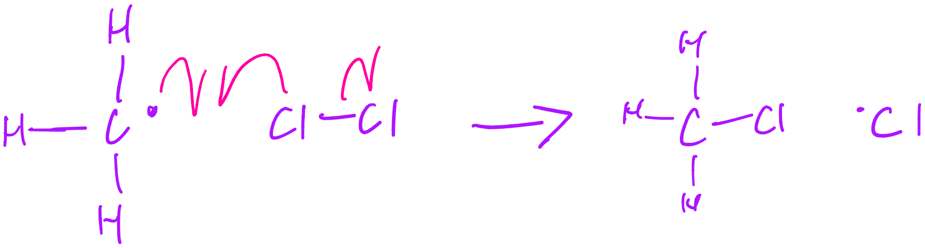
Initiation

Homolytic cleavage

Propagation

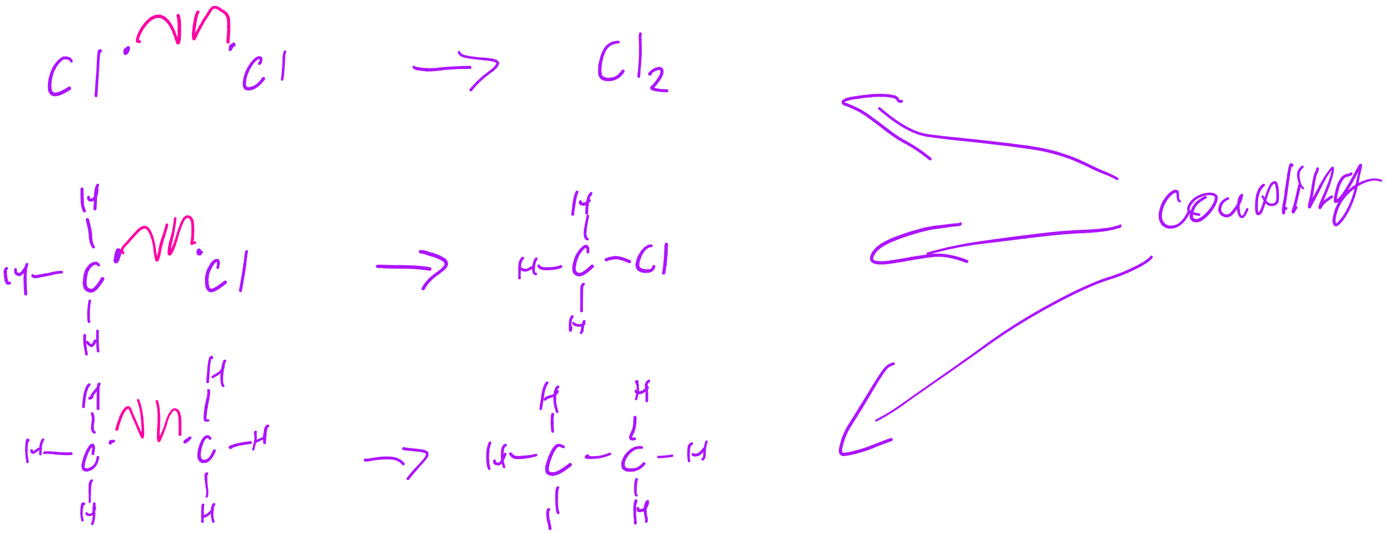


Hydrogen Abstraction

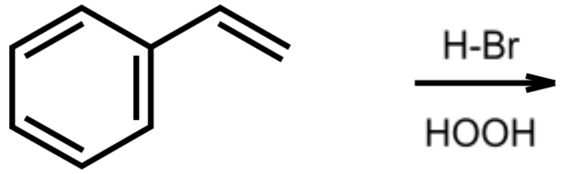


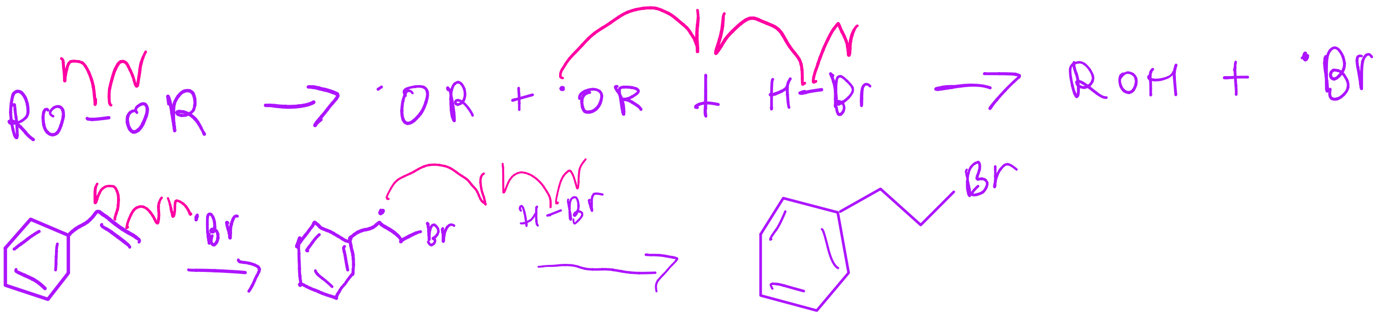
Halogen abstraction

Termination

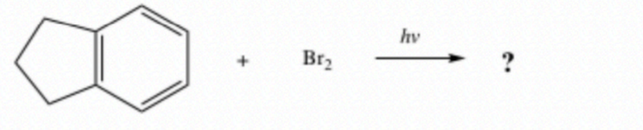


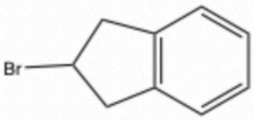
Draw the mechanism and label:

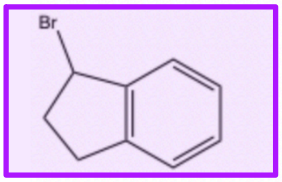




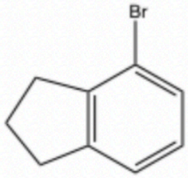
Give the major product of the following reaction.



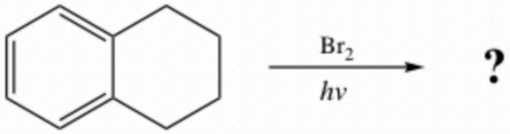


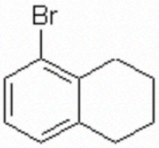
[✓ ]

There is no reaction under these conditions or the product is not listed here.

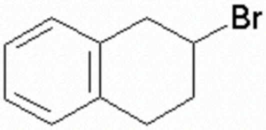


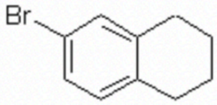
Give the major product of the following reaction.

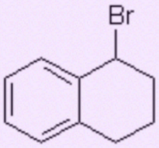


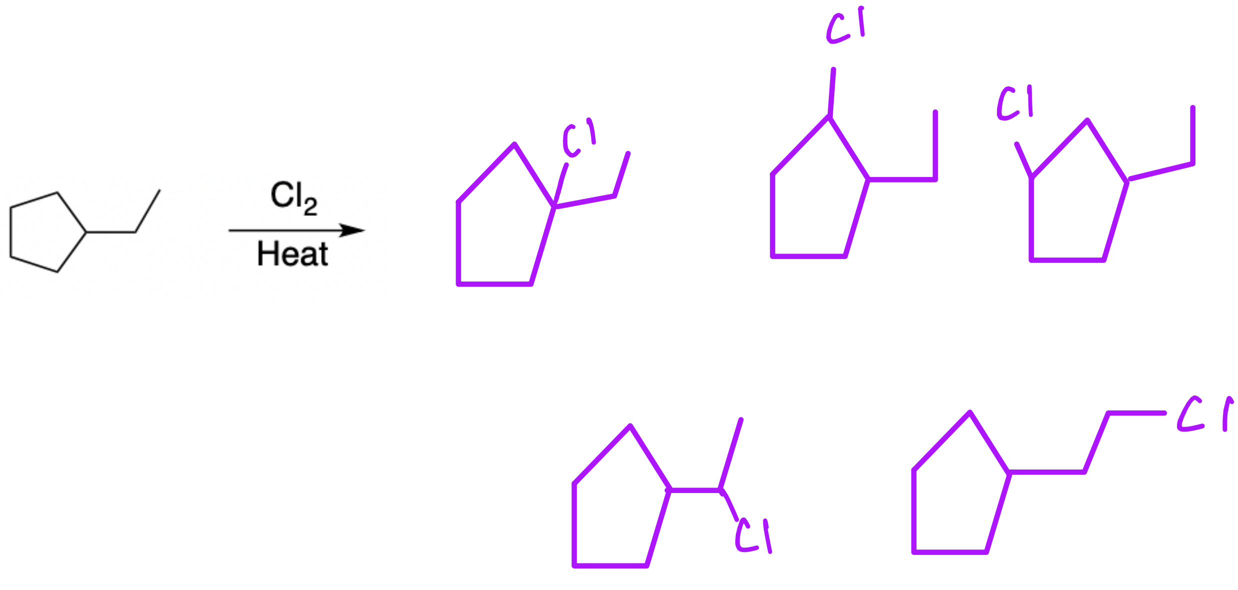


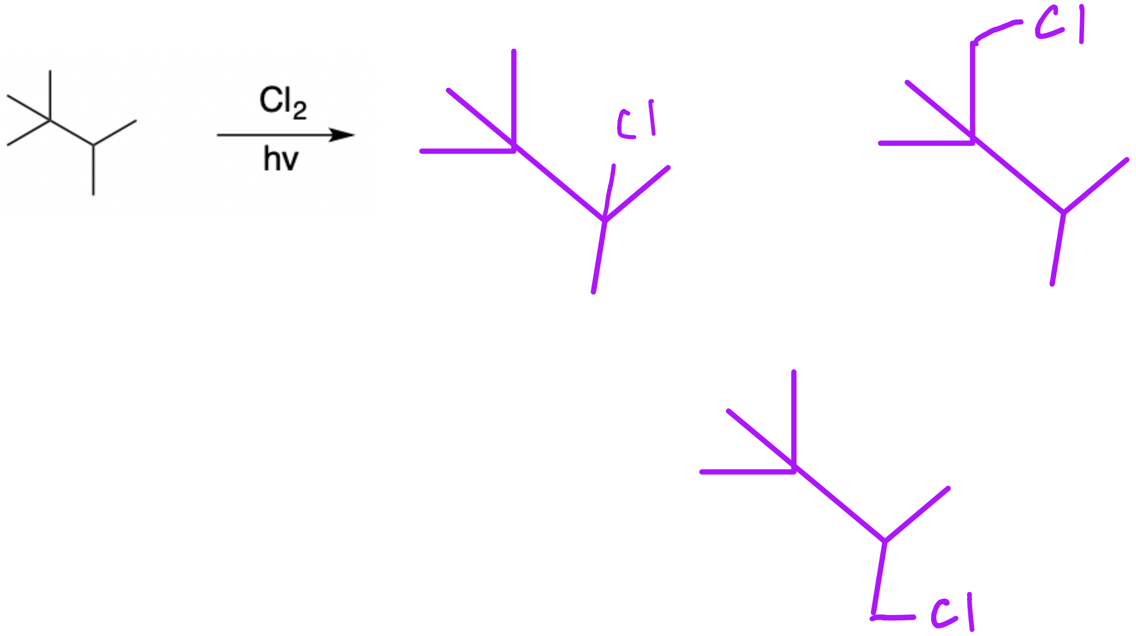
There is no reaction under these conditions or the product is not listed here.

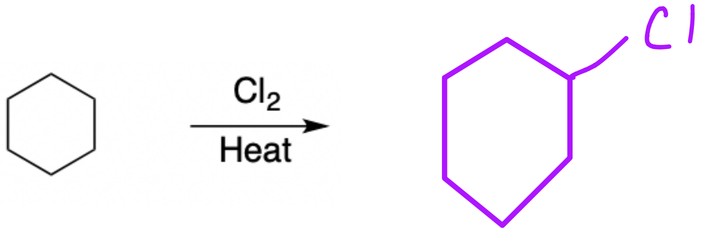




[✓ ]


Cl_2
Heat
Cl
Cl
Cl
Cl
Cl


Cl_2
hv
Cl
Cl
Cl


Cl_2
Heat
Cl

Draw the products of this reaction: