2.3 Introduction to the Common Functional Groups in Organic Chemistry: Their Typical properties, Preparations and Reactions.

A. Alkanes

Physical Properties

- Methane, ethane, propane, and butane are gases at room temperature.
- The unbranched alkanes pentane (C_5H_{12}) through heptadecane ($C_{17}H_{36}$) are liquids.
- Higher homologs are solids.
- The boiling points of unbranched alkanes increase with the number of carbons.

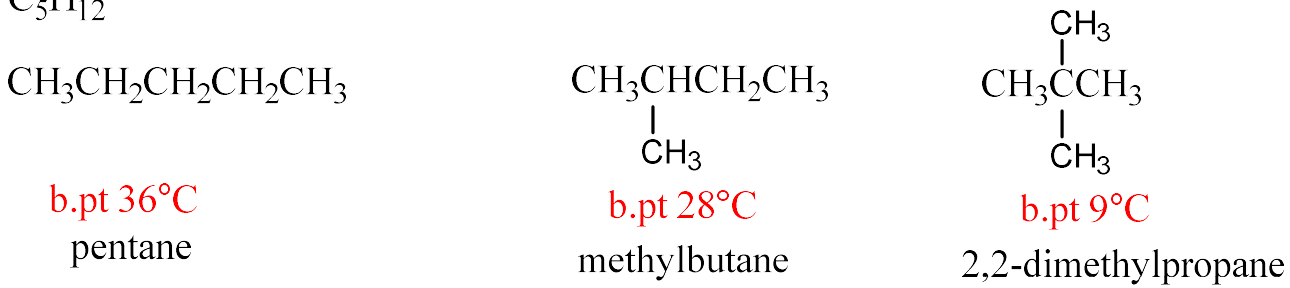
Name	Number of carbons	Molecular formula	Condensed structure	bp (°C)
Methane	1	CH_4	CH_4	−164
Ethane	2	C_2H_6	CH_3CH_3	−88.6
Propane	3	C_3H_8	$CH_3CH_2CH_3$	−42.1
Butane	4	C_4H_{10}	$CH_3(CH_2)_2CH_3$	−0.60
Pentane	5	C_5H_{12}	$CH_3(CH_2)_3CH_3$	36.1
Hexane	6	C_6H_{14}	$CH_3(CH_2)_4CH_3$	68.9
Heptane	7	C_7H_{16}	$CH_3(CH_2)_5CH_3$	98.4
Octane	8	C_8H_{18}	$CH_3(CH_2)_6CH_3$	125.7

Solubility

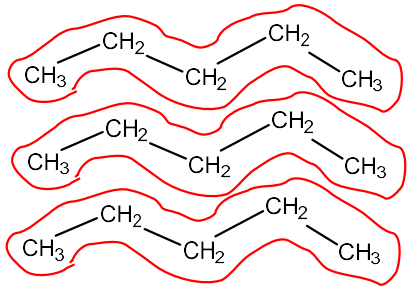
- Alkanes are insoluble in water because the polar water molecules are not attracted to the non-polar alkane molecules.
- Alkanes are soluble in non-polar solvents such as Carbon Tetrachloride, CCl_4.

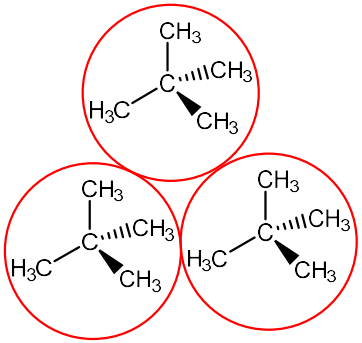
- Branched alkanes have lower boiling points than their unbranched isomers.

C_5H_{12}



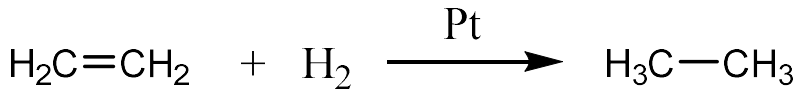
- Pentane molecules have more van der Waals attraction than the other.
  - Straight chain pentane molecules have more surface area available for contact between them than the spherical 2,2-dimethylpropane.



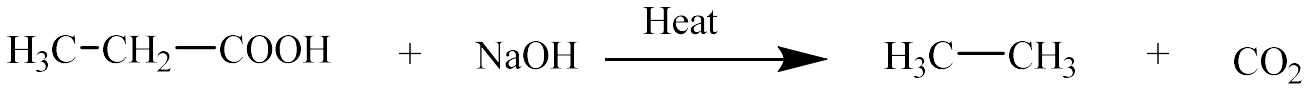


Preparations of Alkanes

1. Catalytic hydrogenation of alkenes or alkynes.



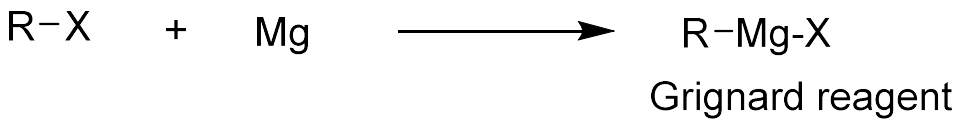
2. Thermal Decarboxylation of a Carboxylate Salt



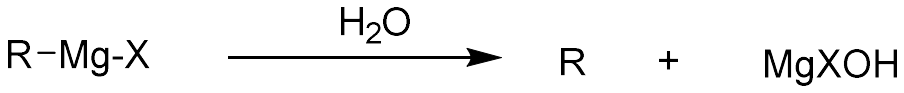
3. Grignard reagents

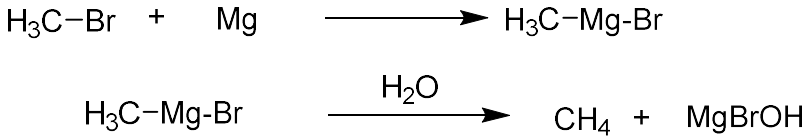
Organic compounds in which a metal atom is directly linked to carbon atom are known as organometallic compound.

Alkyl magnesium halide (R-MgX) are also called Grignard reagents or organometallic compounds.



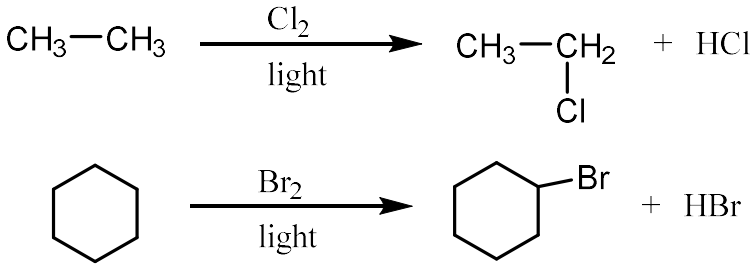
- hydrolyzing of Grignard reagent (react it with water) gives alkane.





Reactions of Alkanes

- Alkanes are sometimes referred to as paraffins, meaning “little affinity”.
- They show little chemical affinity for other substances and are chemically inert to most laboratory reagent.
- Alkanes react with halogens in the presence of heat or light.

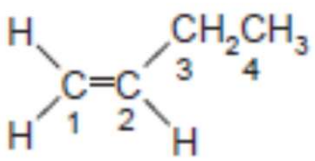


B. Alkenes

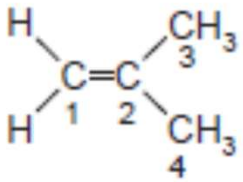
Physical properties of alkenes

- Alkenes are also referred to as "olefins". The word means fat dissolving since fats are relatively non-polar as alkenes are.
- The boiling points and solubilities of alkenes are very similar to the alkanes.
- The b.p and m.p of alkenes increase with increasing molecular weight but show some variations that depend on the shape of the molecule.
- Isomeric alkenes show different b.p and m.p depending on the position of the double bond.

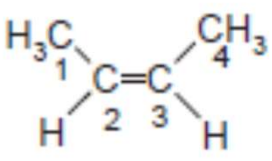
C_4H_{10}



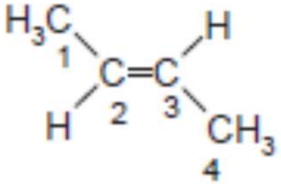
1-Butene
b.p = -6
m.p = -195



2-Methylpropene
b.p = -7
m.p = -144



cis-2-Butene
b.p = +4
m.p = -139

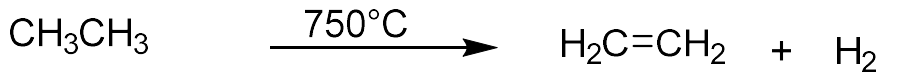


trans-2-Butene
b.p = +1
m.p = -106

Preparation of Alkenes

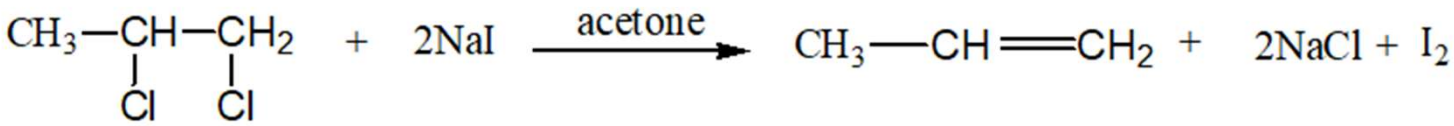
1. Dehydrogenation of Alkanes

High temperature dehydrogenation of alkenes produce alkenes.

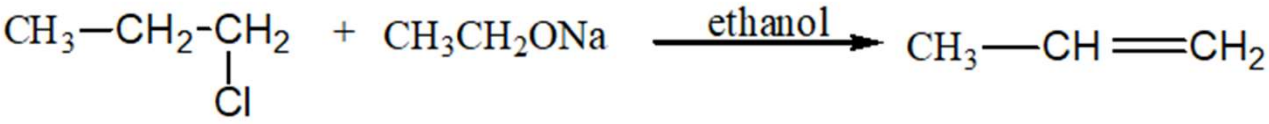


2. Dehalogenation of Vicinyl di-halides

A vicinyldihalide is an alkyl halide that has two atoms of halogen attached to adjacent carbons in the molecule.

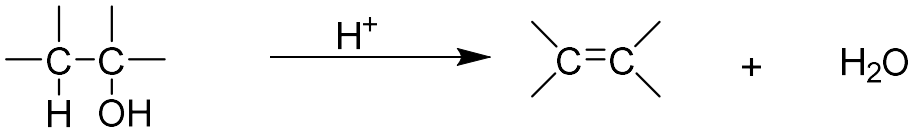


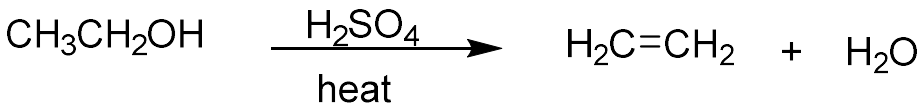
3. Dehydrohalogenation of an alkyl halide

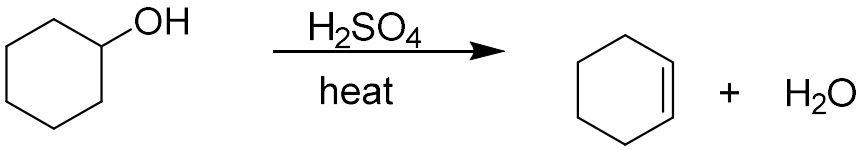


4. Dehydration of an Alcohol

In the dehydration of alcohols, the H and OH are lost from adjacent carbons. An acid catalyst is necessary.

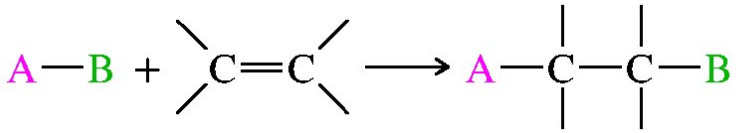




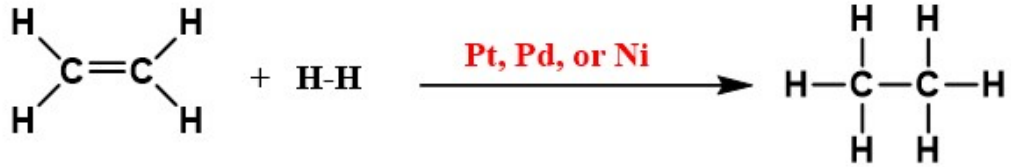


Reactions of Alkenes

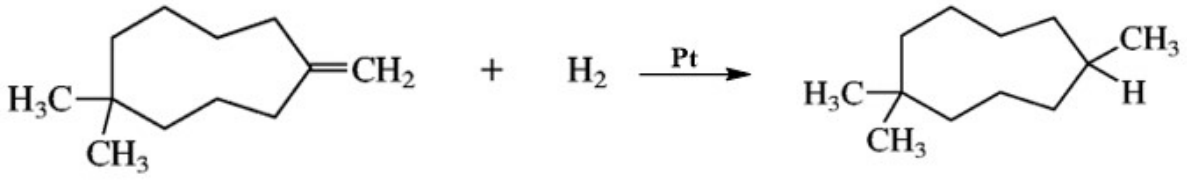
Alkenes are electron-rich species. The characteristic reaction of alkenes is addition to the double bond according to the general equation.



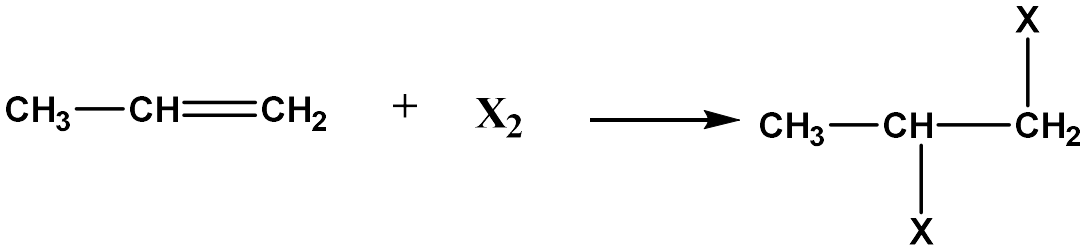
1. Hydrogenation



$(CH_3)_2C{=}CHCH_3 + H_2 \xrightarrow{Pt} (CH_3)_2CHCH_2CH_3$

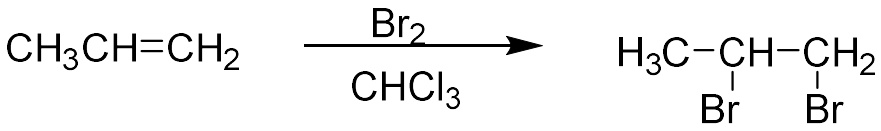


2. Addition of Halogens

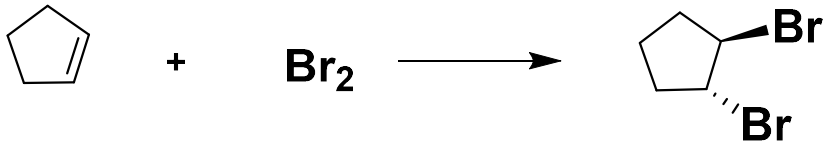


vicinal dihalide

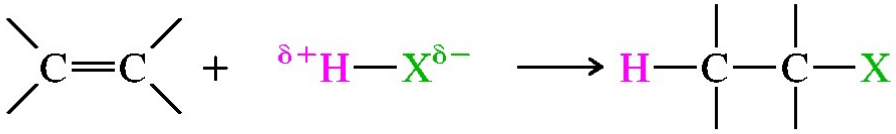
Latin *vicinalis*, means "neighboring."



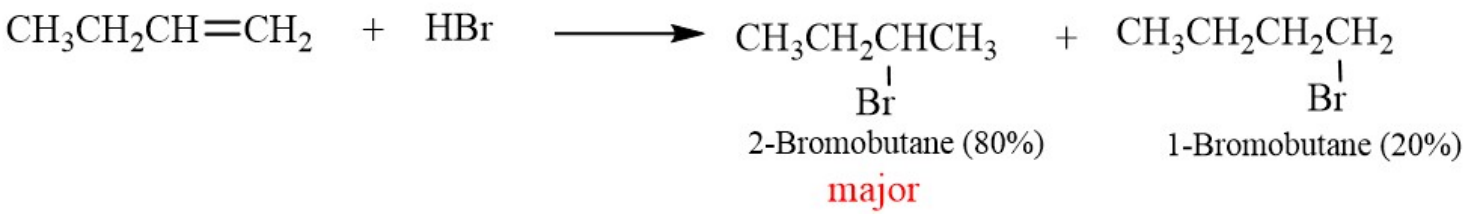
- anti-stereochemistry-two new groups are added to opposite sides of the original pi bond



3. Addition of Hydrogen Halide (HX)

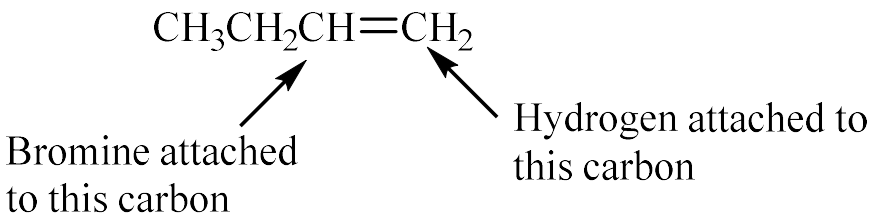


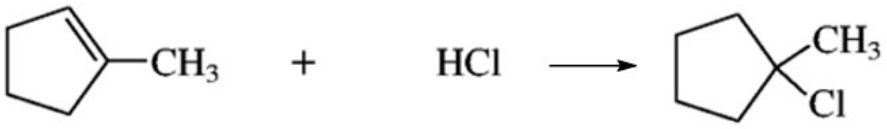
Alkene Hydrogen halide Alkyl halide



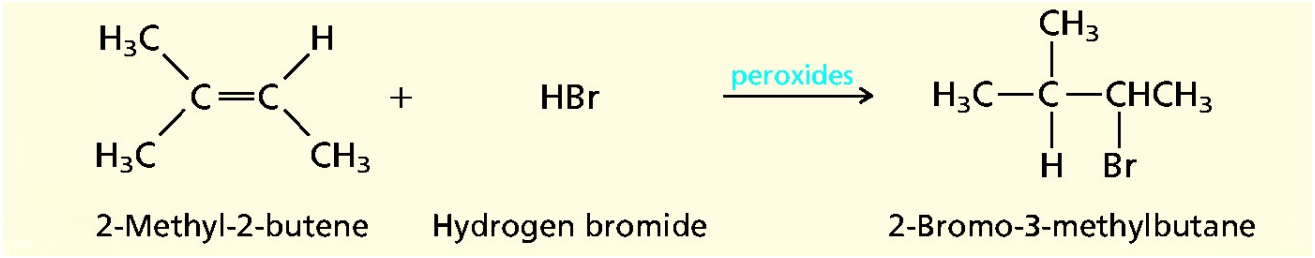
The major product is determined by Markovnikov's rule

Markovnikov's rule states that when an unsymmetrically substituted alkene reacts with a hydrogen halide, the hydrogen adds to the carbon that has the greater number of hydrogens, and the halogen adds to the carbon having fewer hydrogens.





- In the presence of peroxide (ROOR) the hydrobromination follows *Anti Markovnikovaddition* .
- Only HBr addition occurs by this pathway.

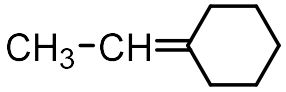


Ex. Write the structure of the major organic product formed in the reaction of HCl with the following

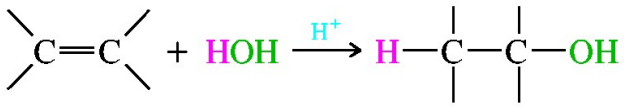
a) 2-methyl-butene

b) 2-methyl-2-butene

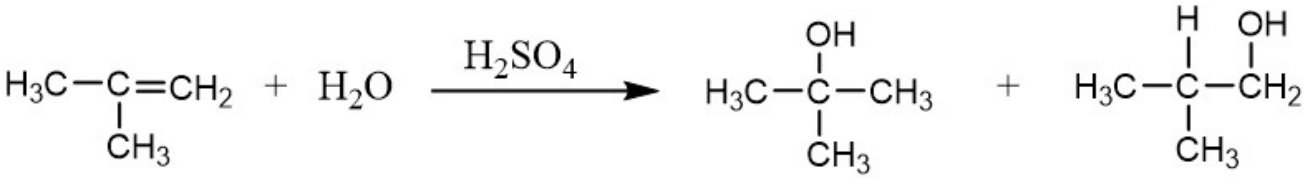
c) cis-2-Butene

d) 

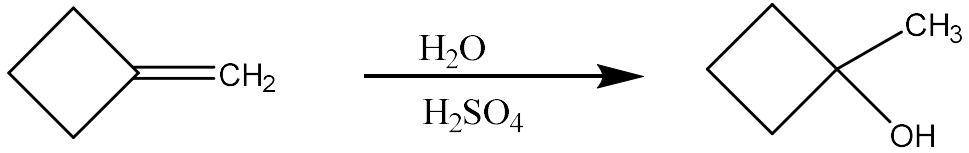
4. Addition of water (Hydration)



Alkene Water Alcohol

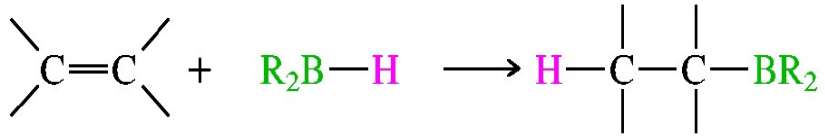


The reaction follows Markovnikov's rule.

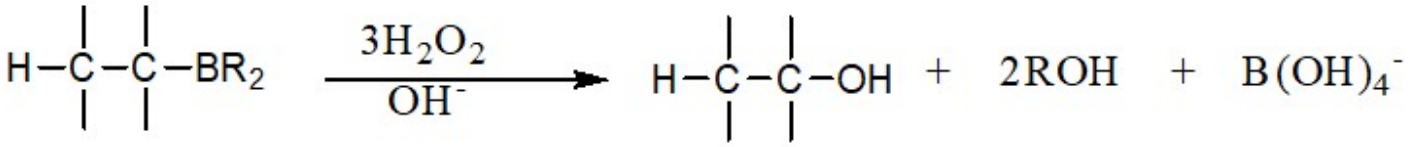


5. Hydroboration-Oxidation of Alkenes

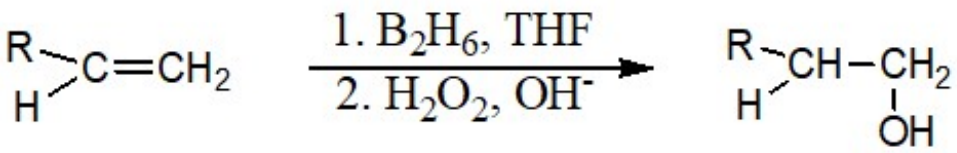
- A two steps reaction



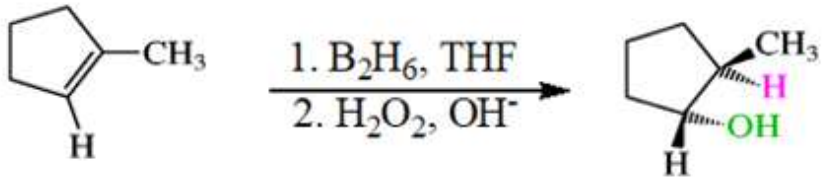
Alkene Boron hydride Organoborane



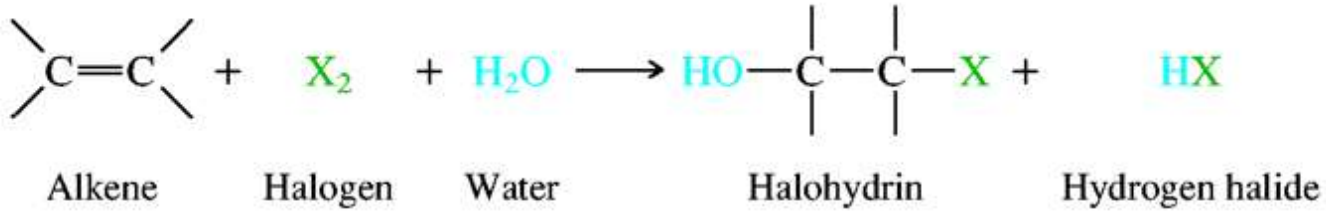
- borane-tetrahydrofuran complex (H_3B-THF)-common hydroborating agent

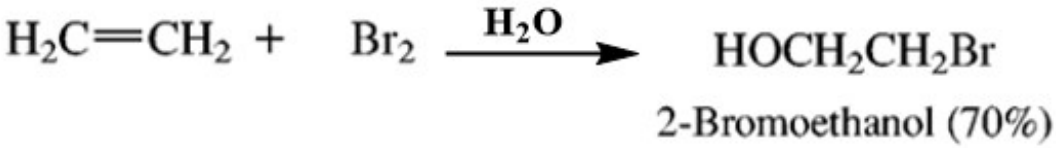


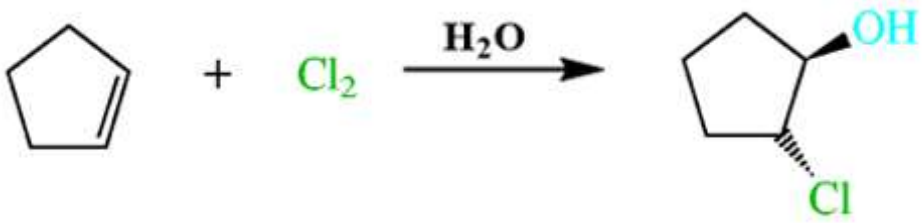
anti-Markovnikov's addition



6. Conversion of Alkenes to Vicinal Halohydrins

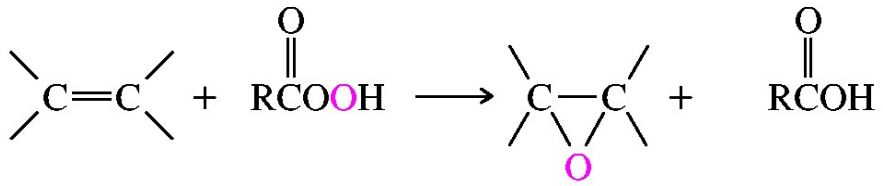




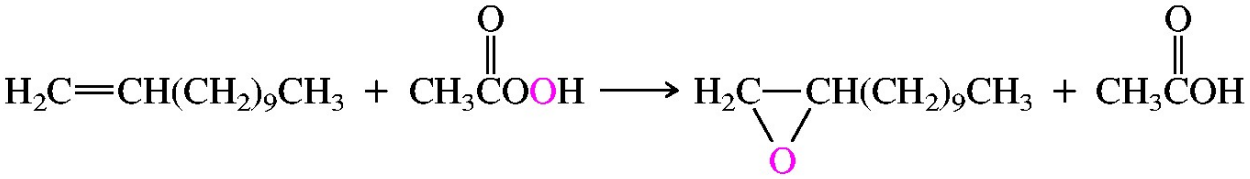


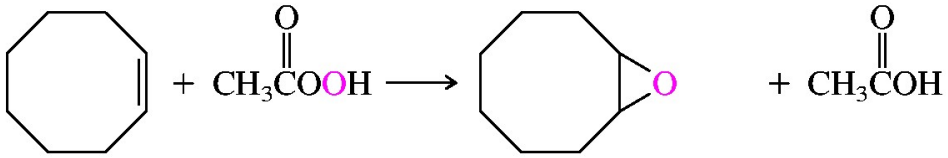
7. Epoxidation of Alkenes

Epoxides are easy to prepare via the reaction of an alkene with a peroxy acid.



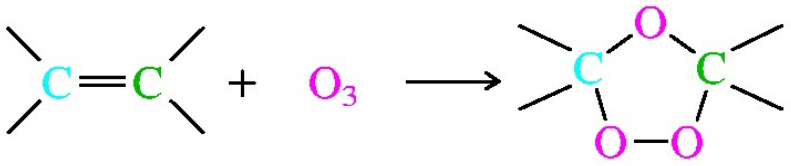
Alkene Peroxy acid Epoxide Carboxylic acid





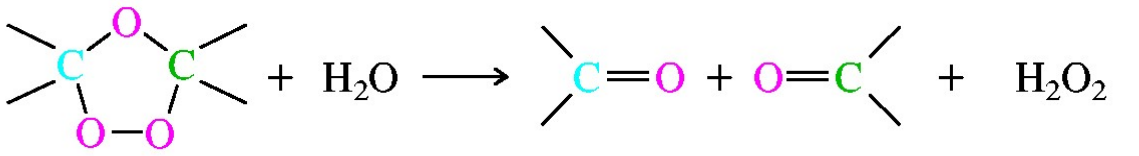
7. Ozonolysis of Alkenes

Ozone is a powerful electrophile and undergoes a remarkable reaction with alkenes in which both the σ and π components of the carbon-carbon double bond are cleaved to give a product referred to as an **ozonide**.



Alkene Ozone Ozonide

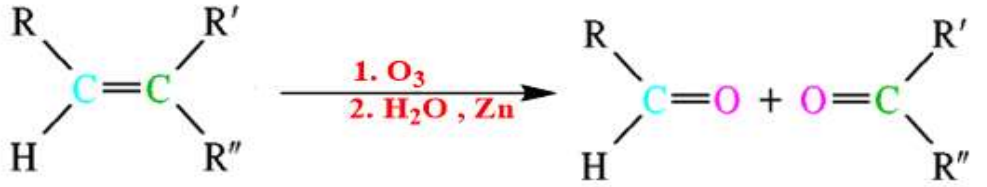
Ozonides undergo hydrolysis in water, giving carbonyl compounds.



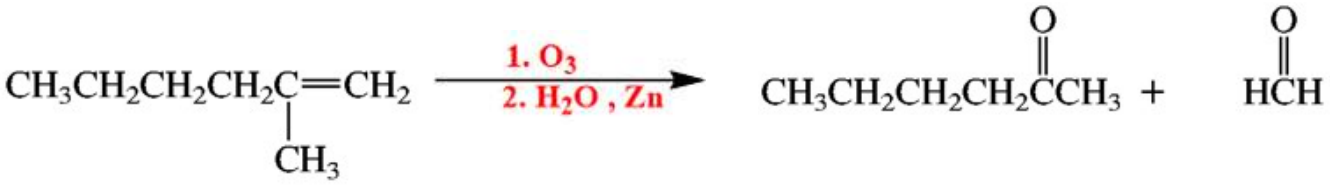
Ozonide Water Two carbonyl compounds Hydrogen peroxide

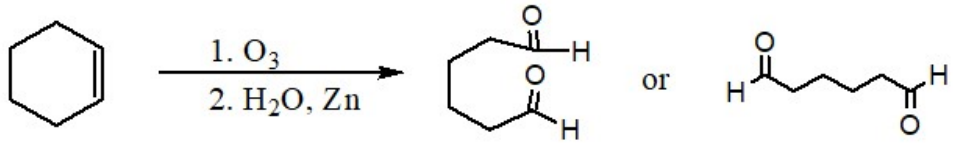
The two-stage reaction sequence is called **ozonolysis**

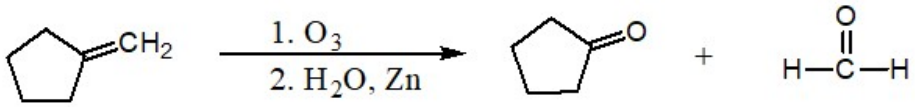
The two-stage reaction sequence is called **ozonolysis** and is represented by the general equation



ozonolysis

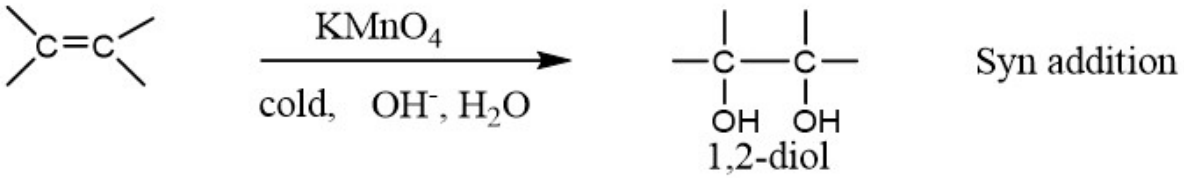




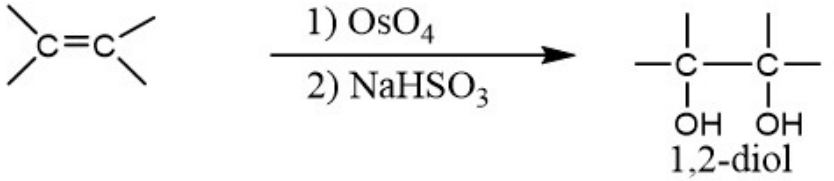


8. Hydroxylation

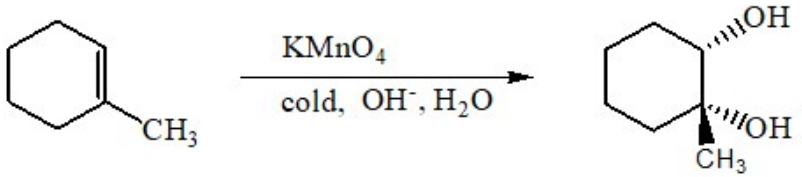
- addition of two OH groups to each of the two double bonded carbon

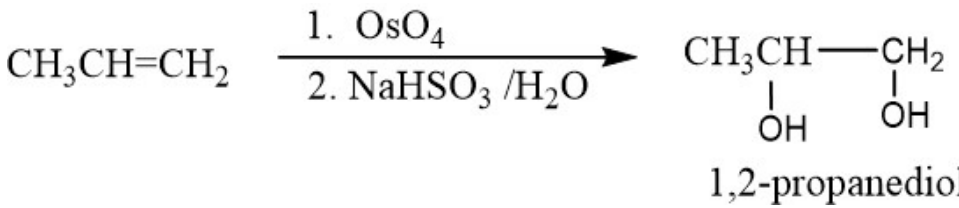


Syn addition



Syn addition





9. Oxidative cleavage of an alkene using hot alkaline $KMnO_4$

Acidic $KMnO_4$ also causes double bond cleavage like ozone.