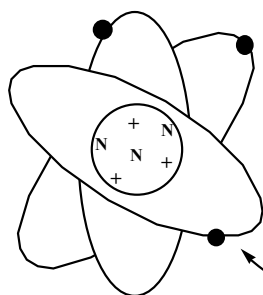


CHEMISTRY 3332 – ORGANIC II

Review Wade Chapters 1-13

See: www.chem.uh.edu/courses/thummel/Chem3331/Wade**REVIEW****Chapter 1 Intro & Review**Consider a simple picture of an **ATOM**:**Nucleus** consists of:

	<u>Mass</u>	<u>Charge</u>
+ Protons	+1	+1
N Neutrons	+1	0

 Electron *ca.* 0 -1

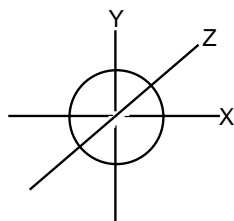
Isotopes of an element have different numbers of neutrons in their nucleus. For

example. ^{12}C has 6 protons + 6 neutrons ^{13}C has 6 protons + 7 neutrons ^{14}C has 6 protons + 8 neutrons ($t_{1/2} = 5730$ years, tell ages up to 50K yrs)

This picture for the nucleus is OK but not so good for the electrons. They cannot be represented as point charges. This problem was solved by the birth of **quantum mechanics**

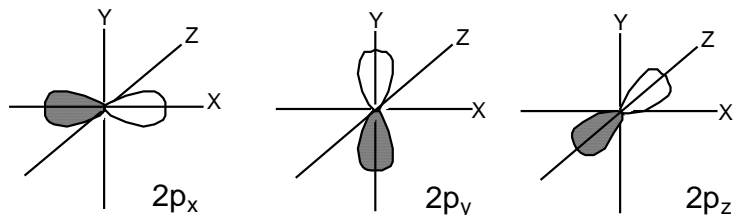
Shapes of Atomic Orbitals (3 types: s, p, d)

1s orbital is lowest in energy and closest to the nucleus

S- orbital
spherically symmetrical

p orbitals have a node at the nucleus and two lobes which extend on either side

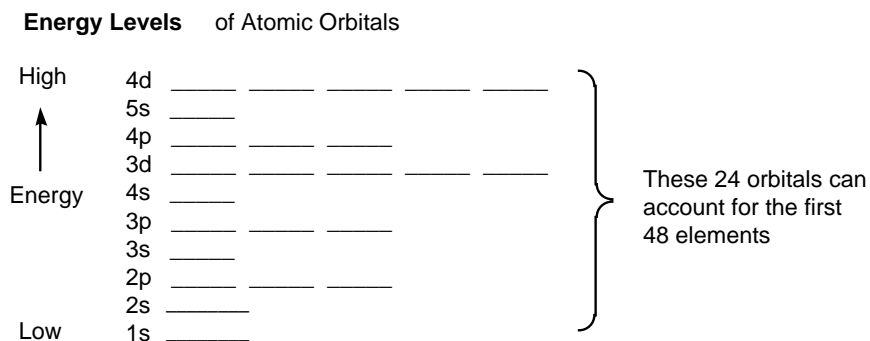
P-orbital has a node at the nucleus



Rules for Filling Atomic Orbitals

1. Aufbau Principle orbitals of the lowest energy are filled first.
2. Pauli Exclusion Principle only two electrons can occupy the same orbital and they must have the opposite spins.
3. Hund's Rule if two or more empty orbitals of equal energy are available, one electron is placed in each until all are half full.

Energy Levels of Atomic Orbitals



Chemical Bonds are the forces that hold atoms together in a molecule.

Note- energy is always released when a bond is formed
i.e. a more stable (lower energy) situation results.

1915 - G. N. Lewis proposed the "octet rule"

Atoms will tend to **transfer** or **share** electrons to acquire a stable (complete) outer shell configuration. (similar to He, Ne, and Ar). This leads us to the two types of chemical bonds:

1. **Ionic Bonds** result from the transfer of electrons creating oppositely charged species which then attract one another.

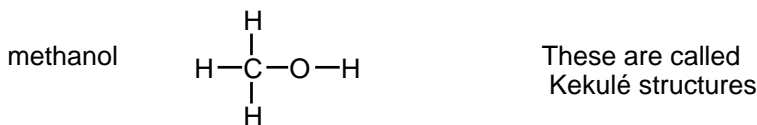
Ionization Energy - tendency of an atom to lose an electron. "Electropositive" elements (*i.e.* Na, sodium) have low I.E. and hence can easily lose an electron to become positively charged.

Electron Affinity- tendency of atom to gain an electron. "Electronegative" elements (*i.e.* F, fluorine) have low (large negative) E.A. and hence can easily add an electron to become negatively charged.

Sodium Fluoride (NaF)
How about carbon ??

2. **Covalent Bonds** - result from the sharing of electrons (to give a complete outer shell configuration).

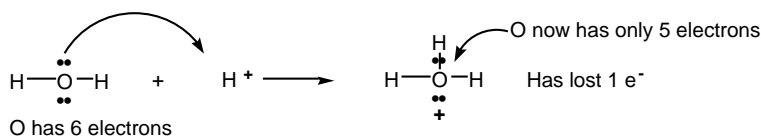
Designate this process using **Lewis Dot Structures**



Formal charges

when an atom loses an electron in forming a covalent bond it acquires a +
when an atom gains an electron, it acquires a -

(a) consider the protonation of water

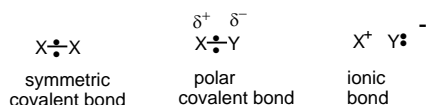


Notice how we use curved arrows to designate the movement of 2 electrons. These arrows do not show the movement of atoms. **VERY IMPORTANT**

Polarization

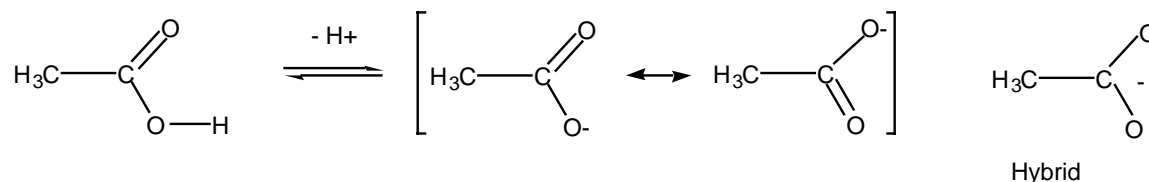
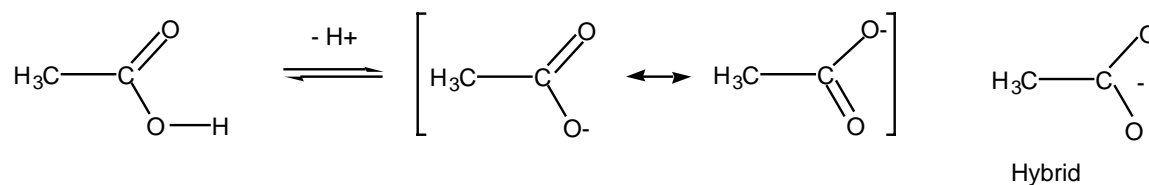
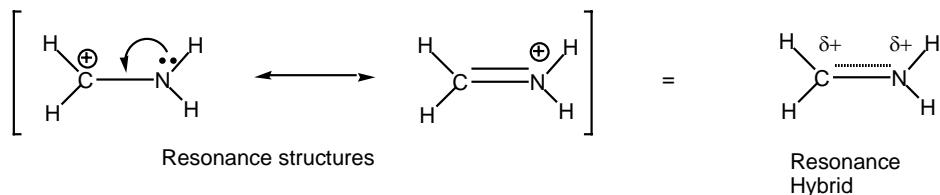
Bonds between non-identical atoms are very often **polar**
i.e. the electron distribution in the bond is unsymmetrical.
 electrons are unequally shared by both nuclei

This **polarity** is due to the intrinsic electronegativity of atoms on the right side of the periodic table



Resonance Structures

Some cmpds are not adequately represented by a single Lewis structure. Two or more valence bond structures which differ only in the arrangement of electrons are called resonance forms (structures).



General Rules for Resonance

1. All resonance structures must be valid Lewis structures
2. Structures differ only in arrangement of electrons. Atoms and bond angles cannot change.
3. Number of unpaired (odd) electrons must remain the same
4. Major resonance contributor is one with lowest energy. Neg charge more stable on electroneg atom.

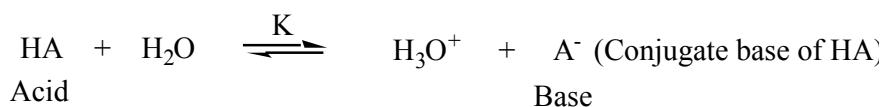
5. The more resonance forms the better

Acid-Base Theory

1. Bronsted -Lowry Definition

Acid = proton donor

Base = proton acceptor



$$K = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}][\text{H}_2\text{O}]}$$

Large (constant) ↗

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]}$$

↑
Acidity Constant

$$\mathbf{pK_a = -\log K_a}$$

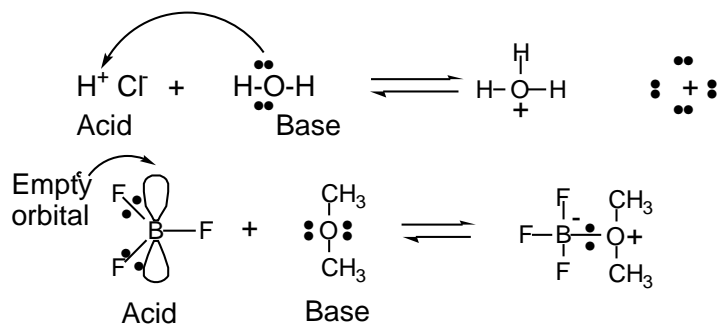
The stronger the acid, the lower the value of pK_a (Explain)

Lewis Definition

Acid- Electron pair acceptor

Base- Electron pair donor

This is more general and covers the Bronsted def. but also includes others.



In general:

Compounds with N, O are good Lewis bases because they have lone pair electrons which they can donate.

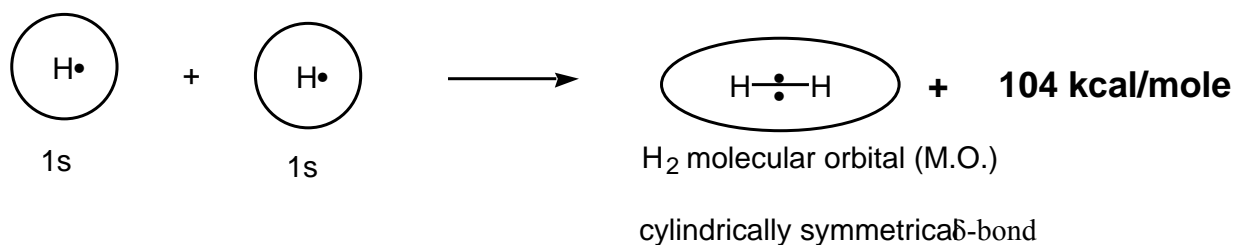
Note:

Another name for Lewis acid is **electrophile** (electron-loving)

Another name for Lewis base is **nucleophile** (nucleus loving)

Chapter 2 Structure and Properties of Organic Molecules

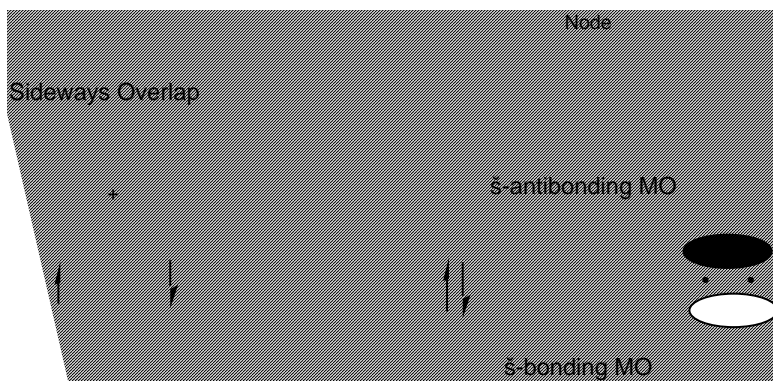
We have used **atomic orbital** (A.O.) theory to explain how electrons are to be arranged in atoms. When 2 AO's combine to form a covalent bond, we have a new **molecular orbital** (MO)



Note energy is released (a lot!)

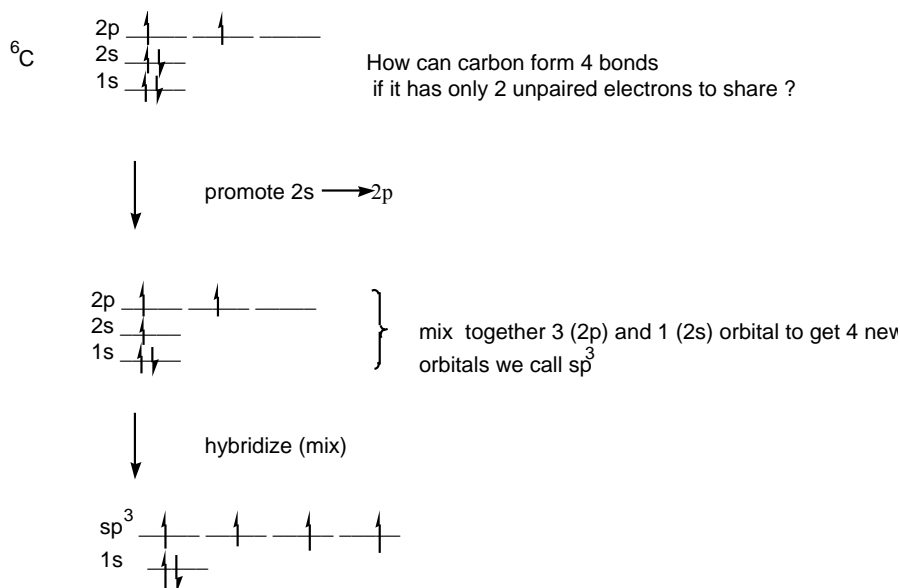
This energy is the bond strength of the H--H bond.

This much energy is required to split H₂ \longrightarrow 2 H•

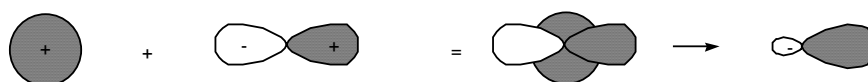


Let's consider the structure of **methane** CH₄

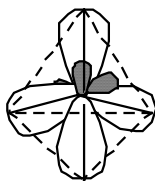
Shape of new sp³ hybrid



Shape of new sp^3 hybrid



Arrange four of these so that they all originate from a common point and are oriented as far apart as possible.

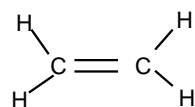


They point to the corners of a regular tetrahedron.

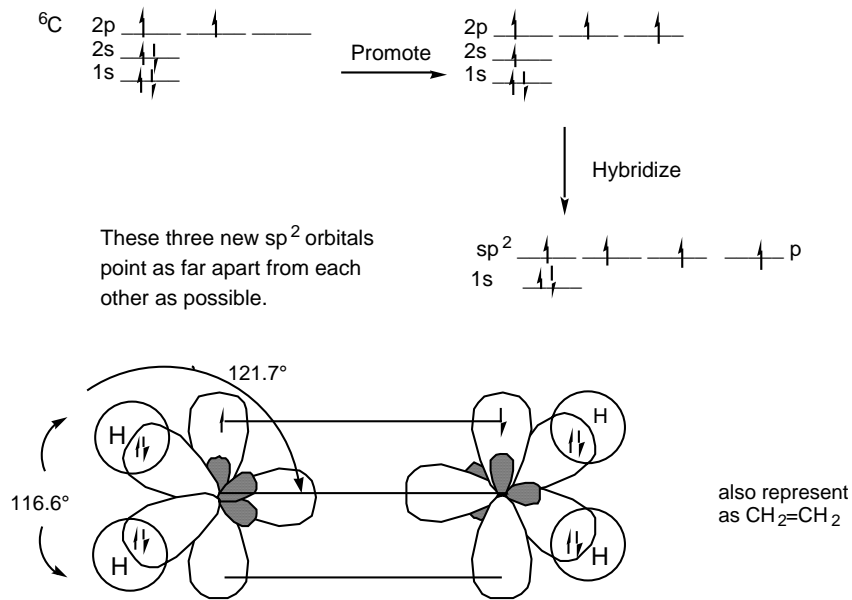


Ethylene: sp^2 Hybridization

The carbons in ethylene (C_2H_4) are each connected to 3 other atoms. The fourth valence of the ethylene involves a $\text{C}=\text{C}$ double bond.

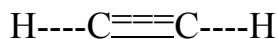


How do we explain this structure in terms of orbitals?

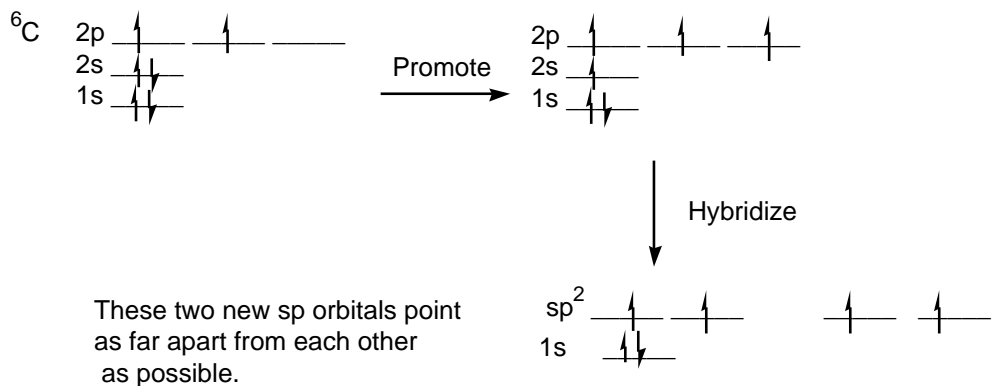


Acetylene: sp Hybridization

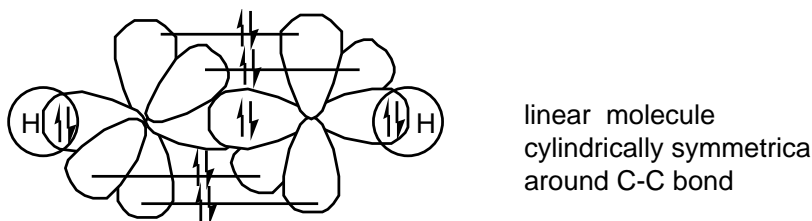
The carbons in acetylene C_2H_2 are each bonded to 2 other atoms. The third and fourth valences involve a $\text{C}\equiv\text{C}$ triple bond.



How do we explain this structure with orbitals?

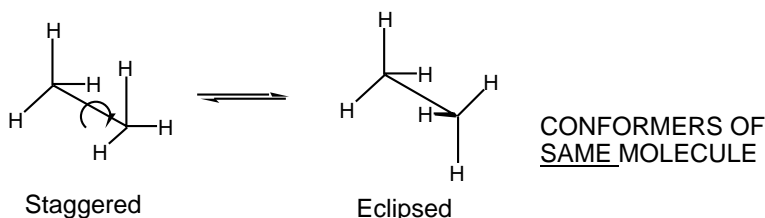


These new sp orbitals point as far apart from each other as possible



Rotation about Bonds - Isomers

There is free rotation about the central C-C bond of ethane, the C-H bonds on one carbon may be *eclipsed* or *staggered* with respect to one another



Structures which differ only by rotations about single bonds are called **conformations**

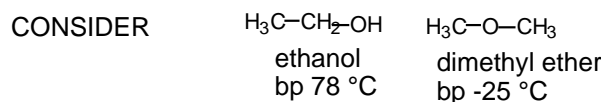
Dipole moments and the forces that attract molecules

We have learned about the planarity of bonds and how to compute the dipole moments of molecules. How can intermolecular forces (attractions or repulsions) help us to understand the 3 states of matter (gas, liquid, solid)?

Dipole-dipole interactions cause attractions between polar molecules. These forces must be overcome in melting or boiling.

What about non-polar molecules? Why do larger molecules have higher BP and MP? This is due to **van der Waals** forces. These result from temporary dipole moments due to the uneven distribution of electrons.

Hydrogen Bonding A hydrogen atom can participate in H-bonding if it is bonded to O, N, F. Since no molecules contain H-F, we consider only O-H and N-H. O-H-----O-C worth about 5 kcal/mole

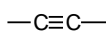


These functional groups can be grouped into three general categories.

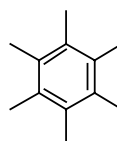
1) Groups with C-C multiple bonds



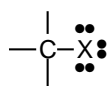
Alkenes



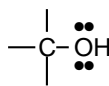
Alkynes



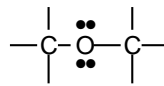
Arenes

2) Groups with carbon singly bonded to an electronegative atom.

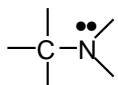
Alkyl halide



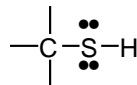
Alcohol



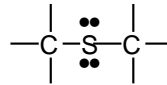
Ether



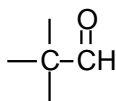
Amine



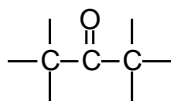
Thiol



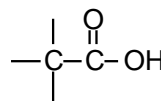
Sulfide

3) Groups with a C=O (carbonyl group)

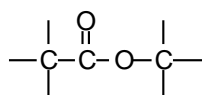
Aldehyde



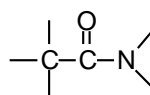
Ketone



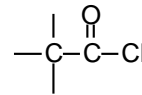
Carboxylic Acid



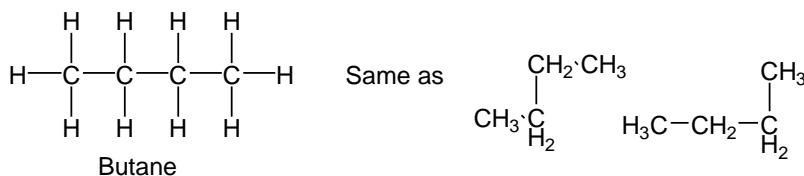
Ester



Amide



Acid chloride

Chapter 3 The Structure and Stereochemistry of Alkanes**Table 3-1 *n*-Alkanes** LEARN NAMES OF FIRST 10 (Think about next 10)

CH ₄	methane
CH ₃ CH ₃	ethane
CH ₃ CH ₂ CH ₃	propane

CH ₃ (CH ₂) ₂ CH ₃	butane	General formula = C _n H _{2n+2}
	pentane	
	hexane	
	heptane	
	octane	Homologs - differ only by number of CH ₂ groups
	nonane	
CH ₃ (CH ₂) ₈ CH ₃	decane	

Isomers are compounds with the same molecular formula but different chemical structures.

Butane	2 isomers
Heptane	9 (draw them)
Decane	75
C ₁₅ H ₃₂	4347
C ₄₀ H ₈₂	62,491,178,805,831 isomers!

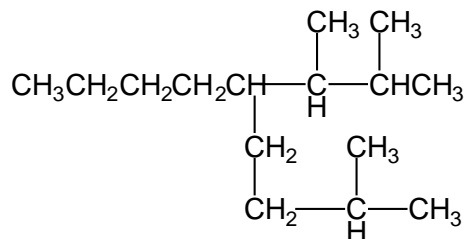
IUPAC Nomenclature Rules for Alkanes

- Find the longest continuous carbon chain and use this name as the base
 - If two chains of equal length are present, choose the one with the more branch points as the parent.
- Number the longest chain beginning with the end nearest a substituent (number structure above)
- Name each substituent group and assign it a number.
 - If there are 2 substs on the same carbon, they both get the same number.
- Write out the name

substituents come in alphabetical order.

use *di-*, *tri-*, *tetra-* for multiples of the same subst.
- Name any complex substituent

For example



2-Methyl-5-(1,2-dimethylpropyl)nonane

Sometimes referred to as paraffins

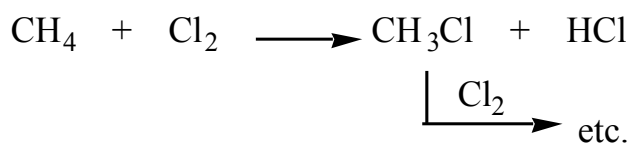
from Latin "parum affinis" = slight affinity

Relatively chemically inert

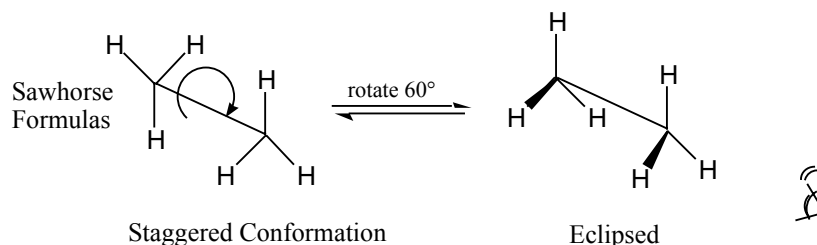
1. Combustion is the reaction with oxygen



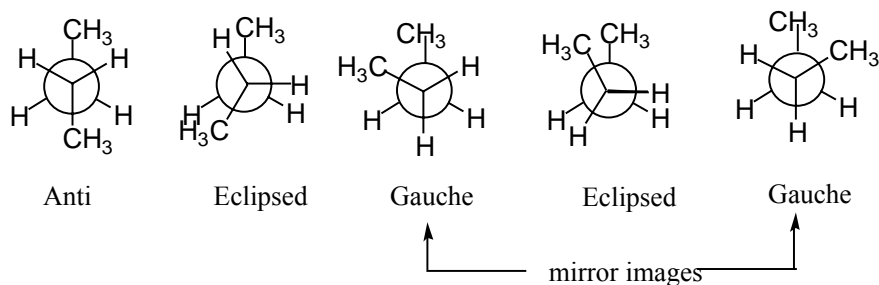
2. Halogenation



Conformations of Alkanes



Conformations of n-butane



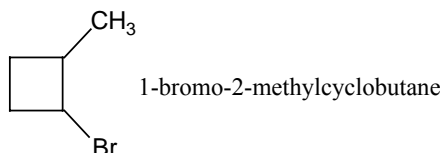
Cycloalkanes

Nomenclature (IUPAC)

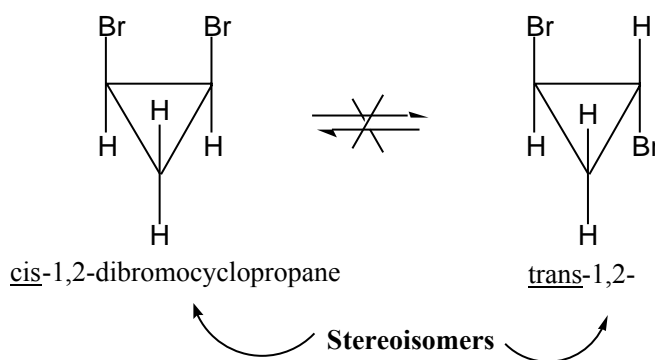
1. Use cycloalkane as base name

2. Number substituents to arrive at the lowest sum of numbers.

When 2 different alkyl groups are present, number alphabetically
Halogen substituents are treated like alkyls.



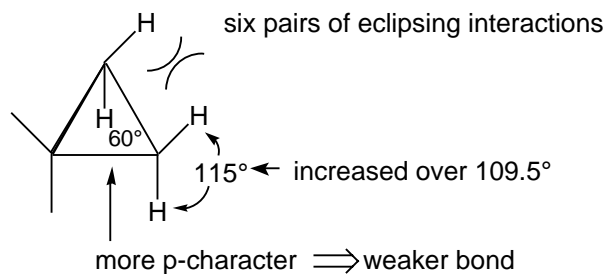
When the acyclic portion of the molecule contains more carbons than the cyclic part or when it contains an important functional group, the cyclic part is named as a cycloalkyl substituent (give example).

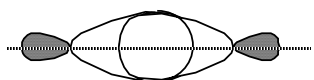


Nature of Ring Strain

- 1). Angle strain- due to expansion or compression of bond angles
- 2). Torsional strain- due to eclipsing of neighboring bonds
- 3). Steric strain- due to repulsive interaction of atoms approaching too closely

1. Cyclopropane





Normal C-C bond
efficient overlap along
C-C axis

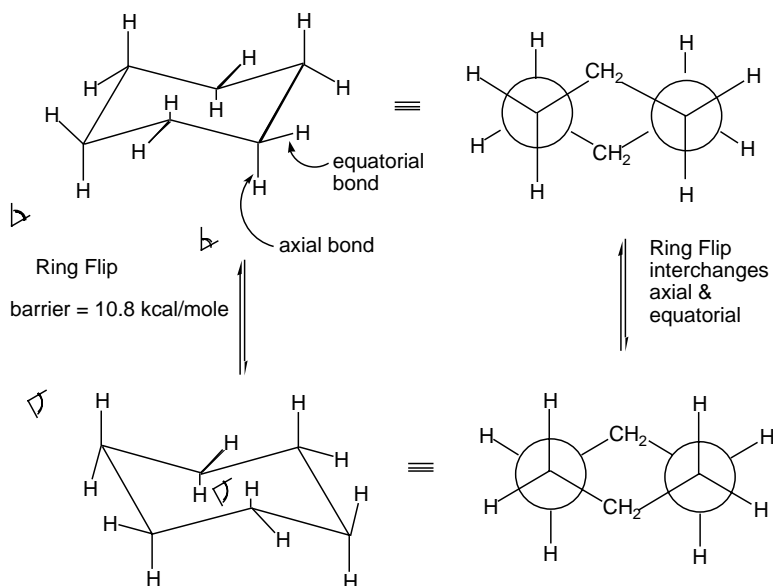


less efficient
overlap,
outside C-C
axis
more p-like
hence orbitals are
 sp^4 - sp^5
" Bent Bonds"
(easier to break-
more reactive)

Cyclohexane - most important of the cycloalkanes.

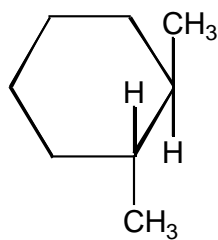
can adopt a conformation that is essentially strain free

no bond angle strain and no eclipsed-hydrogen strain

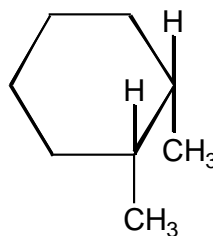


Show how to draw cyclohexanes, axial & eq. bonds.

Substituted cyclohexanes



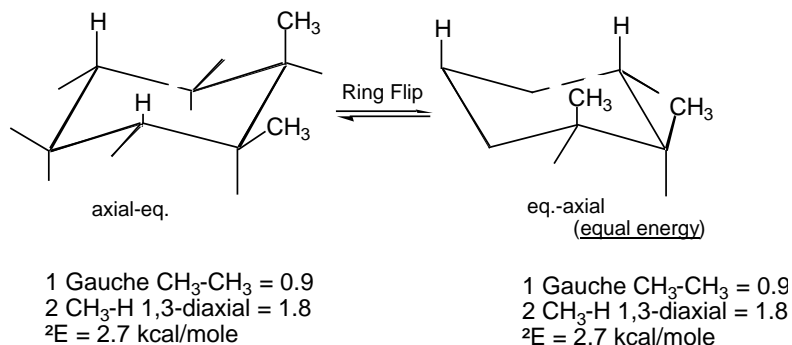
trans



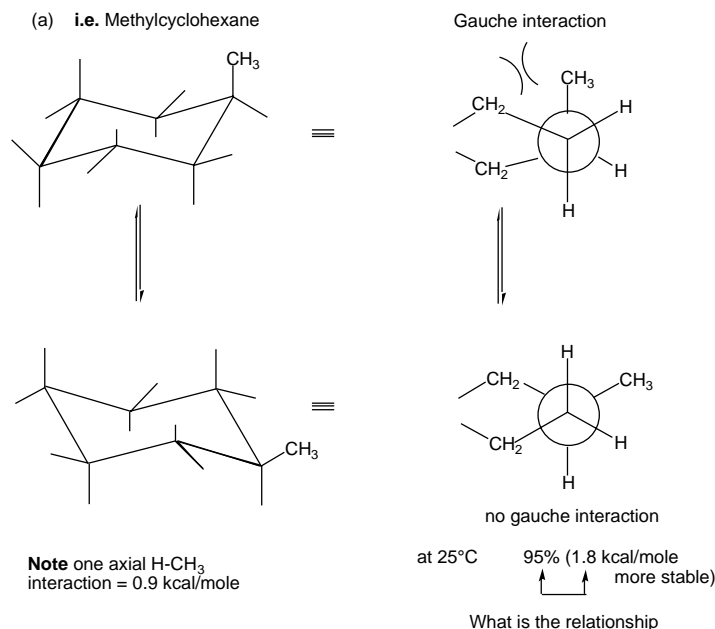
cis

different
chemical
cmpds.
Look
further

1) **cis-1,2**



In fact the two **conformers** are (non-superimposable) mirror images of one another, hence we have conformational enantiomerism (later)



Do same analysis for 1,3- and 1,4-dimethylcyclohexane.

Chapt. 4 The Study of Chemical Reactions

Mechanism is a complete step-by-step description of the bond making and bond breaking steps in a reaction; depends to a large extent on:

Thermodynamics - study of the energy changes that accompany a chemical reaction. Relates to product & reactant stabilities and equilibrium.

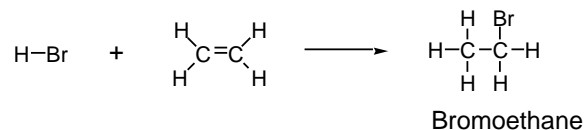
Kinetics - study of reaction rates, how fast reactions occur

Reactions can be organized in 2 ways:

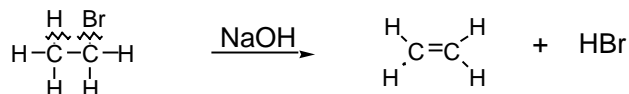
1. What kinds of reactions occur.
2. How reactions occur

Consider #1 first, *kinds of reactions*

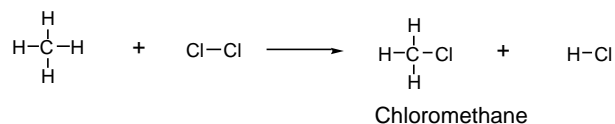
1) **Addition reaction** $A + B \text{ -----} \rightarrow C$



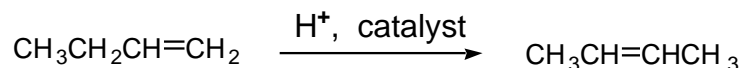
2) **Elimination reaction** $A \text{ -----} \rightarrow B + C$
(reverse of addition)



3) **Substitution reaction** $A + B \text{ -----} \rightarrow C + D$



4) **Rearrangement reaction** $A \text{ -----} \rightarrow B$



Consider how reactions occur - MECHANISM

detailed step-by-step description of a reaction

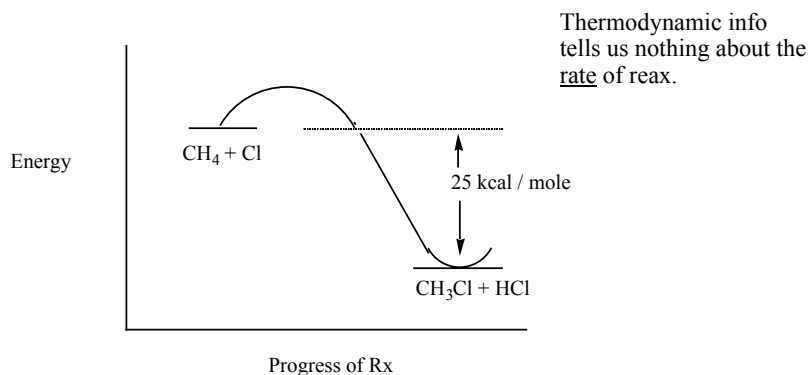
describes all bond-breaking and bond making processes.

Bond breaking and making can occur in two ways:

1). **Homolytic** bond cleavage (radical)

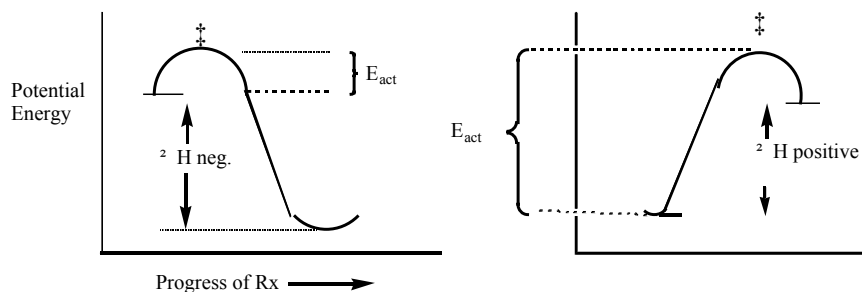
one electron to each fragment





$$\text{Rate} = P Z e^{-E_{\text{act}}/RT} \quad (= P Z / e^{E_{\text{act}}/RT})$$

Look at **Reaction Coordinates**- Potential Energy Diagram



Notice that there is an energy barrier (**Activation Energy**) even for exothermic processes.

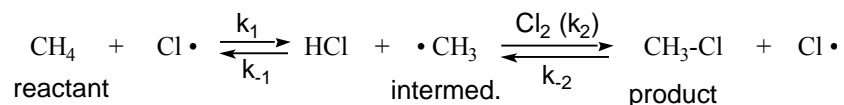
Some reactions have more than one step

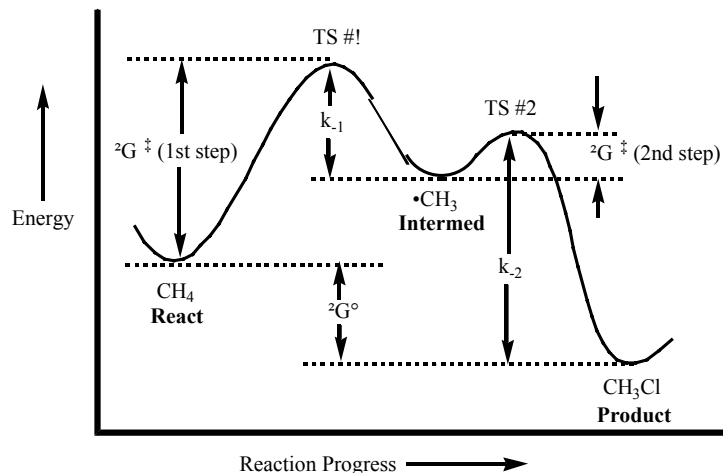
between each step an intermediate is involved.

represented by a minimum on the rxn. coordinate

stability of an intermediate is a function of the depth of this well.

i. e.



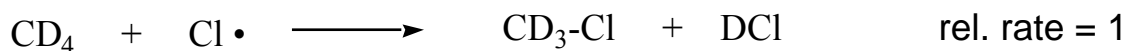
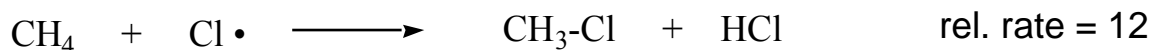


The lower the energy barrier (E_{act}) the larger the rate constant, k

Thus for the above: $k_2 > k_{-1} > k_1 > k_{-2}$

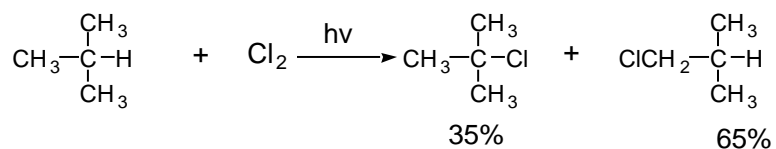
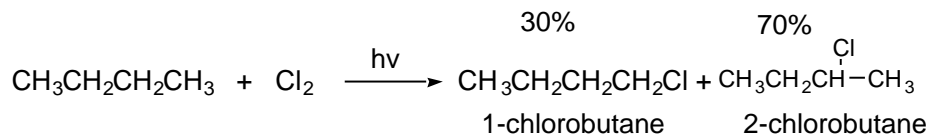
Isotope Effects

Deuterium is the isotope of H with mass 2. The C-D bond is slightly stronger than the C-H bond and hence harder to break. Reactions which involve C-D cleavage go slower than C-H.

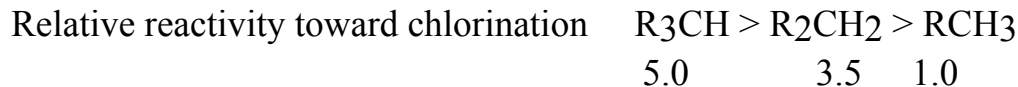


Halogenation of Higher Alkanes

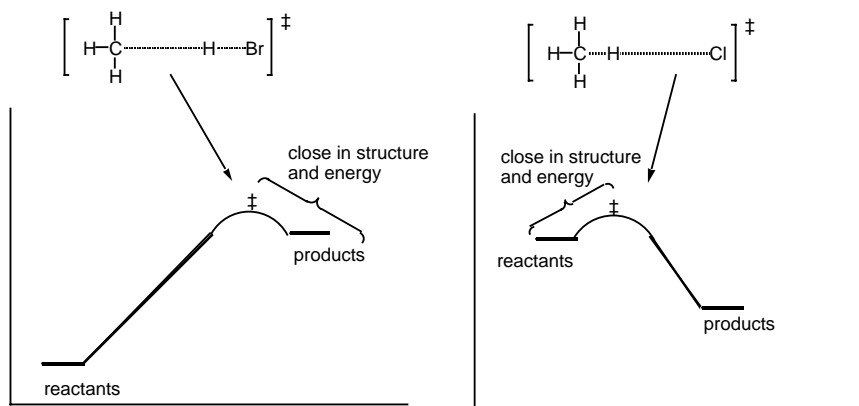
Most alkanes give mixture of products (book give propane & gets slightly different selectivities)



By taking into account: actual product ratios and number of each type of H, we can calculate relative reactivities of the 3 types (1° , 2° , 3°) of hydrogens towards chlorination.

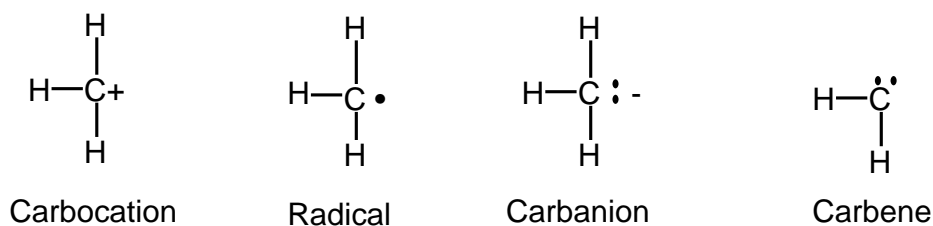


Look at PE diagrams for these two processes:

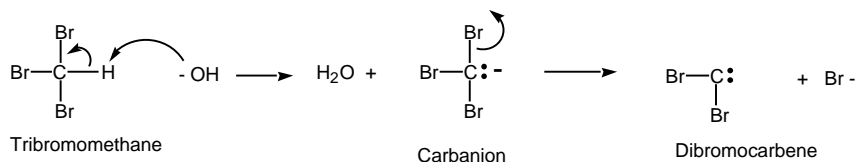


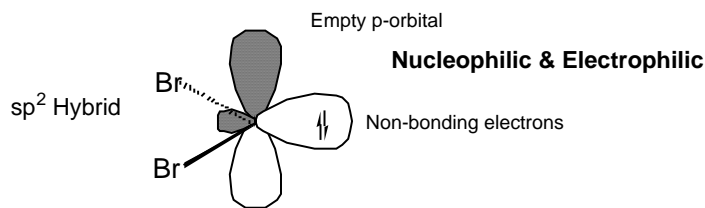
Hammond Postulate Related species that are similar in energy are also similar in structure. The structure of a transition state resembles the structure of the closest stable species.

Reactive Intermediates short lived species that are never present in high conc because they react as quickly as they are formed.



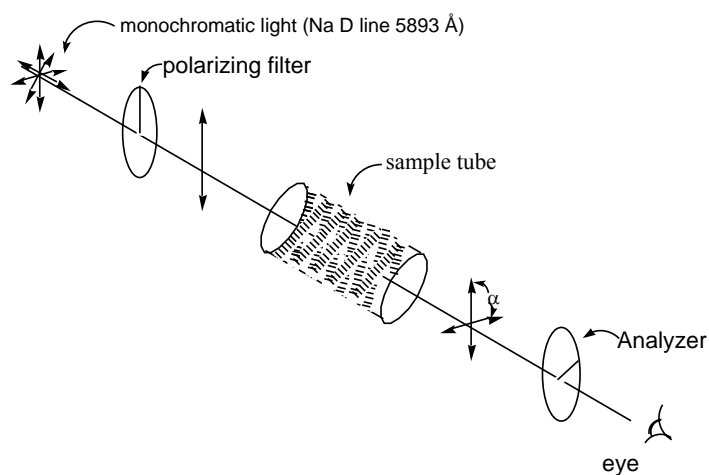
Carbenes:





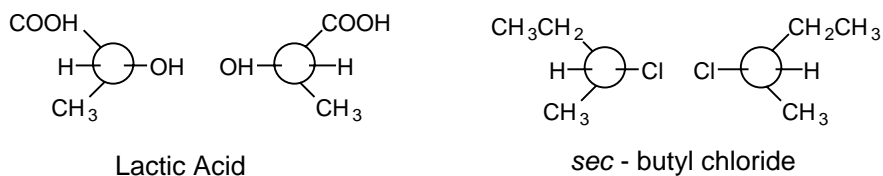
Chapter 5 Stereochemistry Refers to structures in three dimensions.

Polarimeter:



hence $[\alpha] = \frac{\alpha}{l \times c}$ ----> observed (measured) rotation

As predicted, mirror images (non-superimposable) of organic compounds do exist:



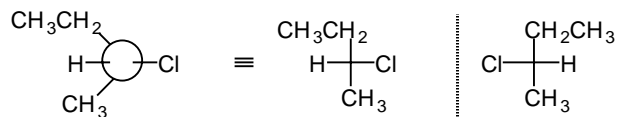
Enantiomers

Optical activity

Chirality

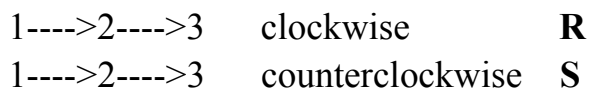
Chiral center

Stick figure representation of a chiral molecule (Fisher projections, later)

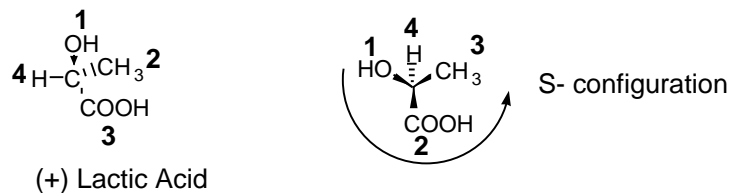
**R & S convention:**

- For a chiral carbon, use the Cahn-Ingold-Prelog sequence Rules to assign priorities to the 4 groups.
 - Rank atoms in order of decreasing atomic number
 - If 2 atoms are the same, work outward to the first point of difference
 - Multiply bonded atoms are considered as if they were an equivalent number of singly bonded atoms.
- Orient the molecule so the lowest priority subst. (#4) is pointing away from you.

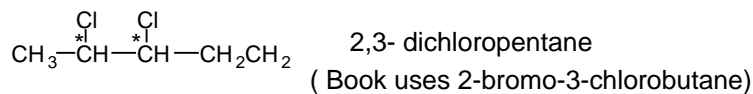
Look at the three remaining groups:



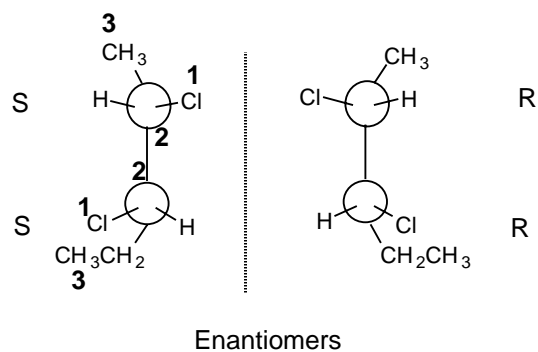
For example:



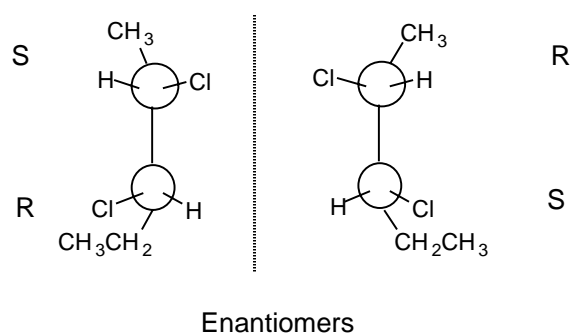
Diastereomers Look at a molecule that has **2** adjacent chiral centers.
 2,3-dichloropentane



Draw configurations



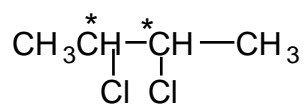
Now let's change configuration of only one carbon.



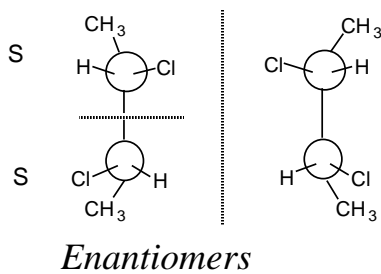
Each member of this pair is a diastereomer of each member of the first pair.

Meso structures

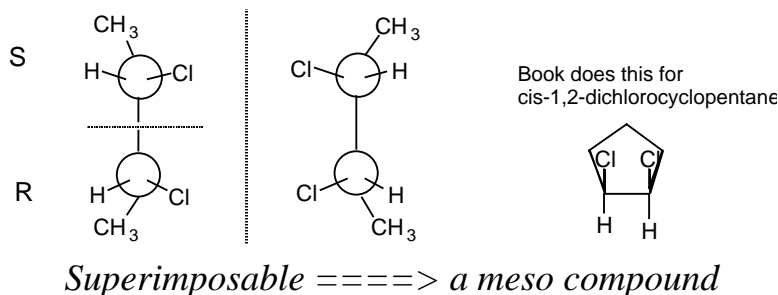
Now let's look at 2,3-dichlorobutane



2 adjacent chiral centers
let's draw configs. again:



Change configuration of one carbon:

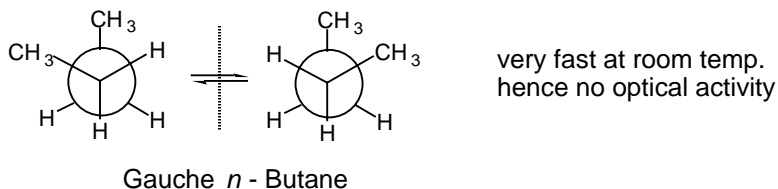


Meso Compound - one whose molecules are superimposable on their mirror images even though they contain chiral centers.

Racemic Mixture - a mixture of equal parts of enantiomers.(50:50)

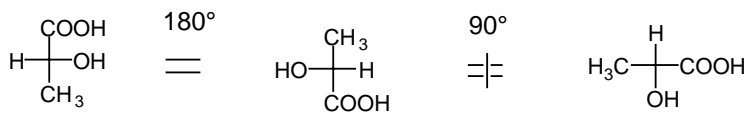
Optically inactive: for every molecule giving a (+) rotation there is another which gives (-), net sum= 0

Use prefix (\pm)

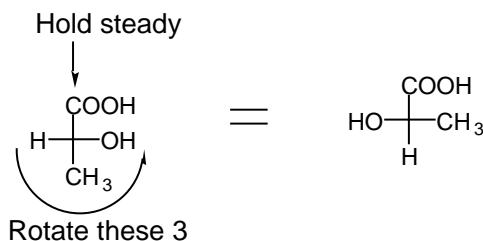


Fisher Projections

1. A Fisher projection can be rotated by 180° but not by 90° or 270°.

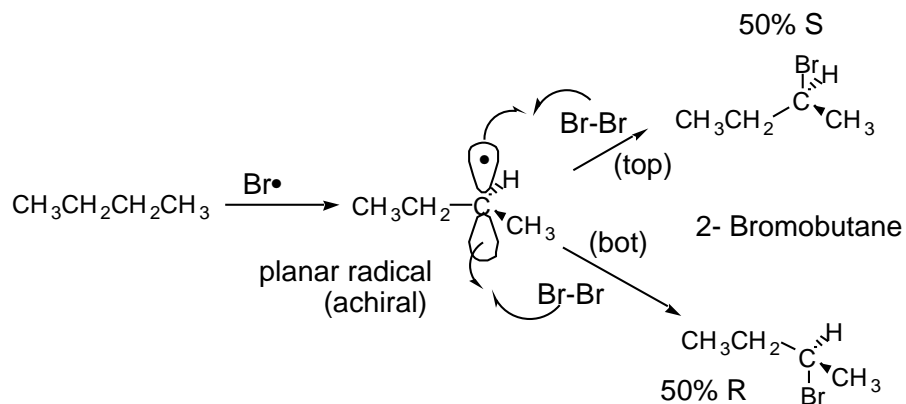


2. Hold one group steady and rotate the other three clockwise or counterclockwise.

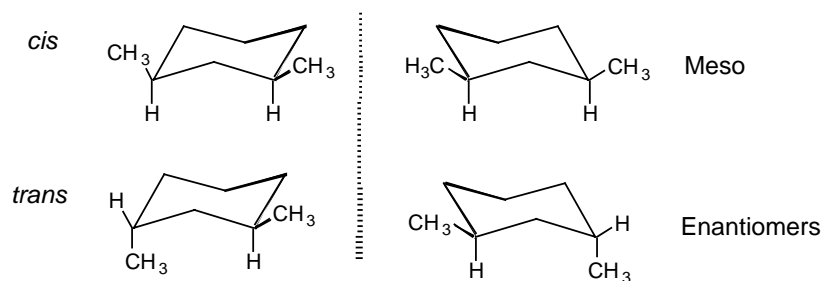


Stereochemistry of Chemical Reactions

1. Reactions at a chiral carbon
2. Reactions that do not involve the chiral carbon
3. Reactions that generate a new chiral carbon



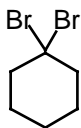
Stereochemistry in cyclohexanes



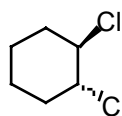
Chapter 6 Alkyl Halides: Nucleophilic Substitution and Elimination

Nomenclature

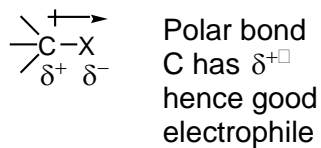
- 1) Name as *halo* alkanes
- 2) Name as Alkyl **halides**
- 3) Common names



1,1-dibromocyclohexane
A **geminal** dihalide

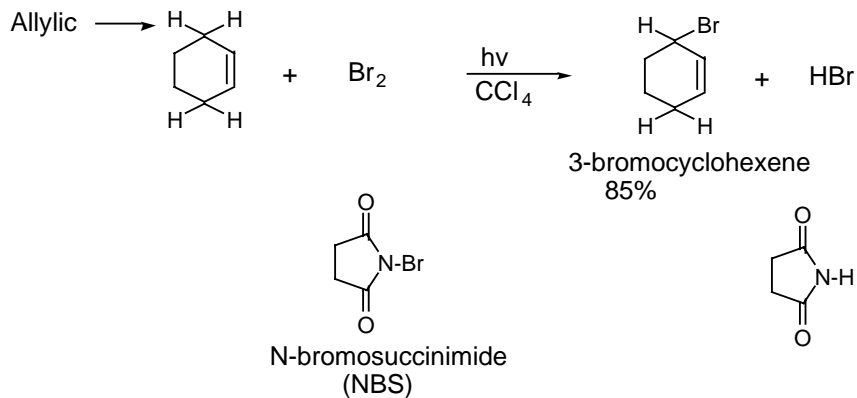


trans-1,2-dichlorocyclohexane
A **vicinal** dihalide

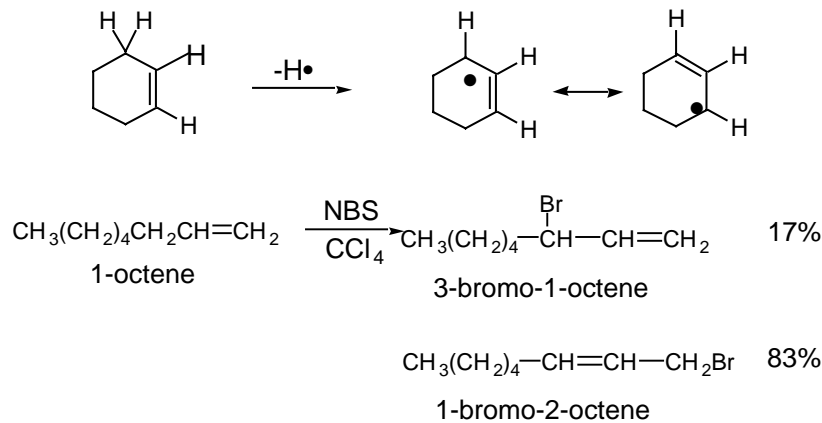


Preparation of Alkyl halides

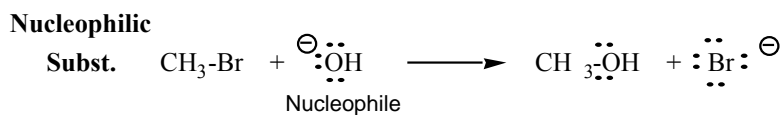
1. Halogenation of alkanes
2. Allylic Halogenation

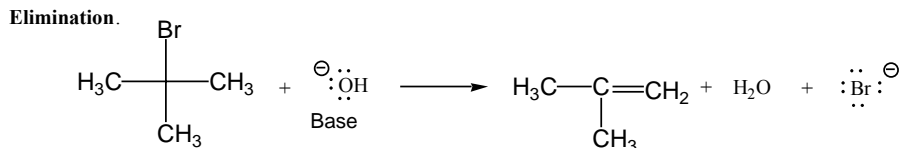


Allylic radical is stabilized by **resonance**.

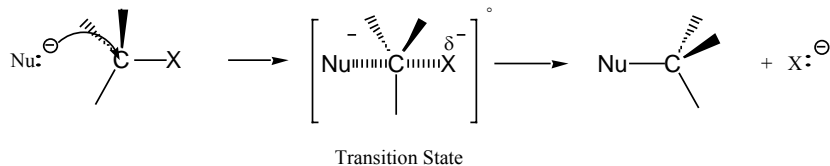


Reactions of Alkyl Halides: Nucleophilic Substitution and Elimination





S_N² Reaction - Substitution, nucleophilic, 2nd order



1. Stereochemistry
2. Kinetics Rate = $k[\text{Nu}^-][\text{CH}_3\text{Br}]$
3. Energy diagram – one hump (no intermediate)

<i>Nucleophile</i>			<i>Product</i>	
:H^-	hydride	$\text{H}_3\text{C}-\text{Br}$	\longrightarrow	CH_4
$\text{H}_3\text{C}-\ddot{\text{S}}^-$	methanethiolate	\longrightarrow	$\text{H}_3\text{C}-\text{S}-\text{CH}_3$	
$\text{H}-\ddot{\text{S}}^-$	hydrosulfide	\longrightarrow	$\text{SH}-\text{CH}_3$	thiol
$\text{N}\equiv\text{C}^-$	cyanide	\longrightarrow	$\text{N}\equiv\text{C}-\text{CH}_3$	nitrile
I^-	iodide	\longrightarrow	$\text{I}-\text{CH}_3$	
HO^-	hydroxide	\longrightarrow	$\text{HO}-\text{CH}_3$	alcohol
$\text{H}_3\text{C}-\ddot{\text{O}}^-$	methoxide	\longrightarrow	$\text{H}_3\text{C}-\text{O}-\text{CH}_3$	ether
$\text{N}=\text{N}=\ddot{\text{N}}^-$	azide	\longrightarrow	N_3-CH_3	
Cl^-	chloride	\longrightarrow	$\text{Cl}-\text{CH}_3$	
$\text{H}_3\text{C}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}^-$	acetate	\longrightarrow	$\text{H}_3\text{C}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{CH}_3$	ester
:NH_3	ammonia	\longrightarrow	$\text{H}_3\text{N}^+-\text{CH}_3\text{Br}^-$	

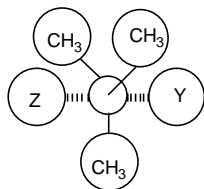
Let's examine the effect on the rate of S_N2 reax. of

1) Nucleophile (Nu:)

Nucleophilicity roughly parallels basicity. See table 6-3 (p. 246)

2) Solvent

3) Substrate (Alkyl group R)

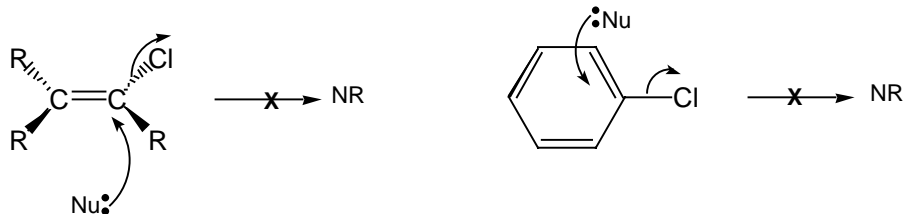
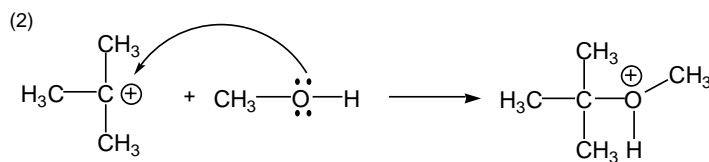
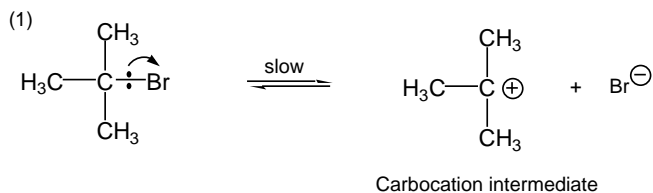


Crowding raises energy of T.S. and slows down reax.

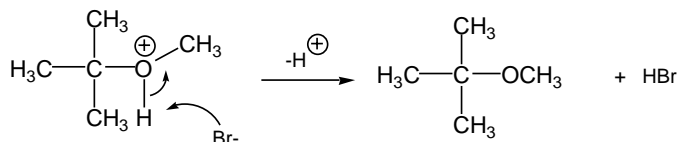
4) Leaving Group (X:)

leaving group is expelled with pair of electrons $R-\ddot{X}$
 ability to stabilize these electrons \implies better leaving group

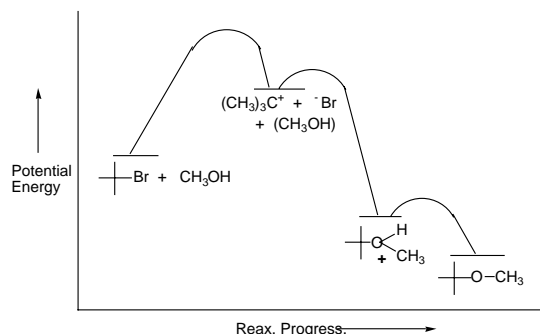
Note: S_N2 only occurs at sp^3 carbon (not sp^2)

**The S_N1 Reaction - substitution, nucleophilic, first order**

Final deprotonation

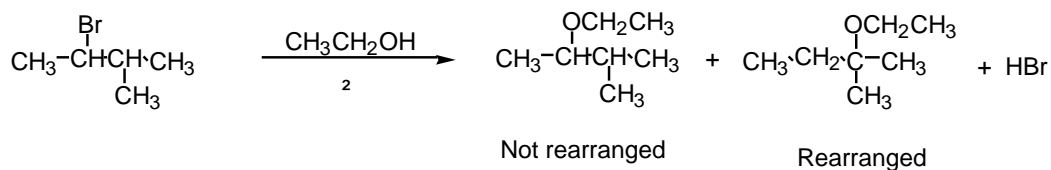


Stereochem: reaction occurs with almost complete racemization.



Carbocation Rearrangements

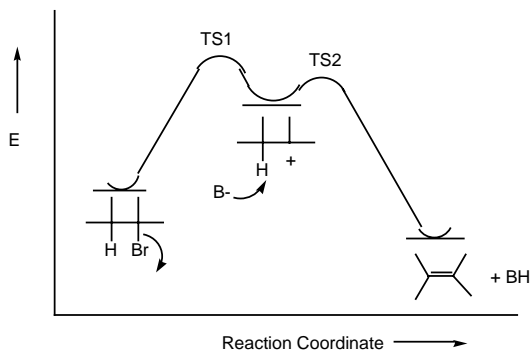
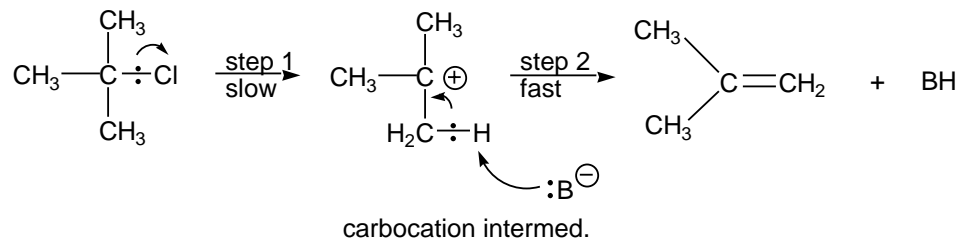
When a more stable carbocation can be formed by the migration of a hydride (H^- with $2e^-$) or CH_3^- , this process will occur some of the time leading to rearranged products:



Eliminations

There are 2 types of eliminations (similar to substs)

E-1



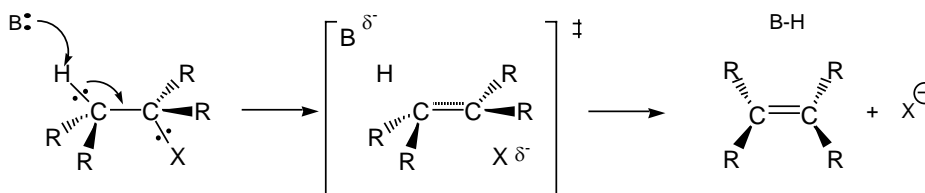
Note No deuterium isotope effect would be observed because C-H bond not being broken in slow, rate-detn. step.

E-2 Elimination, bimolecular (most common)**one** step process

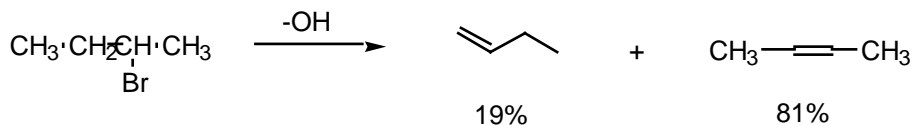
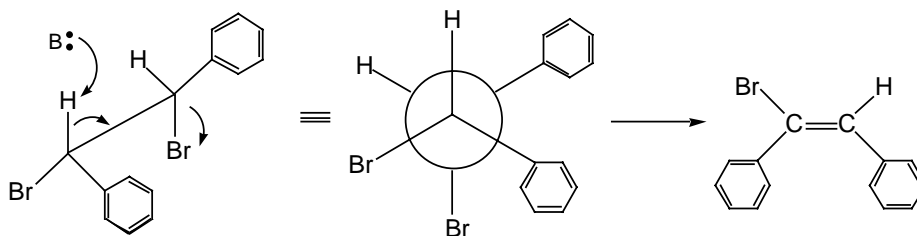
no intermediates

kinetics - 2nd order

$$\text{Rate} = k[\text{RX}] [\text{base}]$$



Very often we can potentially have mixtures of products

Saytzeff's RuleE2 eliminations are often stereospecific:*meso*-1,2-dibromo-1,2-diphenylethane gives **only** E-1-bromo-1,2-diphenylethylene

More apparent in cyclic systems:

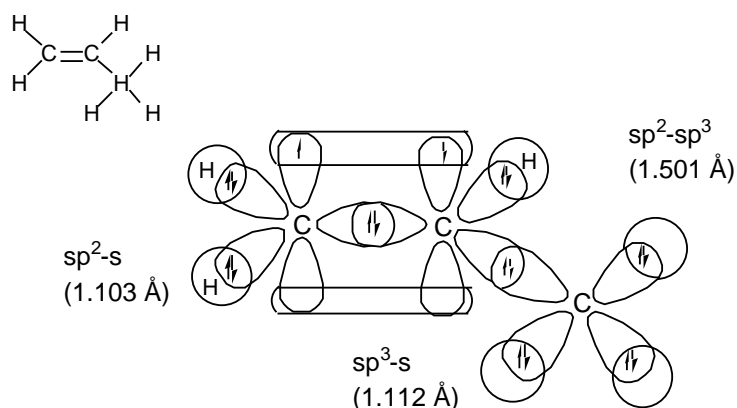
Deuterium Isotope Effect- more evidence for E-2

C- D bond is stronger than C- H (broken in RD step)

Chapter. 7 - Structure and Synthesis of Alkenes

The overall C=C bond energy = 146 kcal/mole

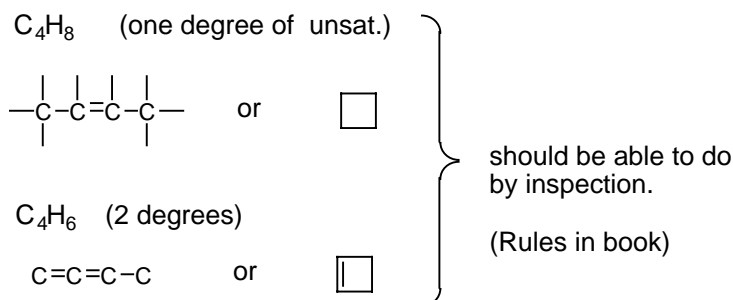
vs. in ethane C- C bond energy = 83 kcal/mole



Degree of saturation

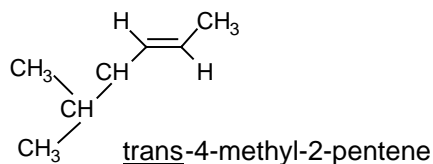
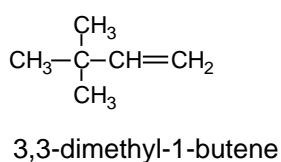
How many rings and/ or $\text{C}=\text{C}$ are present

i. e.



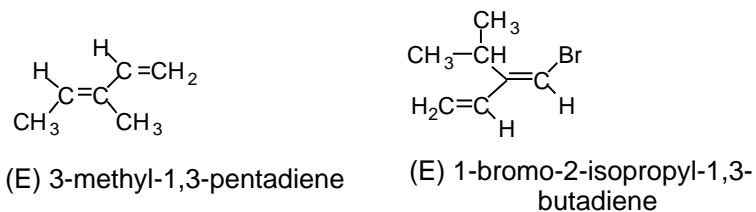
Nomenclature of Alkenes

1. Pick the longest continuous carbon chain containing the double bond. Name this as an alkane but change "ane" to "ene"
2. Indicate the position of the double bond in the parent chain by using the number of the first doubly-bonded carbon when numbering from the end nearest the double bond.
3. Indicate by numbers the position of the alkyl groups attached to the parent chain.



Cycloalkenes (remember cis and trans)

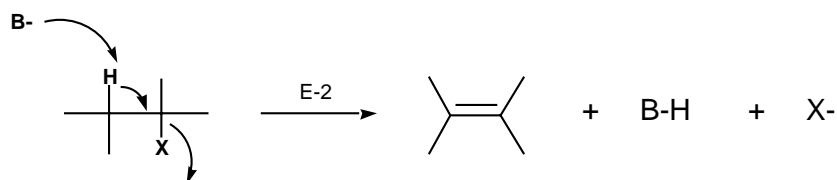
E - Z Nomenclature



Bredt's Rule A bridged bicyclic compound cannot have a double bond at a bridgehead position unless one of the rings contains at least 8 carbons.

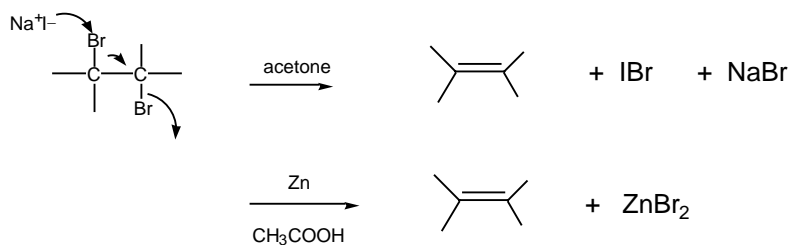
Preparation of Alkenes - elimination reactions

1. Prefer E2 because it avoids carbocation intermediates.



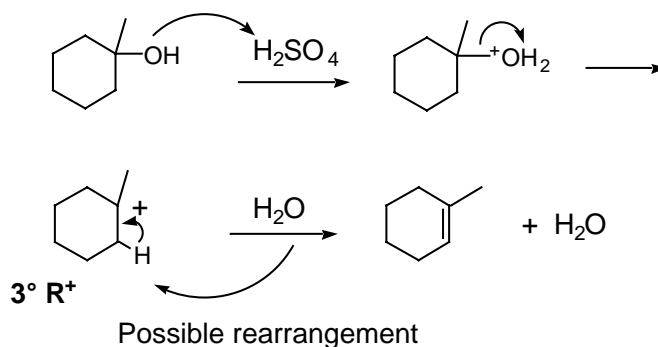
2. Dehalogenation of vicinal dibromides

Not a very useful reaction since vic-dihalides often made from alkenes



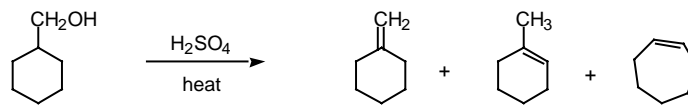
Dehydration of alcohols

E-1

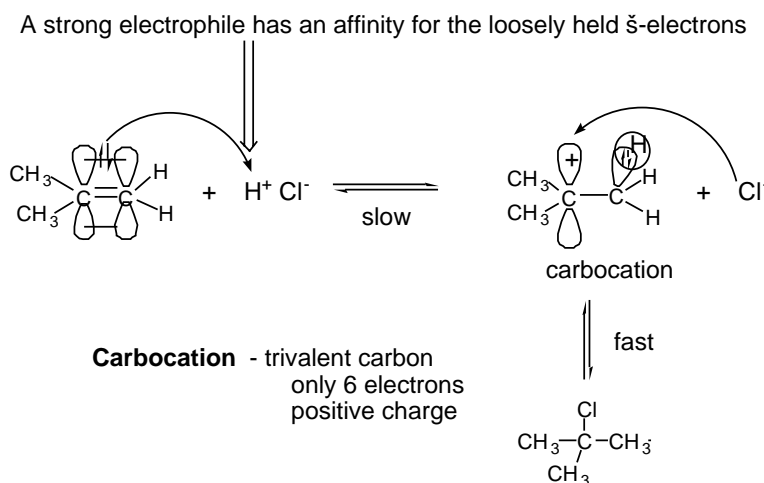


Reaction Mechanisms

Try this one

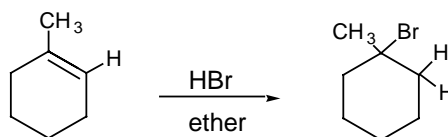


show every step
show electron flow with arrows

Chapter 8 Reactions of Alkenes**Electrophilic addition** Electron rich π -bond reacting with electron poor species

Markovnikov's Rule : In the addition of HX to an alkene, the H always bonds to the carbon with more hydrogens and the X bonds to the carbon with more alkyl groups.

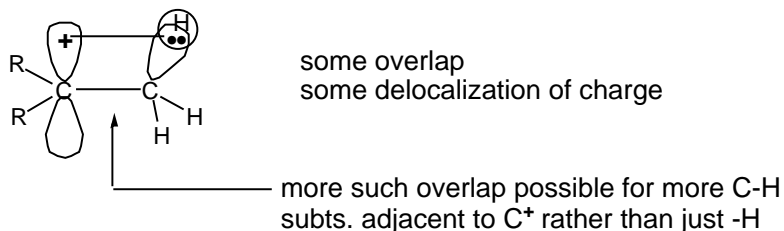
i.e.



Stability order for carbocations:

 $3^\circ > 2^\circ > 1^\circ > \text{methyl}$

Hyperconjugation

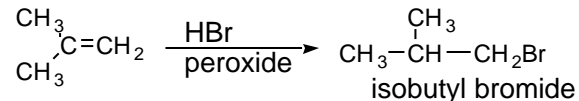


Addition Reactions of Alkenes

1. Addition of Hydrogen halides (also free radical)

(a) ionic mech (Mark's Rule)

(b) radical mech

2. Hydration (direct acid cat. addition of H₂O is poor)

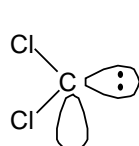
Oxymercuration – Demercuration (Markovnikov & Anti addition)

Hydroboration – oxidation (Anti-Markovnikov & Syn addition)

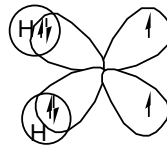
3. Catalytic Hydrogenation

4. Cyclopropanation - carbene addition to alkenes

Singlet and triplet carbenes



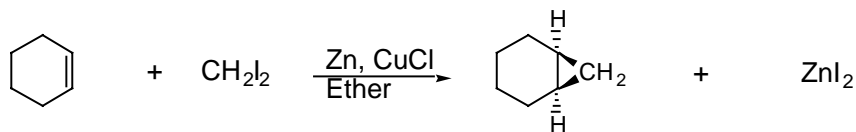
singlet carbene
(electrons paired)



triplet carbene
(electrons unpaired)

Dichlorocarbene (CHCl₂ + KOH)

Simmons-Smith Reaction

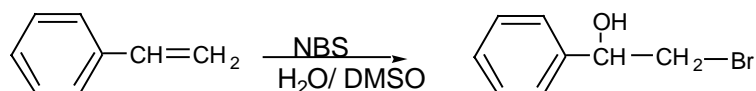


Bicyclo[4.1.0] heptane (59%)

5. Addition of halogen

Stereochemistry – bromonium ions

6. Halohydrin formation



7. Epoxidation

Chapter 9 Alkynes

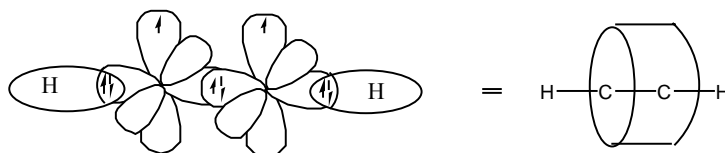
Nomenclature

1. Common names - derivatives of acetylene where hydrogens have been replaced by other groups

2. IUPAC names

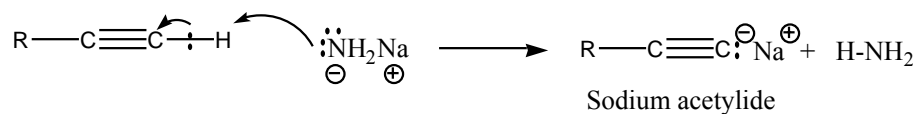
terminal alkyne - ends in CH such as 1-butyne above

internal alkyne - has 2 substs $R-C\equiv C-R$



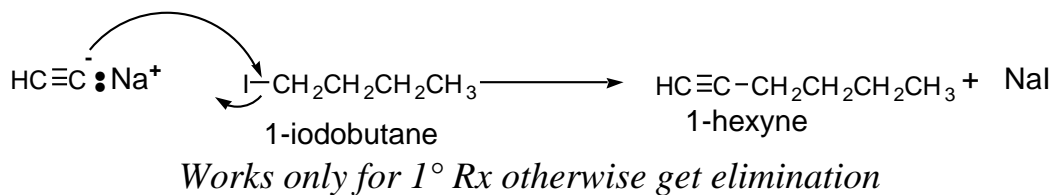
Acidity of Alkynes

terminal alkynes ($R-C\equiv C-H$) are weakly acidic

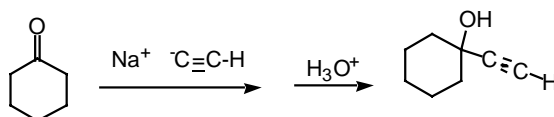


Synthesis of Alkynes

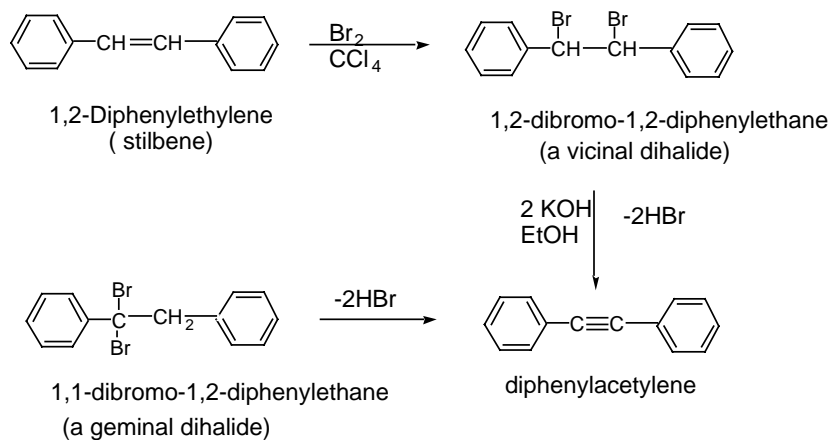
1) Alkylation of Acetylide Anions (S_N2 on 1° RX)



2) Addition of Acetylide Ions to $C=O$ Group



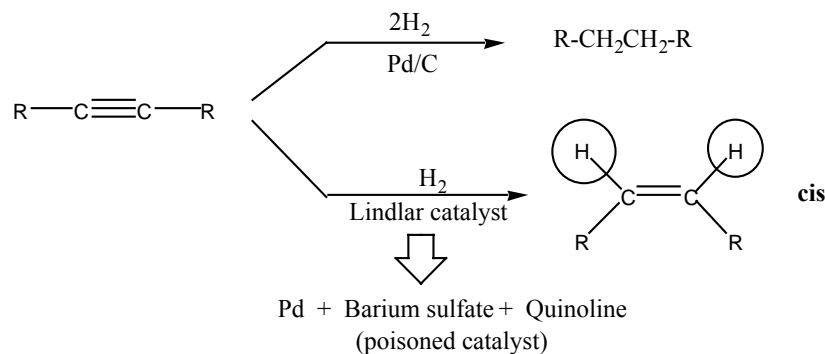
3) Dehydrohalogenation



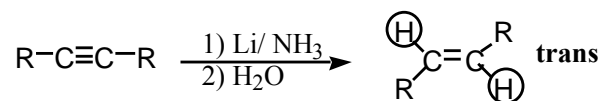
Reactions of Alkynes (reax of the $\text{C}\equiv\text{C}$ bond)

1) Addition of Hydrogen (reduction to alkanes)

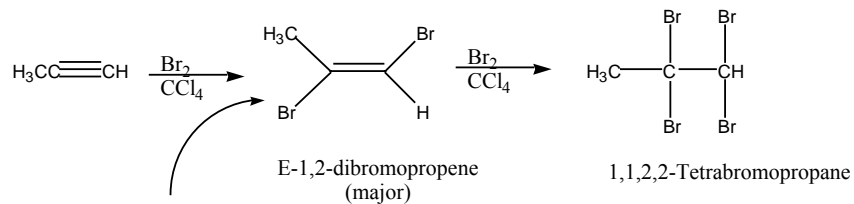
(a) Catalytic hydrogenation gives alkane or cis-alkene



(b) Metal-ammonia reduction gives trans-alkene



2) Addition of X_2

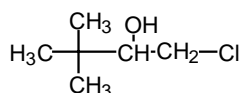


Can be stopped at this stage

Chapter 10 - Structure and Synthesis of Alcohols

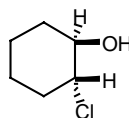
Nomenclature

1. Name the longest continuous carbon chain containing the OH. Drop The "e" and add "ol."
2. Number the longest carbon chain starting at the end nearest the OH and use the appropriate number to indicate the position of the OH
3. Name all substituents and give their numbers



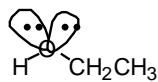
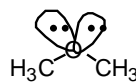
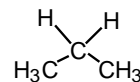
1-chloro-3,3-dimethyl-2-butanol

Cyclic alcohols are named using the prefix *cyclo-*; the hydroxy group is on C1

*trans*-2-chlorocyclohexanol

The OH group maybe named As a *hydroxy-* substituent.

Boiling Points of Alcohols:

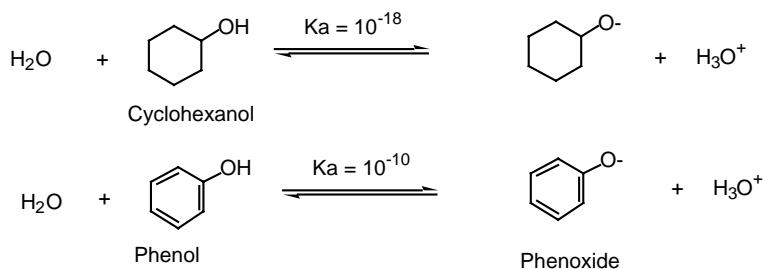
Ethanol
MW = 46
bp = 78°CDimethylether
MW = 46
bp = -25°CPropane
MW = 44
bp = -42°C

hydrophilic, meaning "water loving,"

hydrophobic "water-hating"

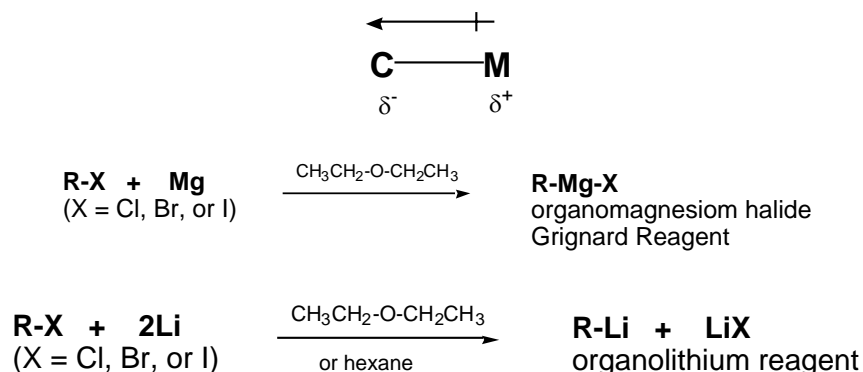
Acidity of Alcohols and Phenols:

A strong base can remove the hydroxyl proton to give an **alkoxide ion**.

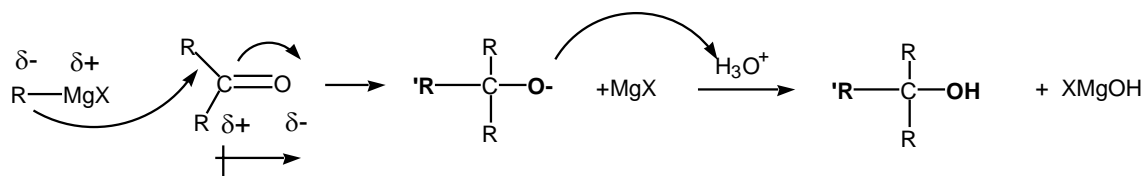


Synthesis of Alcohols:

1. Nucleophilic substitution on an alkyl halide or tosylate (Chapt 6)
2. Oxymercuration-demercuration
3. Hydroboration-oxidation
4. Hydroxylation
5. Organometallic Reagents for Alcohol Synthesis



Addition of Organometallic Reagents to Carbonyl Compounds:



Reaction with Formaldehyde \rightarrow 1° ROH

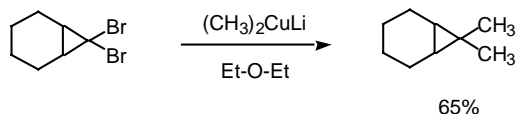
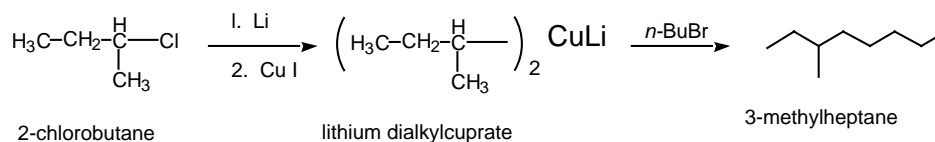
Reaction with Aldehydes \rightarrow 2° ROH

Reaction with Ketones \rightarrow 3° ROH

Addition of Grignard Reagents to Acid Chlorides and Esters

Addition of Grignard Reagents to Ethylene Oxide

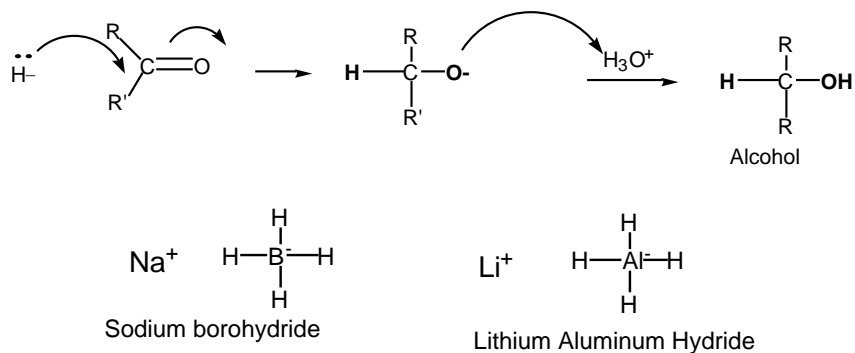
Corey-House reaction uses an organocopper reagent, a **lithium dialkylcuprate**, to couple with an alkyl halide.



Side Reactions of Organometallic Reagents

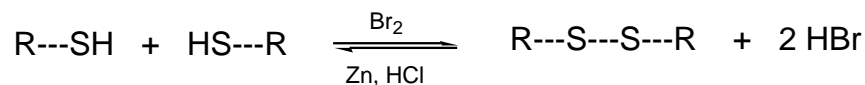
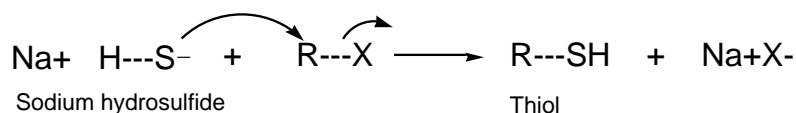
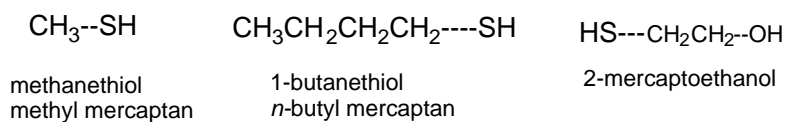
1. Reactions with Acidic Compounds
2. Reactions with Electrophilic Multiple Bonds: We must be sure that there is only one reactive group in the molecule. Avoid "wishful" organic synthesis.

Reduction of the Carbonyl Group: Synthesis of Primary and Secondary Alcohols



NaBH₄ is more selective than LAH – reduces ketones in the presence of esters

Thiols are sulfur analogues of alcohols, with an -SH group in place of the alcohol -OH group.

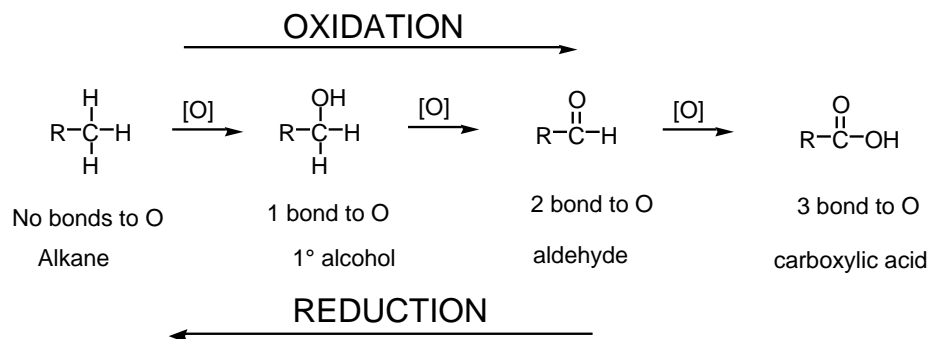


Chapter 11 Reactions of Alcohols

Oxidation of alcohols leads to
ketones
aldehydes
carboxylic acids.

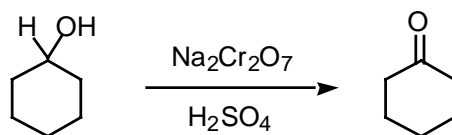
OXIDATION: loss of H₂ or the addition of O or O₂

REDUCTION: addition of H₂ (or H-) or the loss of O or O₂



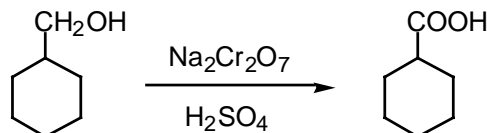
1. Oxidation of Alcohols

1. Oxidation of Secondary Alcohols to ketones.

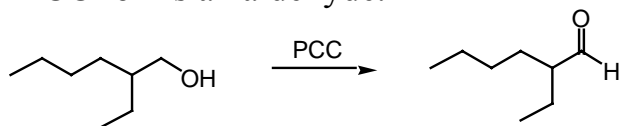


2. Oxidation of Primary Alcohols:

Chromic acid (strong conditions) oxidizes all the way to carboxylic acid

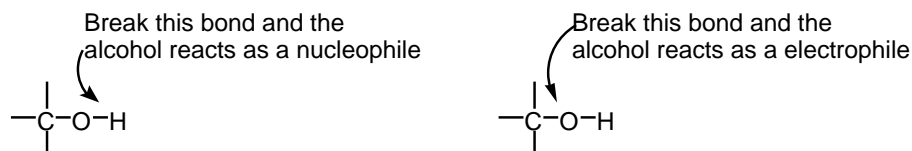


Partial oxidation with PCC forms an aldehyde.

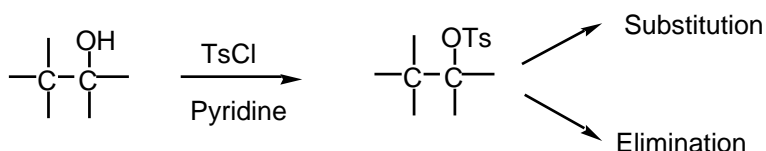


3. Tertiary alcohols do not undergo oxidation normally

Alcohols typically react by breaking either the O-H or the C-O bond:



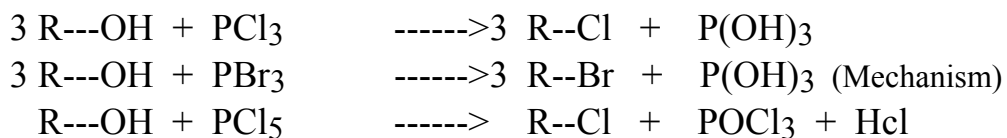
Since OH is a poor leaving group, we can convert it into a better one by preparing the tosylate ester:



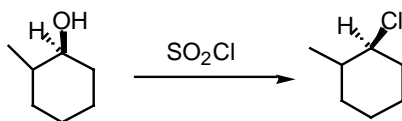
2. Reactions of Alcohols with HX

There are serious limitations on the Use of Hydrohalic Acids with Alcohols

3. Reactions of Alcohols with Phosphorus Halides

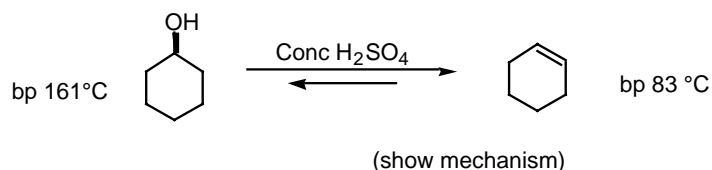


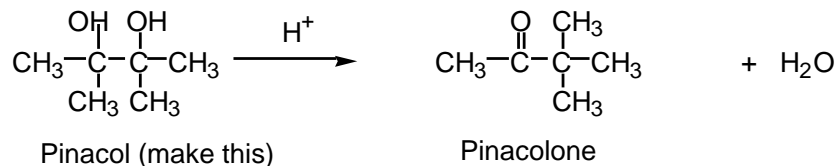
4. Thionyl chloride, SOCl₂



Note: retention of configuration

5. Dehydration Reactions of Alcohols

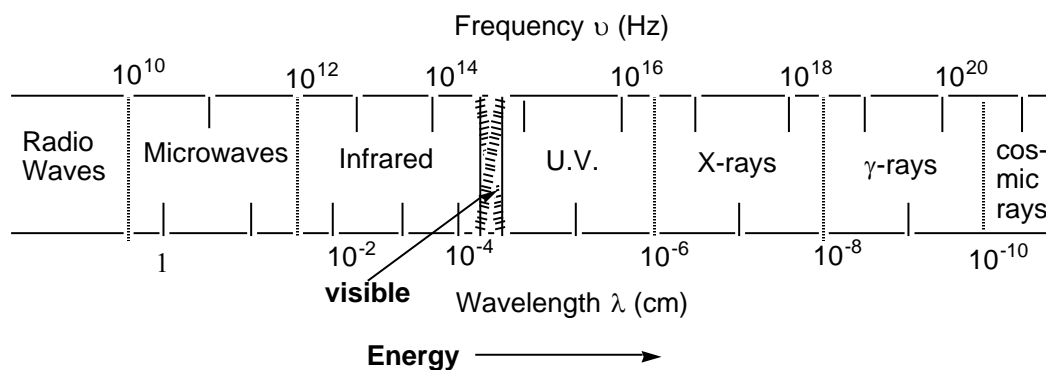


6. The Pinacol Rearrangement:

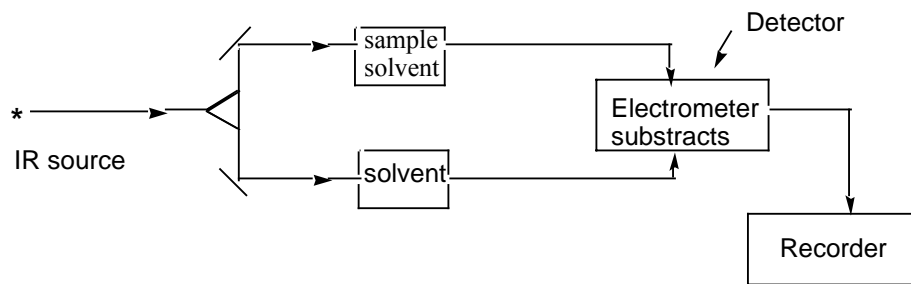
SHOW DETAILED MECHANISM

7. Periodic acid cleavage of glycols**8. Esterification of Alcohols****9. Formation and Reactions of Alkoxides****Chapter 12 Structure Determination - IR and Mass Spectroscopy**

Once you separate these, how do you tell which is which?

1. Infrared Spectroscopy**Electromagnetic Spectrum (fig. 12-1)**

Let's consider the relationship between energy and wavelength



Shows IR light absorbed by sample as a function of λ

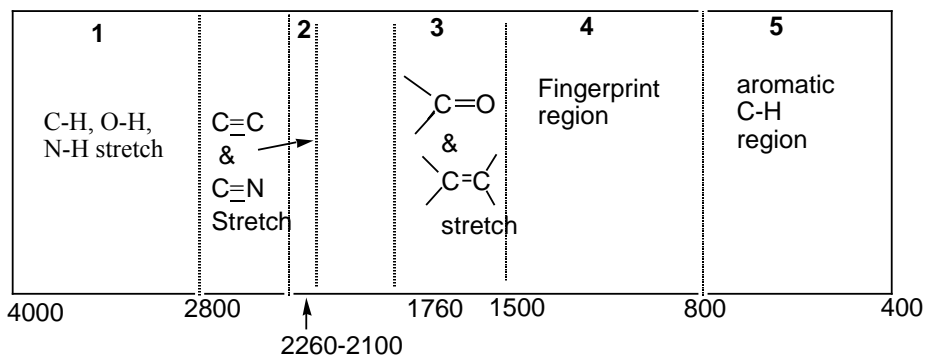
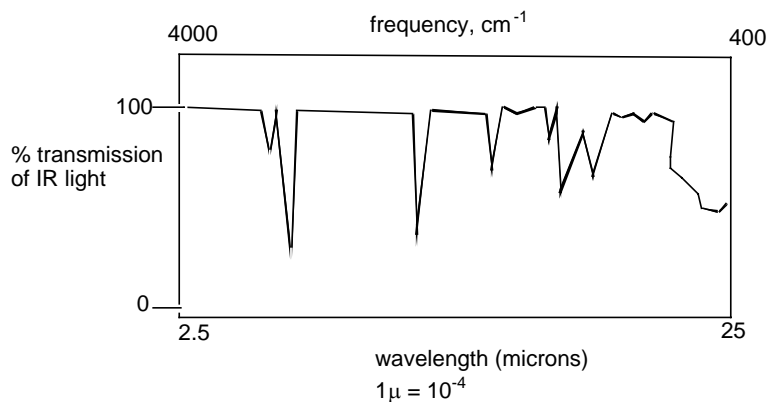
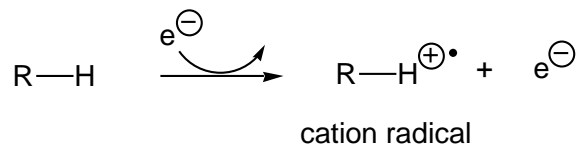


Table summarizes the absorption bands for the important functional groups (do not memorize!)

2. Mass spectroscopy

Bombard sample with high energy electrons (70 eV)

A valence electron is knocked out producing a cation radical



These cation radicals are passed through a magnetic field which deflects them according to their m/e ratio. Deflected particles are detected and recorded by intensity.

Base peak = biggest peak - assign intensity 100

Parent peak = molecular ion M^+ . (generally the highest major m/e value)
(sometimes not observed)

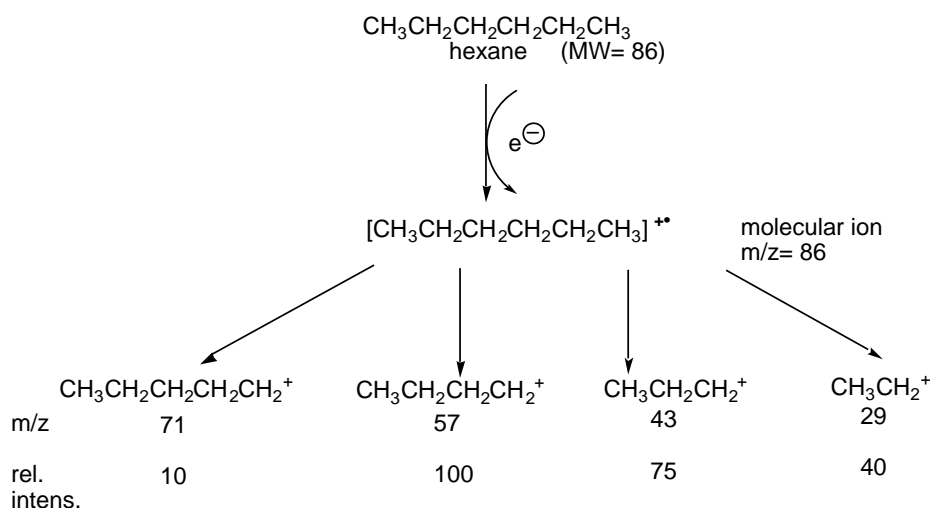
Two useful type of information:

1) Molecular weight

just look for molecular ion - should be highest m/e peak
sometimes see $M+1$ for isotopes containing ^{13}C .
can get very accurate MW's

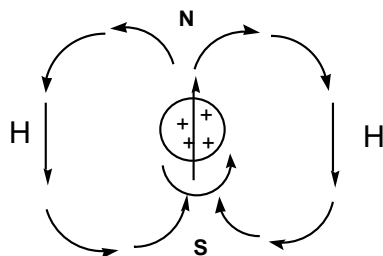
2) Fragmentation

Let's consider the case of n-hexane:



Chapter 13 - Nuclear Magnetic Resonance Spectroscopy NMR

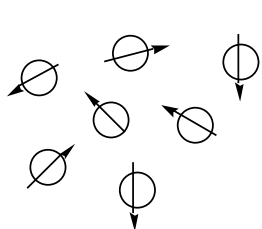
The nuclei of atoms having an odd atomic number or atomic mass (^1H , ^{13}C , ^{19}F , ^{31}P , ^{15}N etc) possess a nuclear spin and can be observed by an nmr spectrometer. These nuclei may be considered as spinning about an axis; since they are positively charged, these spinning nuclei behave like tiny magnets and thus can interact with an externally applied magnetic field. (H_0).



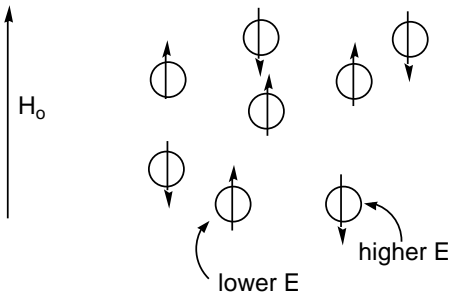
A spinning nucleus generates an induced magnetic field (H) which causes the nucleus to behave like a small bar magnet

Let's see what happens when we put a nucleus in an external magnetic field

Outside applied magnetic field
nuclear spins are randomly oriented



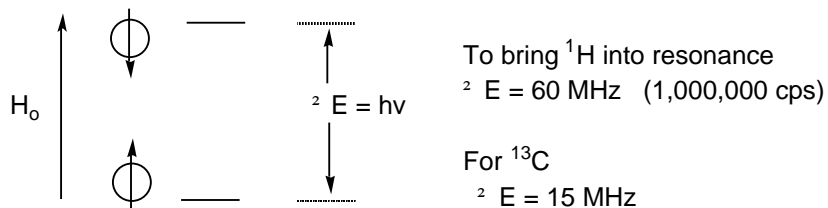
In presence of H_0 , spins align with or against direction of H_0



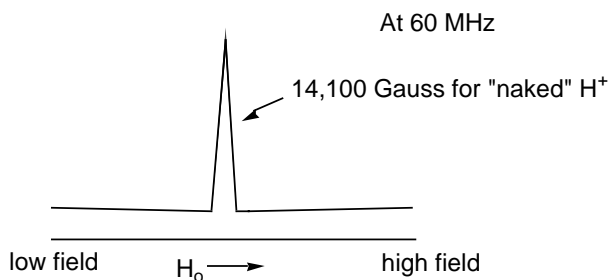
This behavior is observed for ^1H and ^{13}C (not ^2D or ^{12}C) and all nuclei with odd-numbered masses.

The strength of H_0 (for 60 MHz machine) is typically 14,100 gauss.

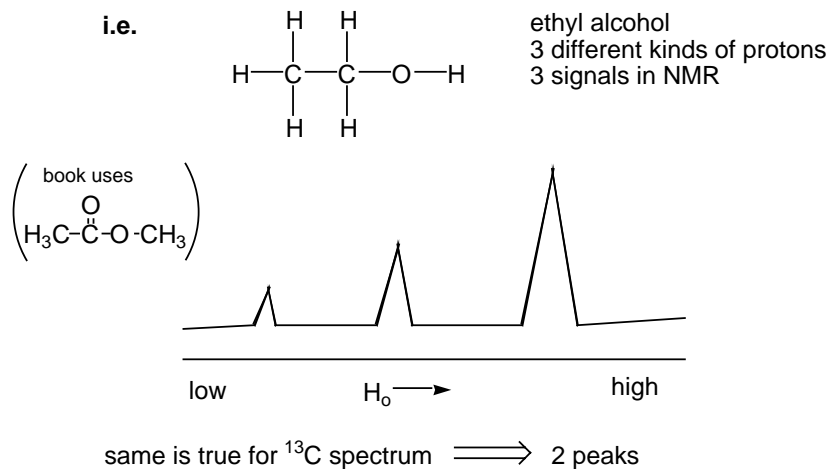
If the oriented nuclei (in H_0) are irradiated with radio waves of the proper frequency, energy absorption occurs and the lower energy state "spin flips" to higher E state. When this occurs we say the nucleus is in **resonance**.



In practice we hold the RF field constant (60 MHz) and vary the field strength



Nuclei are not "naked"! They are clothed by electrons which shield them somewhat from the applied magnetic field H_0 . In order for us to observe resonance of these shielded nuclei, we must apply a magnetic field stronger than H_0 . Thus different nuclei in different environments "see" different effective field strengths and resonate at different values of H_0 .



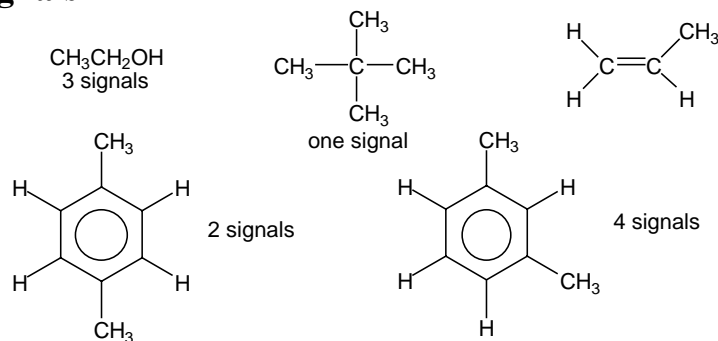
Measure **chemical shifts** relative to tetramethylsilane (TMS)

^1H NMR (proton NMR)

Four important features:

- 1) *Number of signals* - each non-equivalent ^1H can give rise to separate peak.
- 2) *Chemical shift* - position of peak gives us some idea about chemical environment (amount of shielding) of a given nucleus.
- 3) *Integration* - the intensity of a signal tells how many nuclei associated with a specific signal
- 4) *Spin-spin Splitting* - provides information about neighboring magnetic nuclei.

1. Number of signals

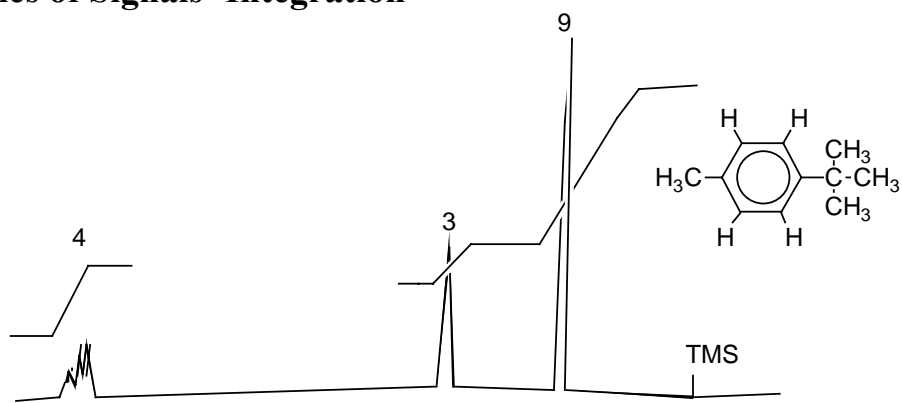


2. Chemical Shifts

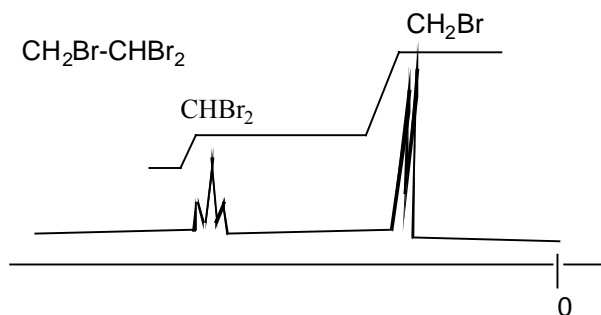
shielding effects (electron donating) move resonance to higher field ---->
 deshielding (electron withdrawing) move to lower field <-----

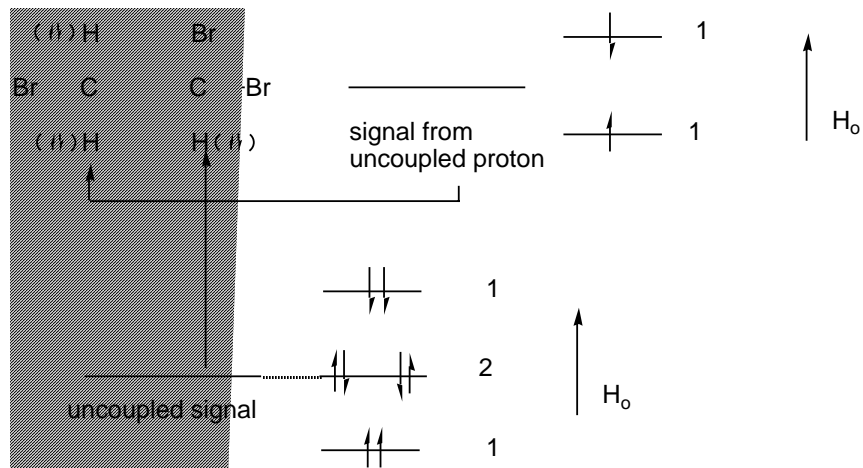
CHCl_3	7.3 ppm (singlet)
CH_2Cl_2	5.3 " "
CH_3Cl	3.0 " "

3. Intensities of Signals- Integration

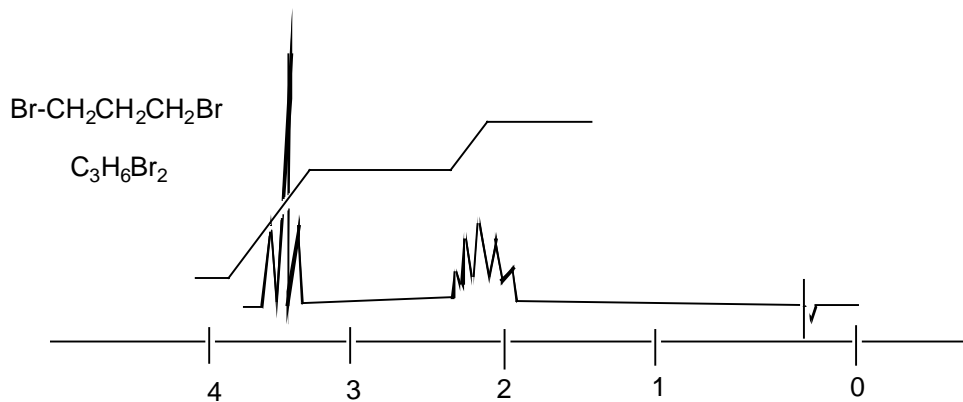
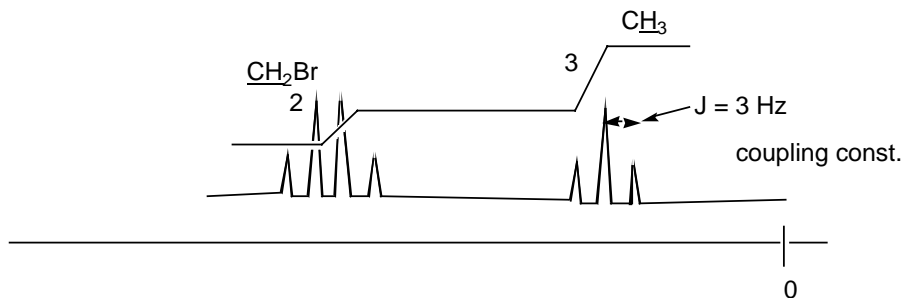


4) Spin-spin Splitting





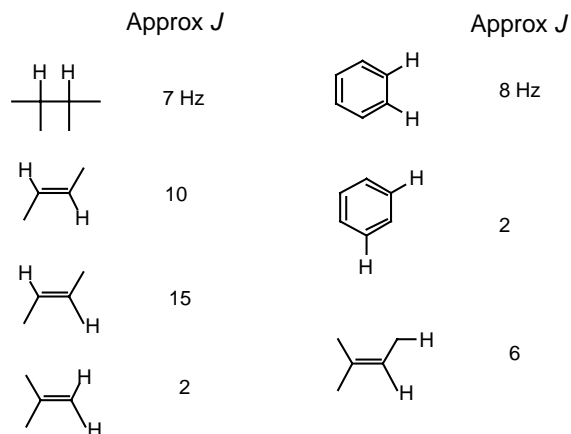
Look at **$\text{CH}_3\text{CH}_2\text{Br}$**



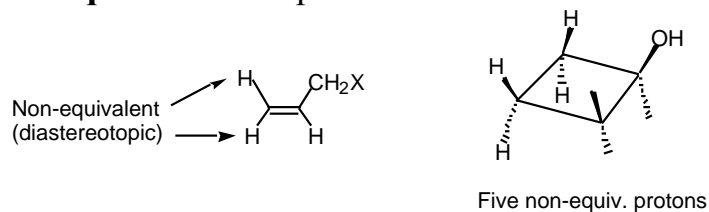
Equivalent nuclei do not split one another.

The amount of splitting is called the coupling constant and is given in Hz

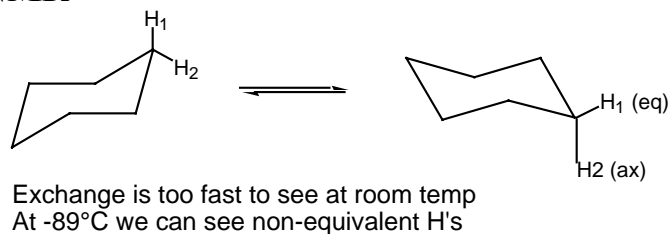
Typical Coupling Constants



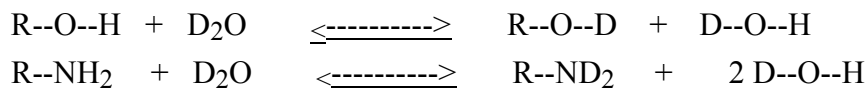
Stereochemical non-equivalence of protons



Time dependent NMR



Fast proton exchange. If we exchange an H by a D, the proton signal will become invisible by NMR. We can also use this trick to simplify NMR spectra.



C-13 NMR

At first it is surprising that we can do ^{13}C nmr on natural abundance carbon which is 99% ^{12}C .

Fourier-Transform (FT) NMR

When we have a weak signal as for C-13 we can enhance the value of the signal by taking many spectra and adding them together. The signals will enhance each other and the noise should cancel out. This can be very time consuming.

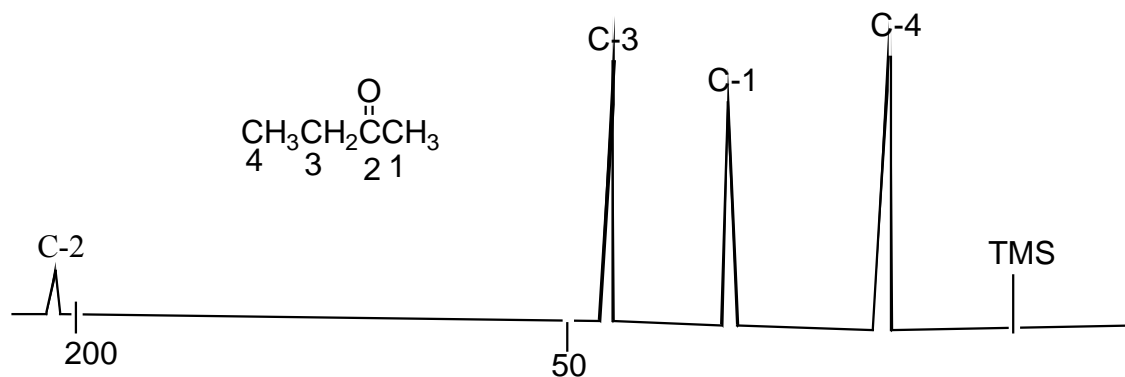
Spectral informaton can be obtained in a very short pulse of the Rf field. This pulse called a free induction decay (FID) can be deconvoluted by a computer (FT analysis) and the spectra (or transients) added up. A C-13 spectrum typically will use from 200-500 pulses depending on concentration.

Proton noise decoupled mode gives one peak for each non-equivalent carbon.

Normal range of chemical shifts is from 0-200 ppm.

Figure 12-40 (p. 570) summarize the values for different carbons.

The size of peaks (area under them) is not normally proportional to the number of carbons responsible for that peak. This is not generally a problem and can, if needed, be avoided by using a gated decoupling mode (requires more time between pulses).



Spin-spin splitting

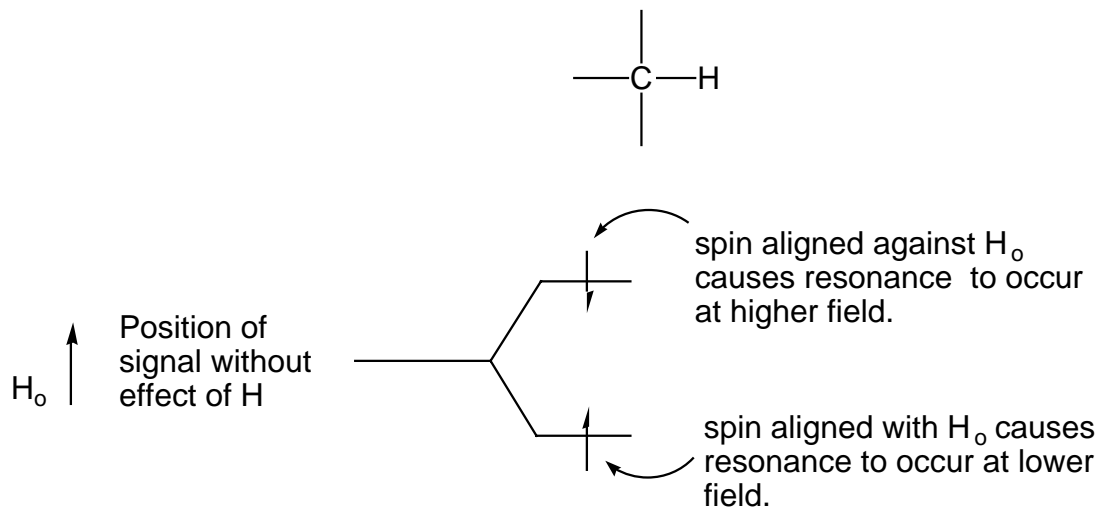
In the *off resonance decoupling mode* :

The magnetic field experienced by ^{13}C nuclei is affected by attached atoms ($^1\text{H}/^{13}\text{C}$) which can also induce small magnetic fields.

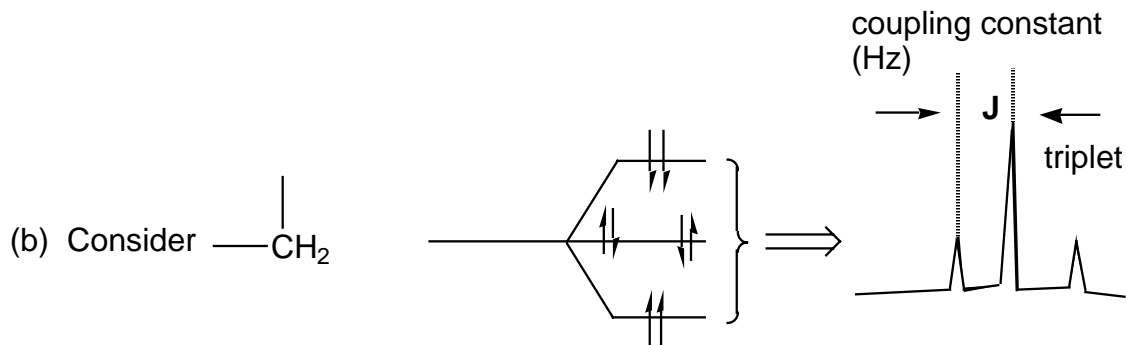
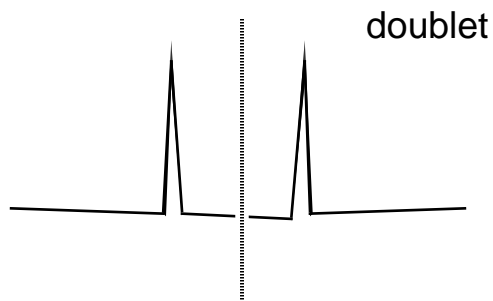
Chances for two adjacent ^{13}C is very small $(.01) \times (.01) = 1/10,000$
 " " " adjacent ^1H is excellent

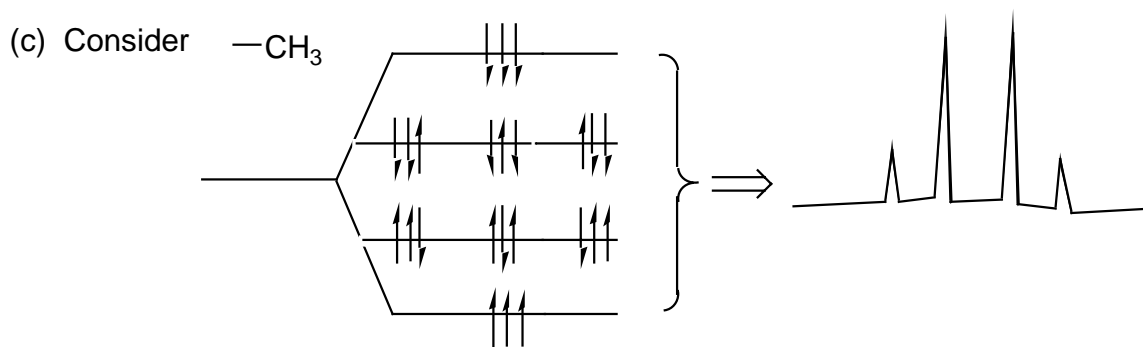
Thus protons attached to ^{13}C can augment or decrease the effective field.

(a) Consider the situation for



Hence in the **off-resonance** mode of the spectrometer, we observe the C-H **coupled** spectrum.





Thus the off resonance expt. tells how many H's bonded to C.

Interpreting ^{13}C NMR Spectra

This is quite similar to ^1H NMR

1. Number of signals tells number of non-equivalent C
2. Chemical shift tells about electronic environment of carbon
3. Peak area not too important
4. Splitting tells about number of attached H's.

WORK SAMPLE PROBLEMS IN WADE