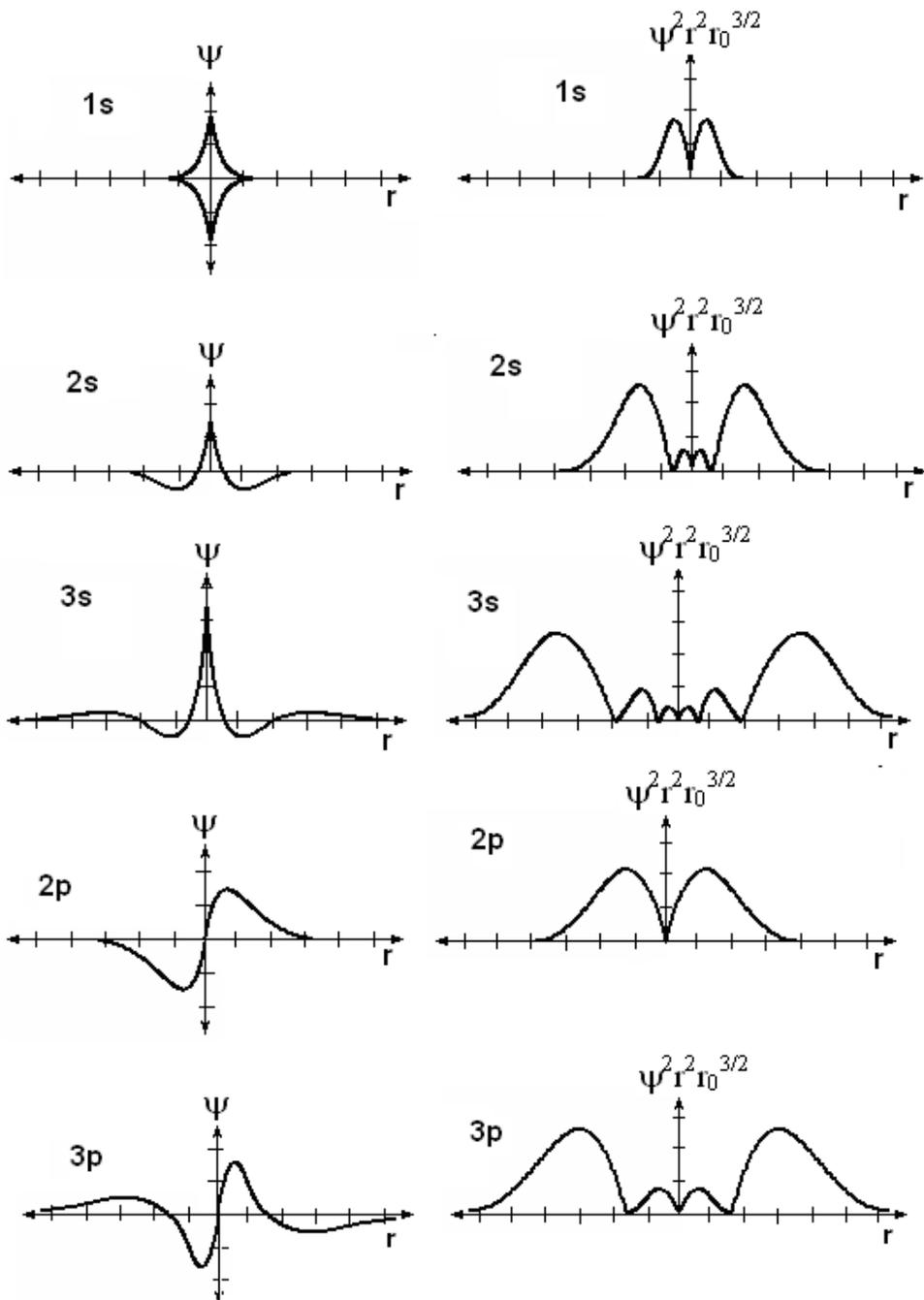


CHM 233 (Gould) Exam 1 Review

Electrons and Bonding

wave functions (ψ) and probability functions (ψ^2)



atomic orbitals and molecular orbitals

Hybridization

# of e^- domains	Hybridization	Bond angle
2	sp	180°
3	sp^2	120°
4	sp^3	109.5°

-the bond angle decreases if the central element is in period two and has non-bonding electrons

Isomers

Energies of Electrons (and Ionization Potential)

- 1) Non-bonding electrons are highest in energy
 - the less electronegative atom they're on, the higher the energy
 - if they're on an atom with a negative formal charge, they're really high energy
- 2) π bonds are almost always higher in energy than σ bonds
 - bonds between less electronegative atoms are higher in energy
- 3) σ bonds are the lowest in energy
 - bonds between less electronegative atoms are higher in energy

Resonance

Lone pairs can move to an adjacent bond

π electrons can move to an adjacent atom or adjacent bond

Electrons tend to move toward a '+' formal charge and/or away from a '-' formal charge

Nomenclature

Alkanes

- 1) Find the longest carbon chain and use as the name of the parent compound.
- 2) Number the parent chain in such a way as to give the substituents the lowest numbers possible.
- 3) Name the substituents before the parent chain with the appropriate numerical labels.
- 4) List substituents in alphabetical order
- 5) If there is more than one way of numbering the chain to give the substituents the lowest possible numbers, rank the substituents by alphabetical order giving the lower number to the substituent beginning with the the letter closer to 'A.' Numerical and hyphenated prefixes don't count as far as the alphabet goes, but iso- and cyclo- do.
- 6) If there is more than way of to come up with the longest parent chain, then choose the one with the most substituents.

Alkyl halides, Ethers, Alcohols, Amines

1	meth
2	eth
3	prop
4	but
5	pent
6	hex
7	hept
8	oct
9	non
10	dec
11	undec
12	dodec

Newman Projections

Staggered and eclipsed conformations

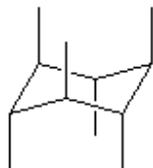
Gauche Interactions

Chair Conformations of Cyclohexane

Substituents in equatorial positions are lower in energy (i.e. more stable) than in axial positions



equatorial bonds



axial bonds

Intermolecular Forces

London Dispersion Forces (van der Waals Forces) – weak interactions due to a transient (temporary) dipole

-all molecules have these; the larger you are, the larger the force

Dipole-Dipole Forces – interaction between molecules having permanent dipole moments

-the larger the dipole moment, the larger the force

Hydrogen Bonding – a super strong dipole-dipole force (sort of)

-must have hydrogen bound to F, O, N to H-bond as a pure liquid

-must only have F, O, N to hydrogen bond with water

Effects on melting pt and boiling pt

Solubility: "Like dissolves like."

CHM 233 (Gould) Exam 2 Review

Newman Projections

Staggered and eclipsed conformations

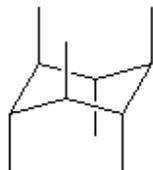
Gauche Interactions

Chair Conformations of Cyclohexane

Substituents in equatorial positions are lower in energy (i.e. more stable) than in axial positions



equatorial bonds



axial bonds

Mass Spectrometry

A beam of electrons is used to remove an electron (or electrons) from a molecule

if the molecule doesn't fragment, this results in a radical cation which is called the molecular ion
the molecule may also fragment forming a radical and a cation

only the cation is detected!

the tallest peak on the spectrum is the base peak

the rest of the peaks are given values expressed as a percentage of the height of the base peak

Predicting fragmentation patterns

the most stable fragments will yield the tallest peaks

resonance-stabilized and more substituted carbocations are more stable

Patterns to identify

Bromine's M+2 peak is nearly as tall as its M+ peak

Chlorine's M+2 peak is about 1/3 the size of its M+ peak

Nitrogen-containing compounds have an odd m/z for the M+ peak

Iodine-containing compounds have a large 'gap' in the spectrum corresponding to the MW of 127 for iodine; often there is a peak at 127 as well

Alcohols don't typically have a true parent peak, but usually have an M-18 peak as the peak furthest to the right corresponding to the loss of H₂O

Substituted benzenes typically fragment to form the tropylium ion (m/z 91)

m/z 15 methyl group

m/z 29 ethyl group

m/z 43 propyl group

m/z 57 butyl group

m/z 41 allyl group

Infra-red (IR) Spectroscopy

Infra-red light results in the stretching and/or bending of bonds

Bonds will stretch or bend at characteristic frequencies that allow us to determine the type of bond

this allows us to identify many of the functional groups

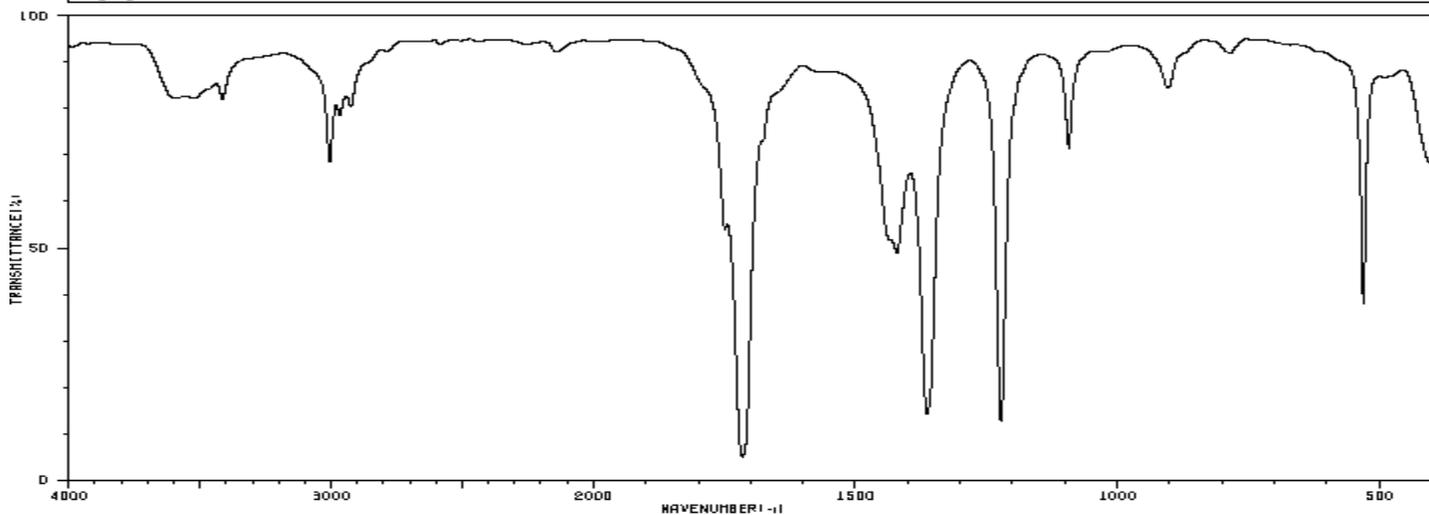
Frequencies are measured in inverse cm (cm⁻¹) which are called wavenumbers

Stretching a bond must change the dipole of a molecule for the bond to be IR active

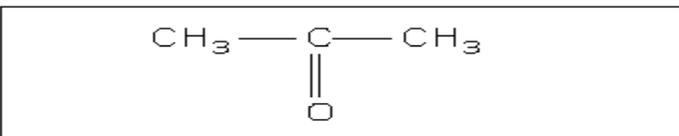
You need to be able to identify the following absorptions:

Aromatic C-C	two peaks usually in the range of 1500-1600 cm ⁻¹
C=C	~1650 cm ⁻¹
C=O	~1710 cm ⁻¹ (shifts to ~1735 cm ⁻¹ for esters)
C≡C	~2100-2300 cm ⁻¹
C≡N	~2100-2300 cm ⁻¹
C-H (aldehyde)	Two peaks at 2710 and 2810 cm ⁻¹
sp ³ C-H	just to the right of 3000 cm ⁻¹
sp ² C-H	just to the left of 3000 cm ⁻¹
sp C-H	~3300 cm ⁻¹
N-H	~3300 cm ⁻¹ (one peak for -NH-, two peaks for -NH ₂)
O-H (alcohol)	~3400 cm ⁻¹ (a broad, smooth peak)
O-H (acid)	~2500-3500 cm ⁻¹ (a very broad, ugly peak—not smooth)

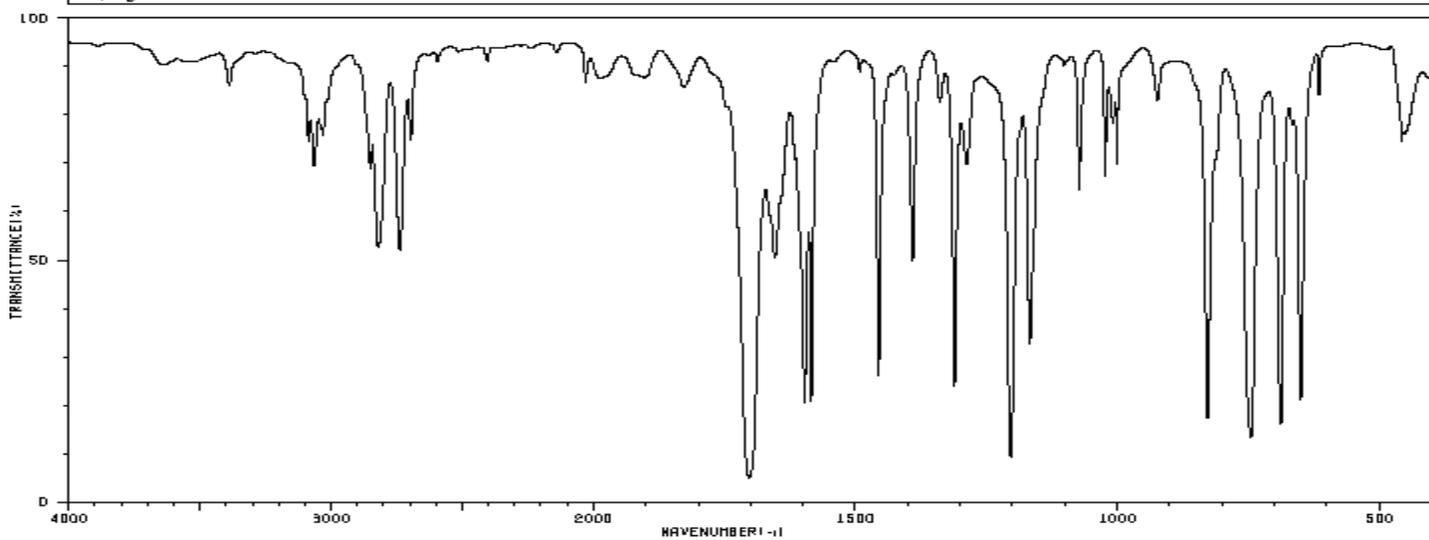
HIT-NO=960 | SCORE= () | SDBS-NO=319 | IR-NIDA-63533 : LIQUID FILM
 ACETONE
 C_3H_6O



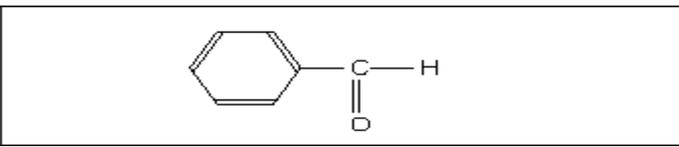
3414	79	1421	47
3005	66	1363	13
2966	74	1223	12
2926	77	1093	68
1749	52	903	81
1715	4	531	36
1434	49		



HIT-NO=1117 | SCORE= () | SDBS-NO=672 | IR-NIDA-05223 : LIQUID FILM
 BENZALDEHYDE
 C_7H_6O

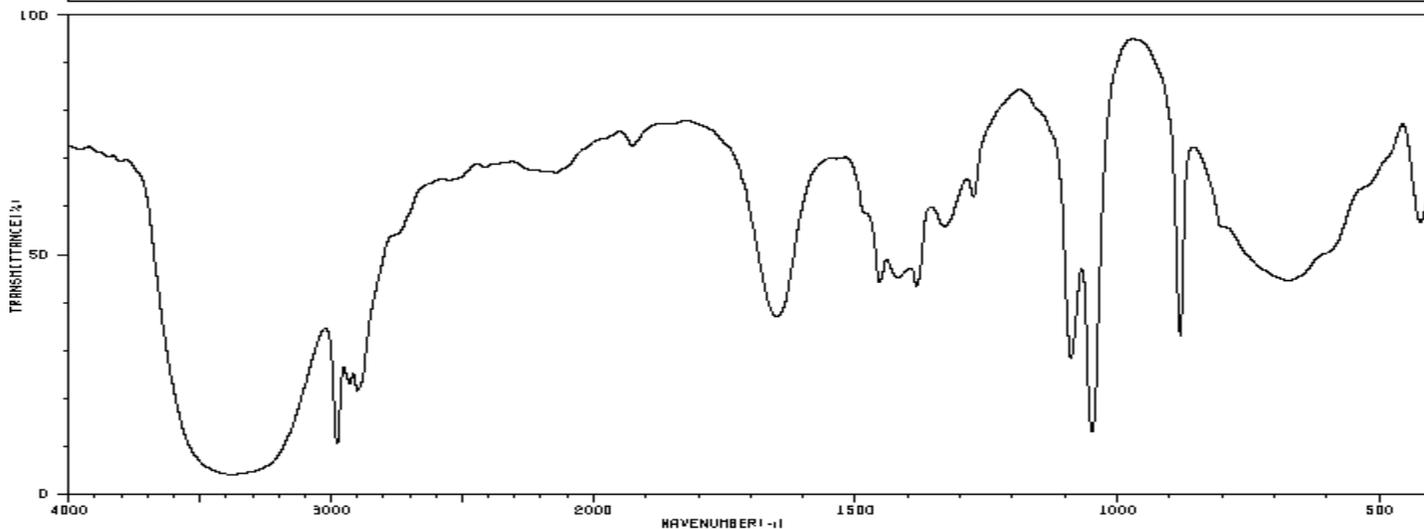


3086	72	1981	84	1697	20	1204	8	628	16
3065	66	1916	84	1584	20	1168	31	746	13
3031	72	1909	84	1456	25	1073	62	668	15
2860	66	1901	84	1391	47	1023	64	667	74
2820	50	1828	81	1339	79	1008	74	650	20
2738	50	1703	4	1311	23	1001	66	615	61
2696	72	1664	48	1288	88	924	78	467	72



HIT-NO=1374 SCORE= () SDBS-NO=1300 IR-NIDA-21941 : LIQUID FILM
ETHYL ALCOHOL

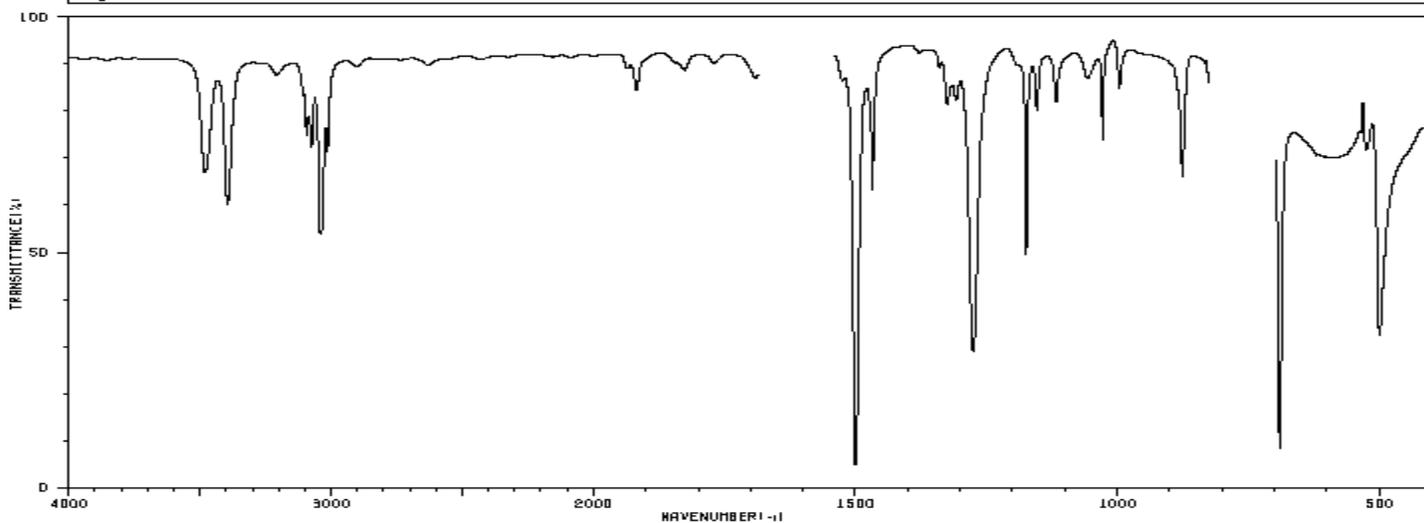
C₂H₆O



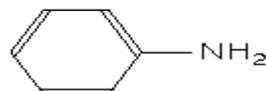
2977	4	1384	32
2930	13	1329	44
2899	12	1275	52
1925	62	1089	18
1650	26	1048	6
1454	33	880	22
1418	33		

HIT-NO=1070 SCORE= () SDBS-NO=905 IR-NIDA-08669 : CCL4 SOLUTION
ANILINE

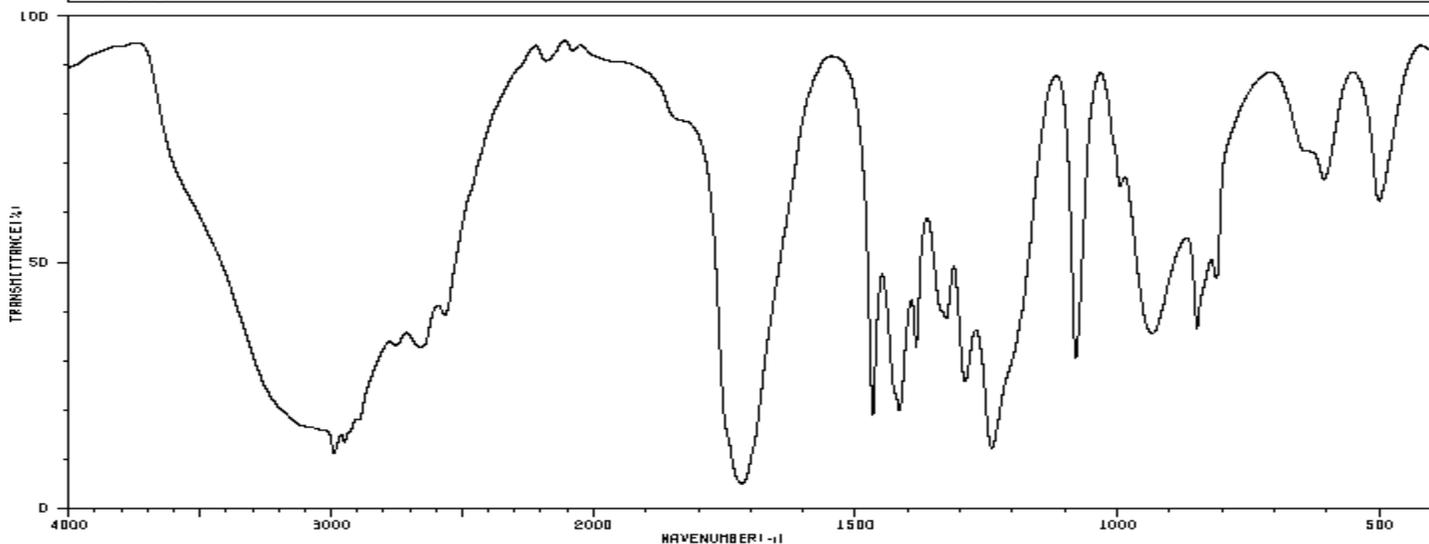
C₆H₇N



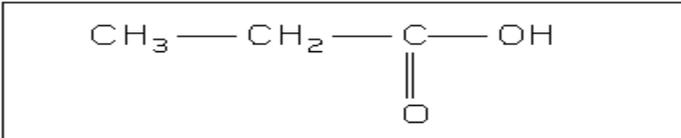
3480	64	2905	86	1340	86	1058	84
3395	58	2630	86	1325	79	1028	72
3209	84	1918	61	1306	79	995	61
3094	72	1833	86	1275	28	876	64
3074	70	1826	86	1174	47	690	8
3041	52	1500	4	1154	77	526	70
3013	68	1468	60	1117	79	500	31



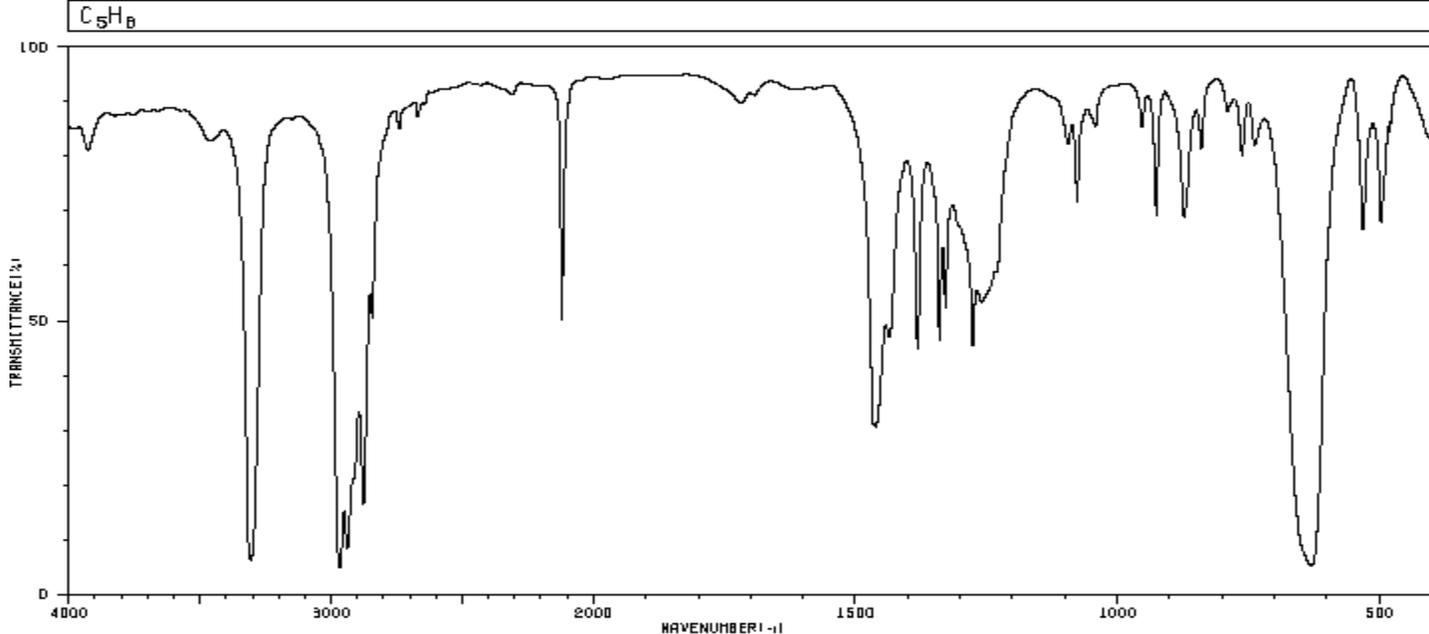
HIT-NO=1276	SCORE= ()	SDBS-NO=1033	IR-NIDA-05127 : LIQUID FILM
PROPIONIC ACID			
C ₃ H ₆ O ₂			



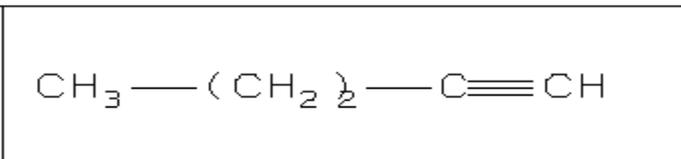
2986	10	1384	32	848	36
2948	12	1327	37	811	44
2860	31	1291	25	814	86
2565	38	1240	12	805	84
1716	4	1080	29	501	60
1467	18	995	62		
1416	19	933	34		



HIT-NO=2943	SCORE= ()	SDBS-NO=5386	IR-NIDA-13676 : LIQUID FILM
1-PENTYNE			
C ₅ H ₈			



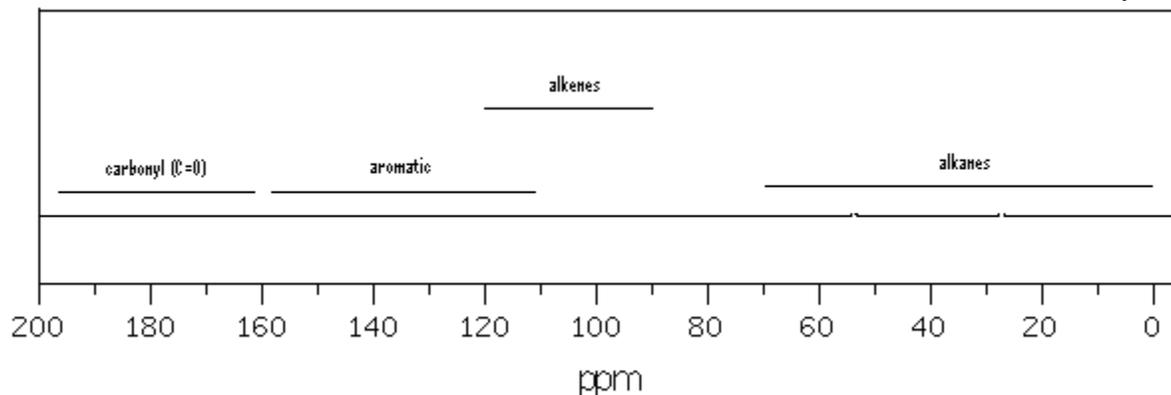
3928	79	2741	81	1381	43	1041	81	739	79
3457	79	2670	84	1340	44	954	81	630	5
3307	6	2120	47	1326	50	926	66	532	54
2968	4	1718	86	1276	43	872	66	497	66
2938	7	1466	29	1259	52	840	79	481	81
2876	16	1460	29	1095	79	791	84		
2843	49	1435	44	1077	68	762	77		



^{13}C NMR

gives the number of carbon environments in a molecule

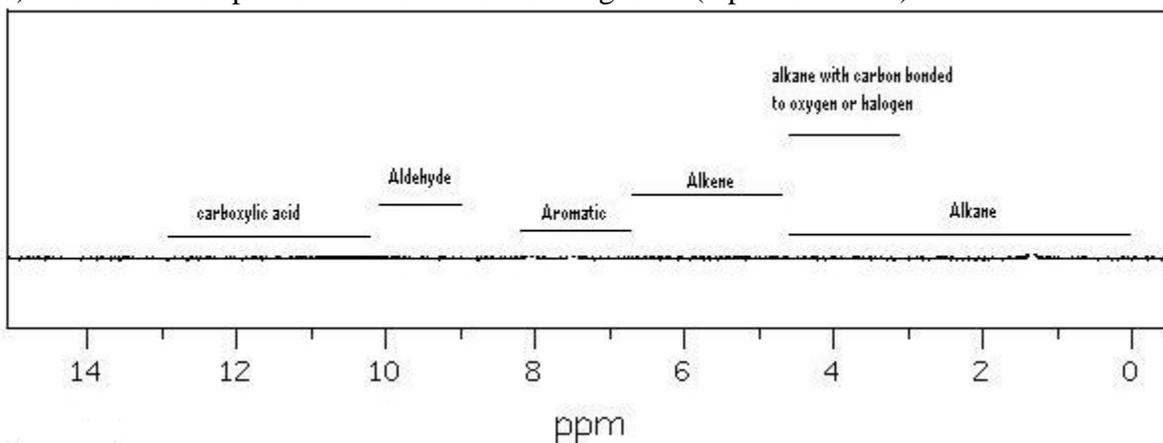
the chemical shift also tells whether the carbon is an alkane, alkene, aromatic, or carbonyl ($\text{C}=\text{O}$)

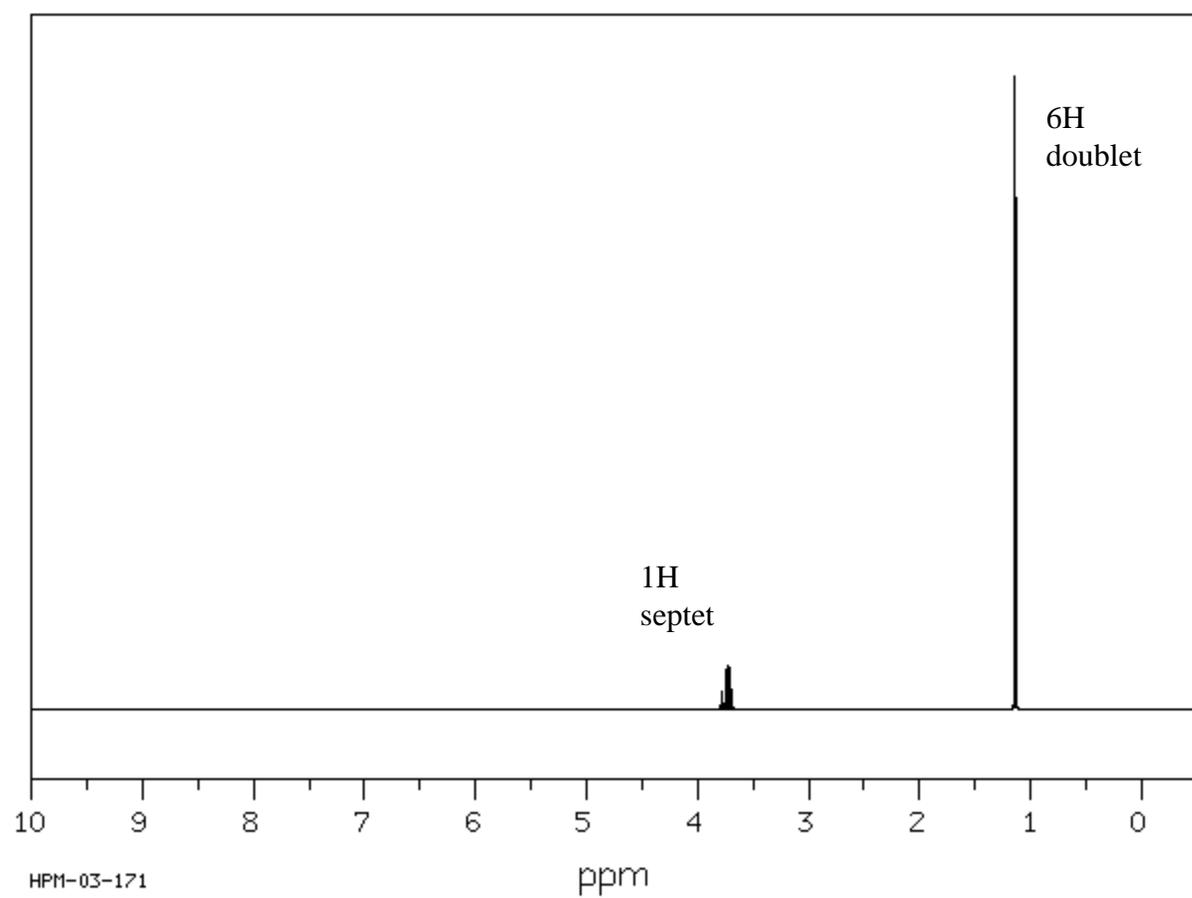
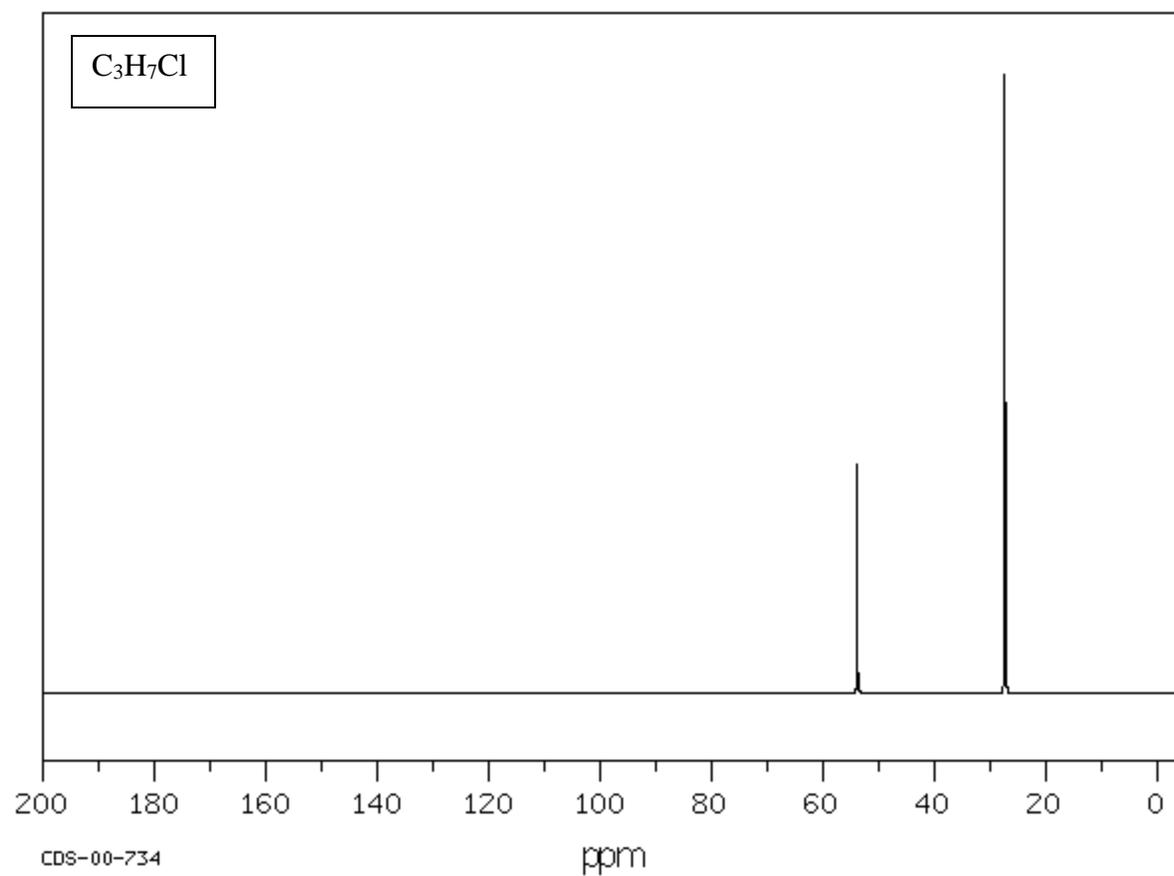


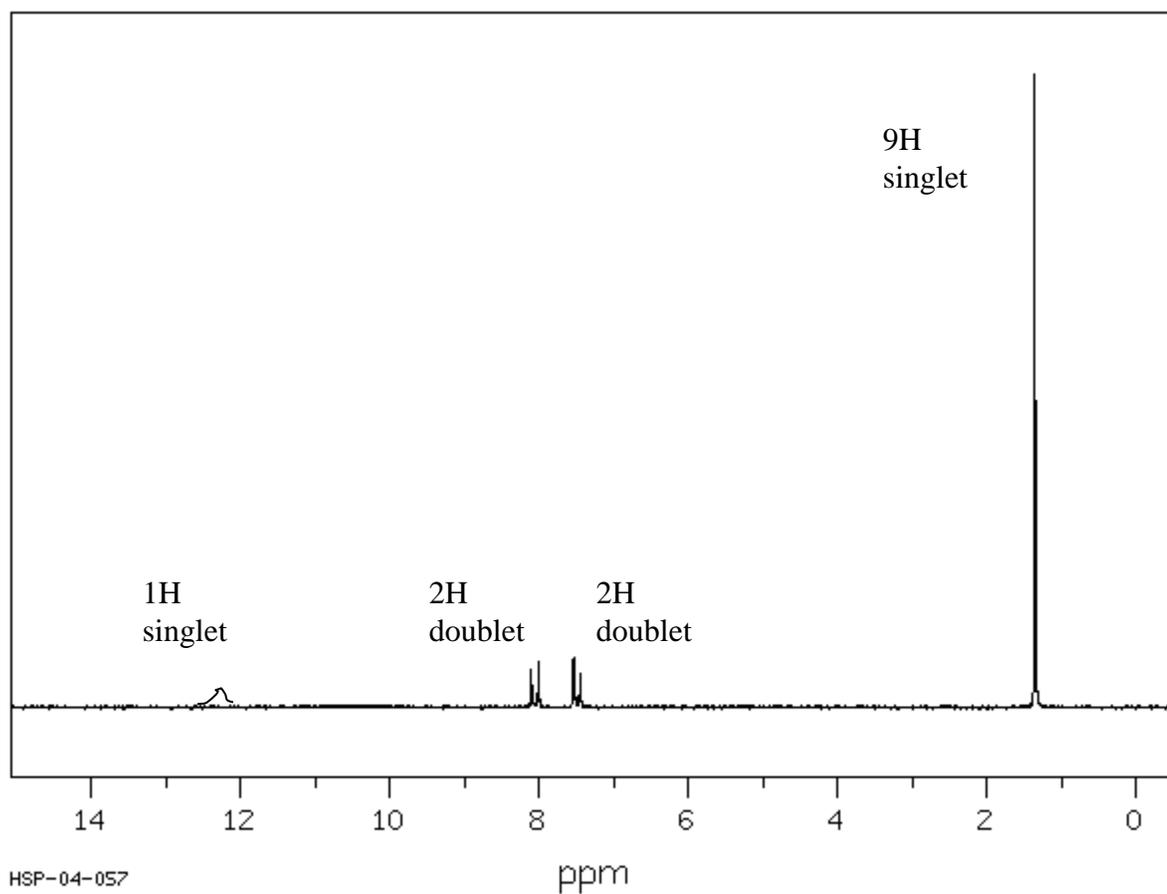
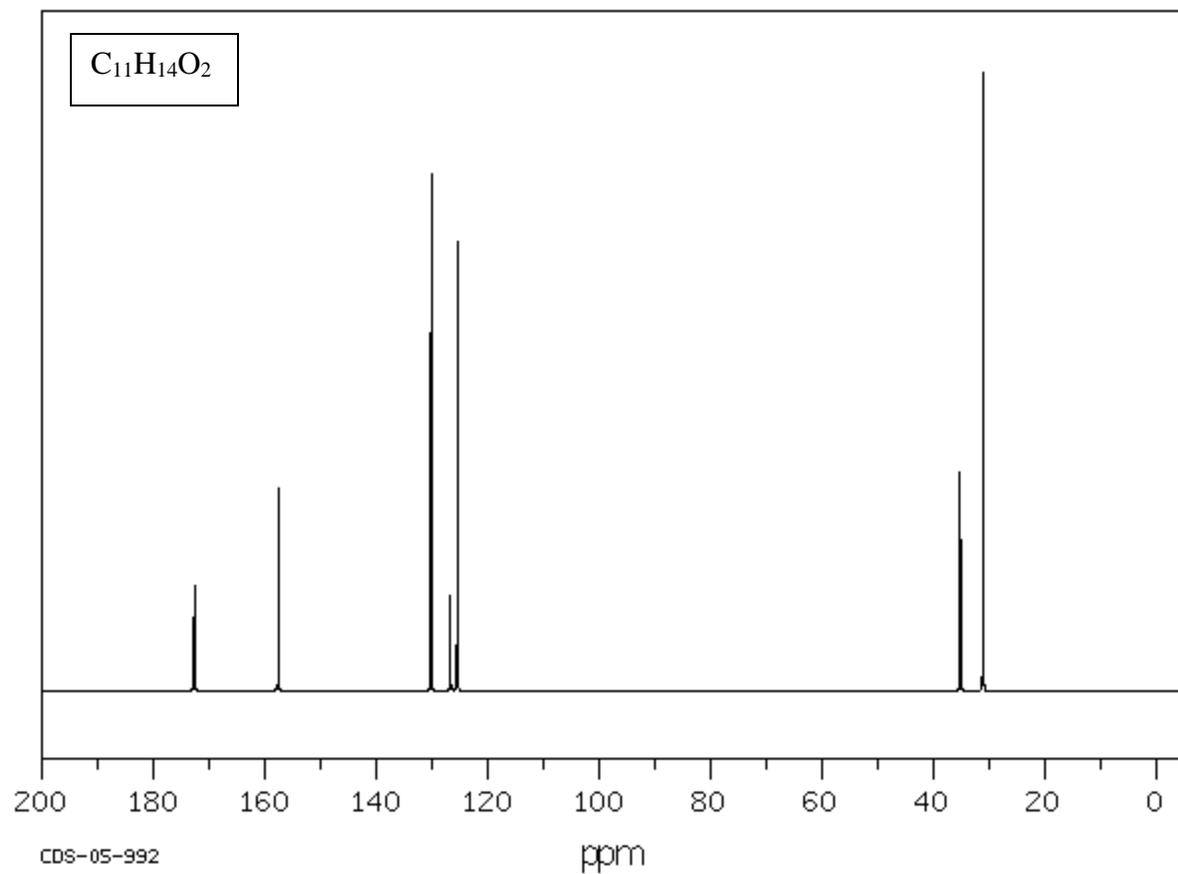
^1H NMR

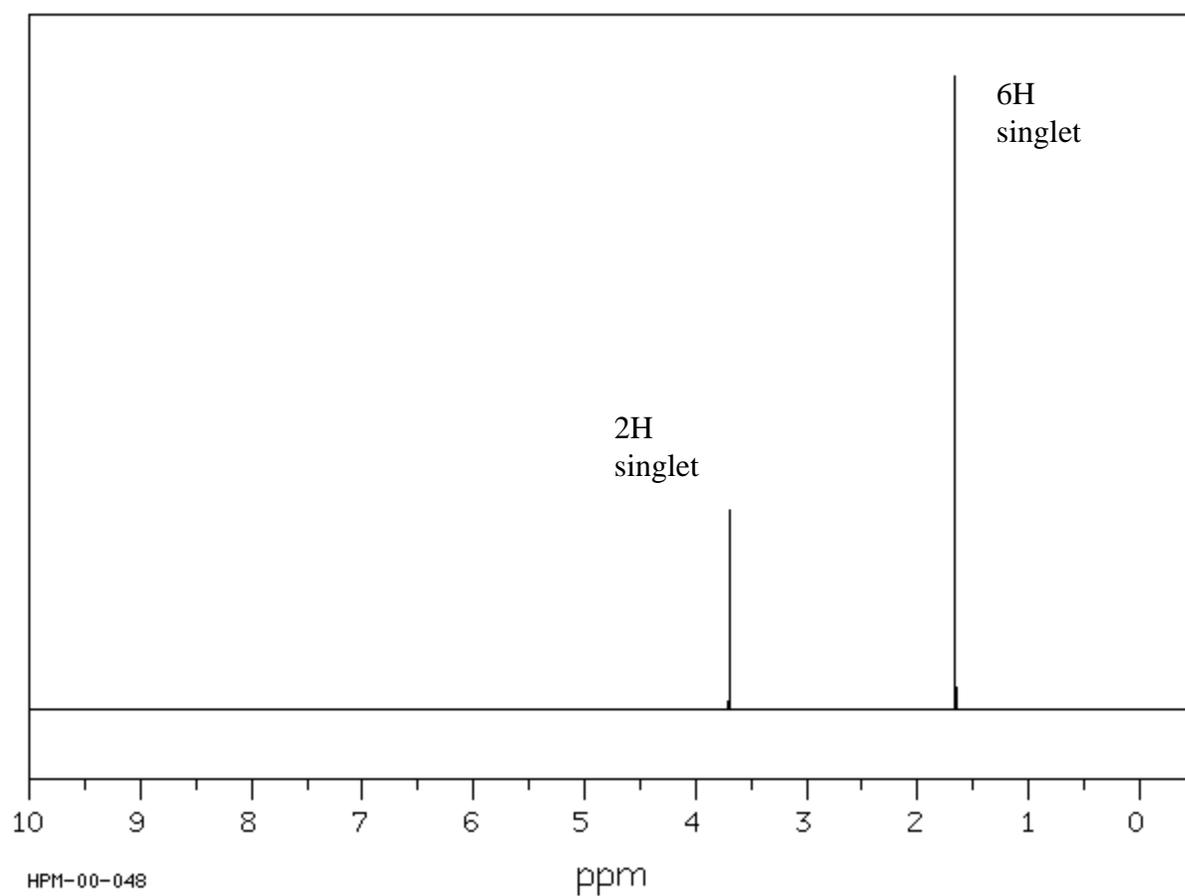
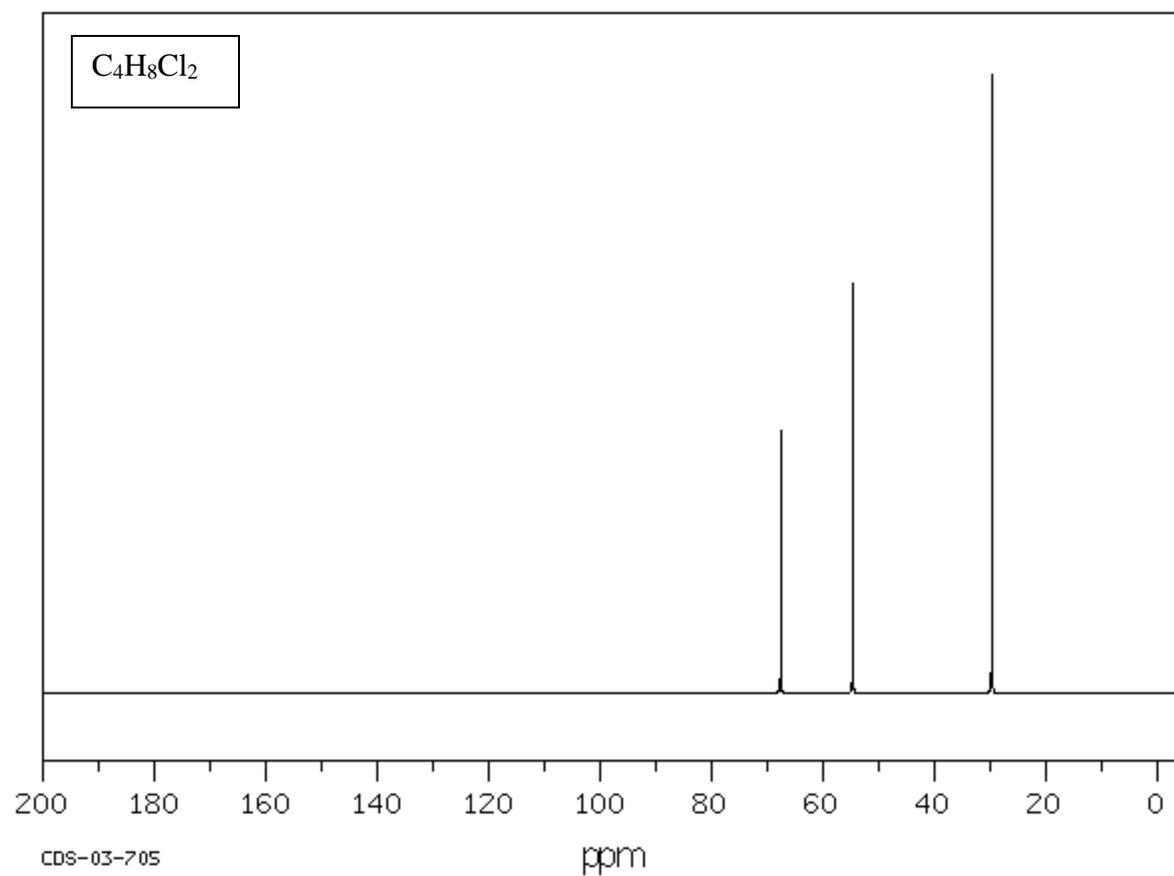
-gives the number of hydrogen environments in a molecule

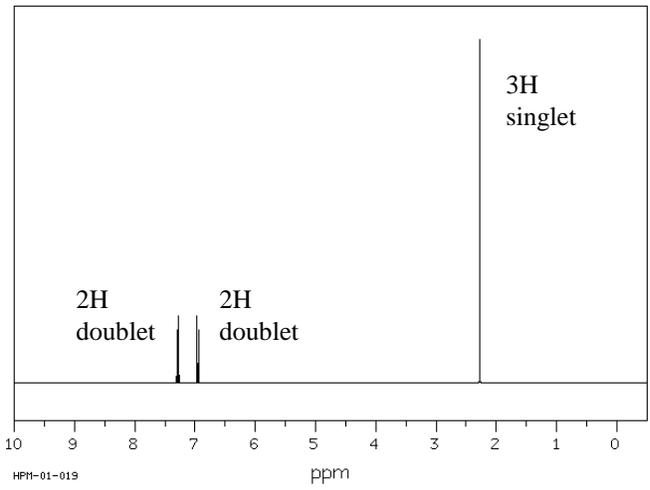
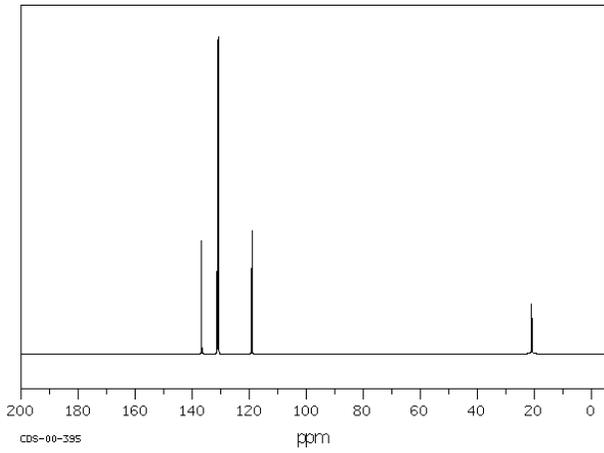
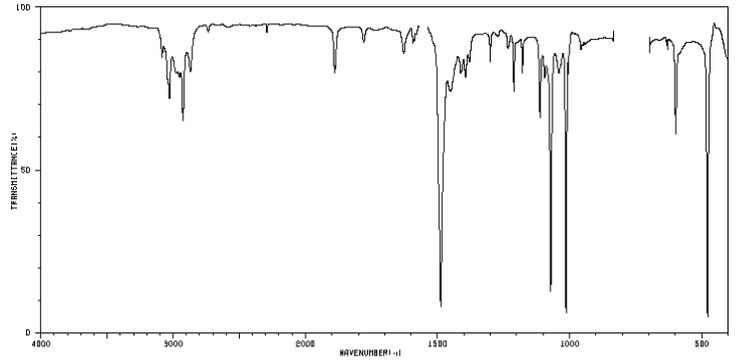
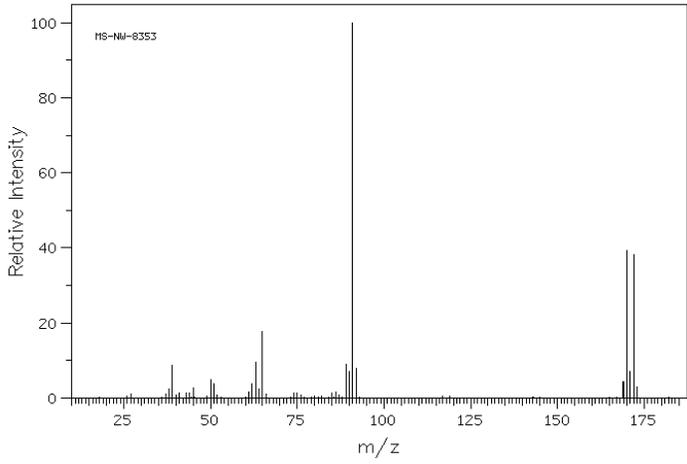
- 1) The chemical shift tells whether the hydrogen is an alkane, alkene, aromatic, aldehyde, or carboxylic acid
- 2) The area under the signal or integration tells how many hydrogens a signal represents (or at least the ratio)
- 3) The number of peaks tells the number of neighbors ($\# \text{ peaks} = n + 1$)

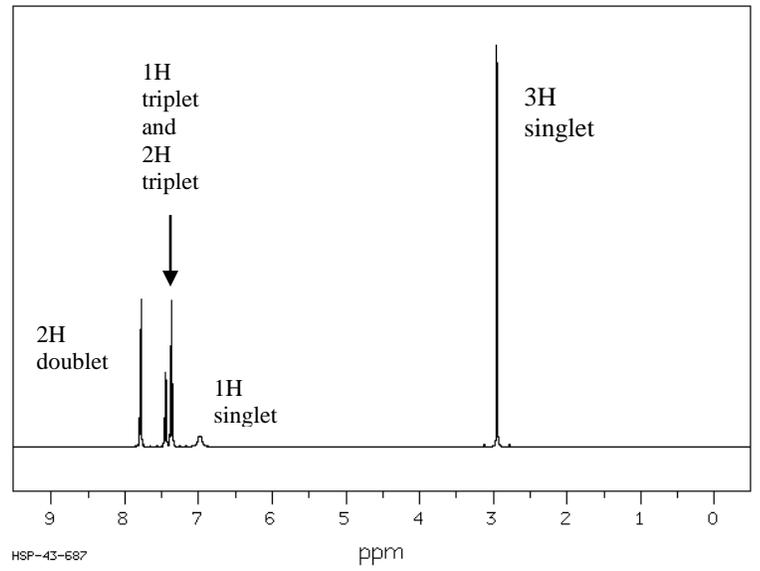
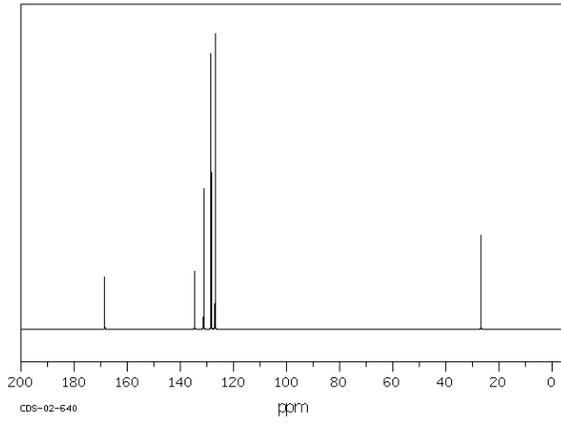
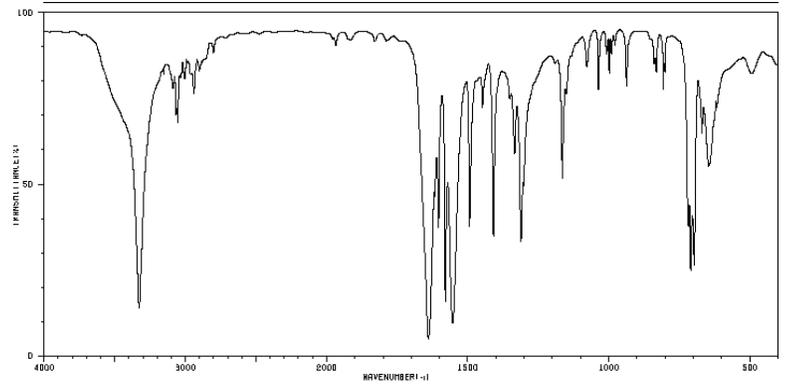
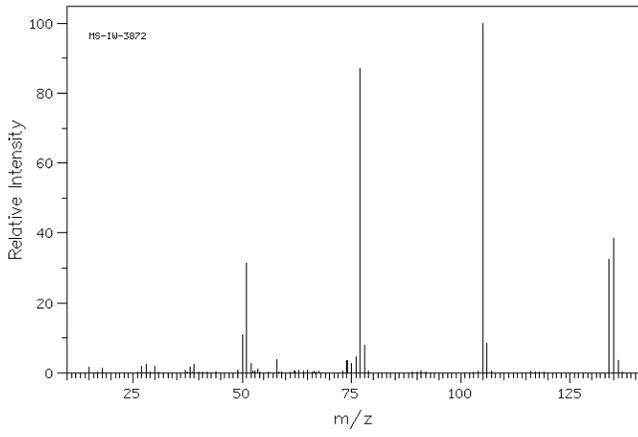












CHM 233 (Gould) Exam 3 Review

Bronsted Acids and Bases

$\downarrow pK_a$ = stronger acid, $\downarrow pK_b$ = stronger base

The stronger the acid, the weaker its conjugate base and vice-versa.

The more stable the base, the weaker the base.

Ranking Acids and Bases

- 1) Charge - More negatively charged species are typically more basic, and more positively charged species are typically more acidic.
- 2) Atom - The larger and/or more electronegative the atom with a negative charge, the more stable it is.
- 3) Resonance stabilization.
- 4) Dipole Induction - Electron withdrawing groups (i.e., electronegative atoms) near the atom that has the negative charge stabilize the ion/molecule.
- 5) Orbitals (Hybridization Effects) – a pair of electrons is more stable as follows: $sp > sp^2 > sp^3$

Alkenes

Nomenclature

-E/Z

Stability (More substituted alkenes are more stable)

Addition Reactions to Alkenes

Reagents	What's added	Regioselectivity	Stereoselectivity	Intermediate	Rearrangements
HBr (or HCl, HI)	H ⁺ and Br ⁻	Markovnikov	-	carbocation	Possible
H ₃ O ⁺ (ex. H ₂ SO ₄ /H ₂ O)	H ⁺ and OH ⁻	Markovnikov	-	carbocation	Possible
HBr / ROOR	H and Br	Anti-Markovnikov	-	Radical	Not possible
Br ₂ /CCl ₄ Cl ₂ /CCl ₄	Br ⁺ and Br ⁻	-	Anti	bromonium ion chloronium ion	Not possible
Br ₂ /H ₂ O Cl ₂ /H ₂ O	Br ⁺ and OH ⁻ Cl ⁺ and OH ⁻	Markovnikov	Anti	bromonium ion chloronium ion	Not possible
Br ₂ /ROH Cl ₂ /ROH	Br ⁺ and OR ⁻ Cl ⁺ and OR ⁻	Markovnikov	Anti	bromonium ion chloronium ion	Not possible
(1) Hg(OAc) ₂ , H ₂ O (2) NaBH ₄	H ⁺ and OH ⁻	Markovnikov	Anti	mercurinium ion	Not possible
(1) Hg(OAc) ₂ , ROH (2) NaBH ₄	H ⁺ and OR ⁻	Markovnikov	Anti	mercurinium ion	Not possible
(1) BH ₃ ·THF (2) H ₂ O ₂ , OH ⁻ , H ₂ O	H ⁺ and OH ⁻	Anti-Markovnikov	Syn		Not possible
H ₂ /catalyst (Catalyst = Pt/C, Pd/C, or Ni)	H and H	-	Syn		Not possible

Mechanisms and Rxn Profile diagrams

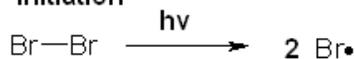
Radical Reactions

1) Br₂ / hν 2) Cl₂ / hν 3) NBS / hν 4) HBr / ROOR

Free Radical Halogenation

(Br₂ / hν or Cl₂ / hν or NBS / hν)

Initiation



Propagation

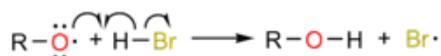
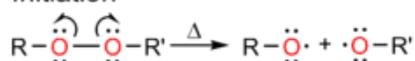


Termination

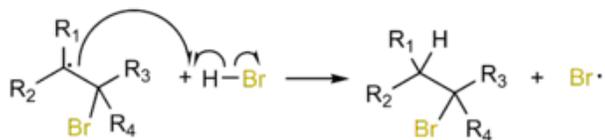


Addition of HBr / ROOR

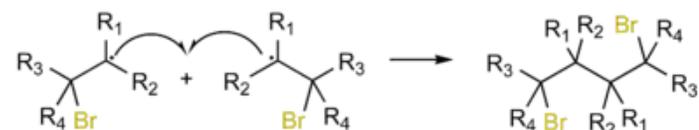
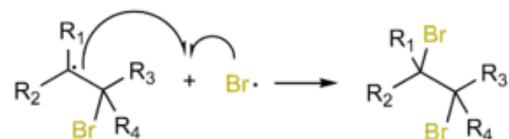
Initiation



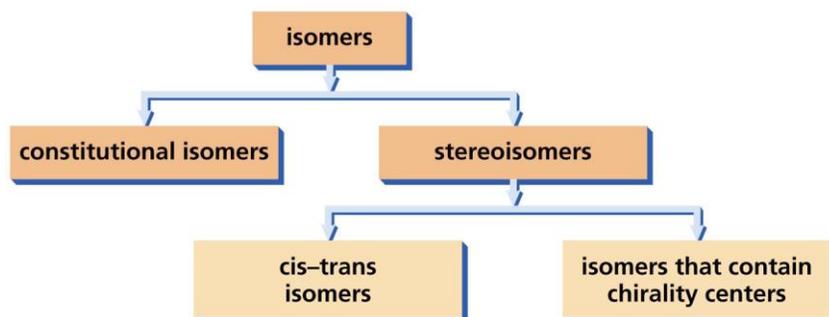
Propagation



Termination



Stereochemistry



Chiral compounds have non-superimposable (non-identical) mirror images called *enantiomers*.

Achiral compounds have mirror images that are superimposable (identical).

Chiral compounds are said to be *optically active*.

A 50/50 mixture of enantiomers is called a *racemic mixture* and is optically inactive.

Stereogenic centers are tetrahedral centers with four different substituents (also called asymmetric or chiral centers).

R vs. S

Fischer projections

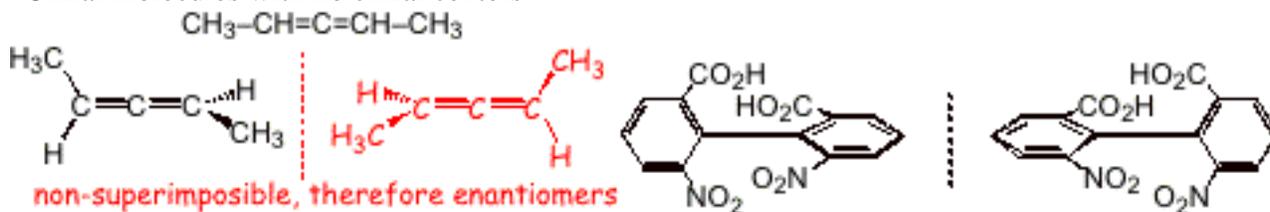
Multiple chiral centers

Diastereomers

Meso compounds (achiral but having chiral centers)

Amine inversion

Chiral molecules with no chiral centers

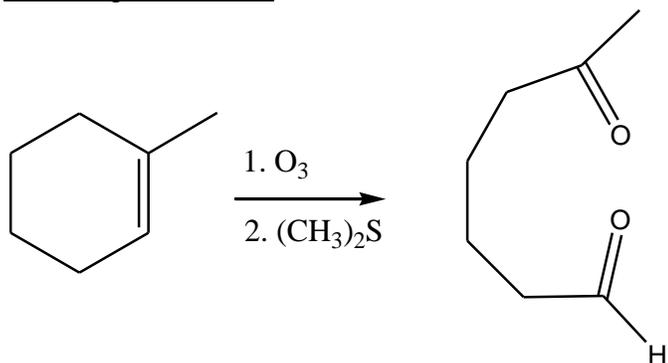


Addition Reactions to Alkenes

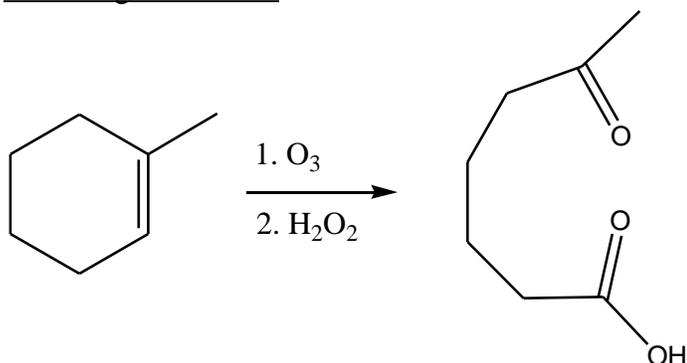
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HBr / ROOR	H and Br	Anti-Markovnikov	-	Radical	Not possible
Br ₂ /CCl ₄ Cl ₂ /CCl ₄	Br ⁺ and Br ⁻	-	Anti	bromonium ion chloronium ion	Not possible
Br ₂ /H ₂ O Cl ₂ /H ₂ O	Br ⁺ and OH ⁻ Cl ⁺ and OH ⁻	Markovnikov	Anti	bromonium ion chloronium ion	Not possible
Br ₂ /ROH Cl ₂ /ROH	Br ⁺ and OR ⁻ Cl ⁺ and OR ⁻	Markovnikov	Anti	bromonium ion chloronium ion	Not possible
(1) Hg(OAc) ₂ , H ₂ O (2) NaBH ₄	H ⁺ and OH ⁻	Markovnikov	Anti	mercurinium ion	Not possible
(1) Hg(OAc) ₂ , ROH (2) NaBH ₄	H ⁺ and OR ⁻	Markovnikov	Anti	mercurinium ion	Not possible
(1) BH ₃ ·THF (2) H ₂ O ₂ , OH ⁻ , H ₂ O	H ⁺ and OH ⁻	Anti-Markovnikov	Syn		Not possible
H ₂ /catalyst (Catalyst = Pt/C, Pd/C, or Ni)	H and H	-	Syn		Not possible
(1) OsO ₄ (2) H ₂ O ₂	OH and OH	-	Syn	-	Not possible
KMnO ₄ (cold, dilute)/ OH ⁻	OH and OH	-	Syn	-	Not possible
(1) RCO ₃ H (MCPBA) (2) H ₃ O ⁺	OH and OH	-	Anti	-	Not possible

Ozonolysis

Reducing Conditions

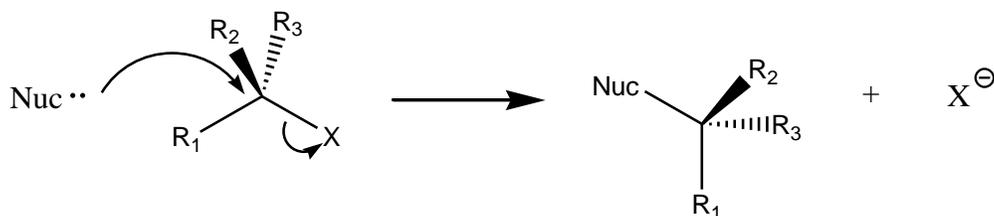


Oxidizing Conditions



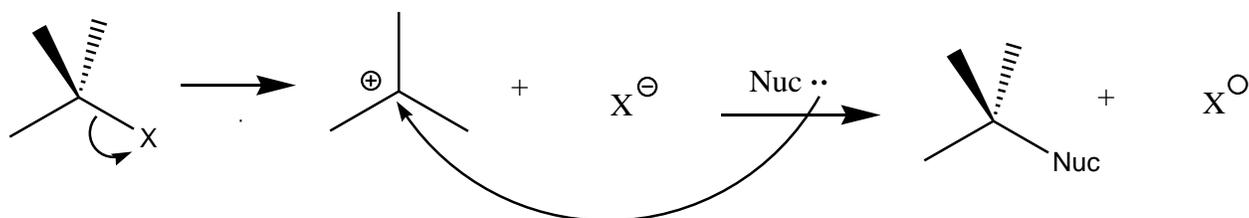
Substitution Reactions

S_N2 reactions – Substitution Nucleophilic Bimolecular Mechanism



rate = $k[\text{substrate}][\text{nucleophile}]$
results in inversion of configuration

S_N1 reactions – Substitution Nucleophilic Unimolecular Mechanism



Rate = $k[\text{substrate}]$
Carbocation rearrangements are possible
Results in both inversion and retention of configuration (racemization)
Weak nucleophiles (or low concentrations of strong nucleophiles) are ok as it isn't in the RDS
Addition of AgNO_3 facilitates carbocation formation

S_N2 vs. S_N1

	S_N2	S_N1
Nucleophile	strong required	weak is ok
Electrophile (has LG)	$\text{CH}_3 > 1^\circ > 2^\circ$	$3^\circ > 2^\circ$
Solvent	polar aprotic (preferred)	polar protic
Leaving Group	Good ($\text{I}^- > \text{Br}^- > \text{Cl}^- > \text{F}^-$)	Good ($\text{I}^- > \text{Br}^- > \text{Cl}^- > \text{F}^-$)
Rearrangements	Not Possible	Possible
Inversion	Yes	No (Racemization)

polar aprotic solvents include DMSO, acetone, DMF, and acetonitrile (know structures)

benzylic and allylic substrates

aryl and vinyl halides are unreactive

nucleophile strength

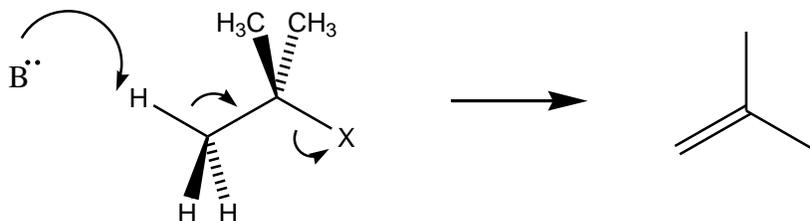
in protic solvent

in aprotic solvent

Elimination Reactions

E2 reactions – Elimination Bimolecular

Mechanism



$$\text{rate} = k[\text{substrate}][\text{base}]$$

H and X (leaving group) should be anti-periplanar (anti-coplanar)

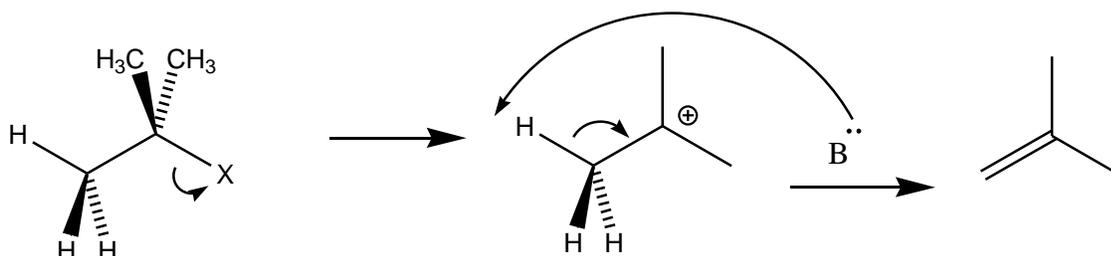
Forms most substituted double bond (Zaitsev's Rule)

Forms least substituted (Hofmann) if a bulky base (t-butoxide) is used with 3° halide

Forms least substituted (Hofmann) if F⁻ is the leaving group

E1 reactions – Elimination Unimolecular

Mechanism



$$\text{Rate} = k[\text{substrate}]$$

Carbocation rearrangements are possible

Forms most substituted double bond (Zaitsev's Rule)

Favored by heat due to entropy

E2 vs. E1

	E2	E1
Base	strong base	weak base
Electrophile (has LG)	3° > 2° > 1°	3° > 2°
Solvent	polar aprotic (better)	polar protic
Leaving Group	Good (I ⁻ > Br ⁻ > Cl ⁻ > F ⁻)	Good (I ⁻ > Br ⁻ > Cl ⁻ > F ⁻)
Rearrangements	Not possible	Possible
Stereochemistry	Anti-coplanar	None

	S_N2	E2	S_N1	E1
Electrophile (has LG)	CH ₃ > 1° > 2°	3° > 2° > 1°	3° > 2°	3° > 2°
Nucleophile/Base	strong nuc	strong base	weak nuc	weak base
Solvent	polar aprotic (preferred)	polar aprotic (preferred)	polar protic	polar protic
Leaving Group	good	good	good	good

CHM 234 Gould Final Exam Review

Alpha Additions

Acidity of alpha hydrogens

Keto-enol tautomerism

LDA (lithium diisopropyl amide) is a strong base used to form enolate ions

Alpha halogenation

Base-promoted (X_2/OH^- , H_2O)

Acid-catalyzed halogenation of ketones

Alpha alkylation

Alkylation of enolate ions (S_N2 rxn with an enolate attacking an alkyl halide); only for ketones

Stork rxn – convert ketone to enamine with 2° amine and α -alkylate followed by hydrolysis

Alkylation at Beta Carbon

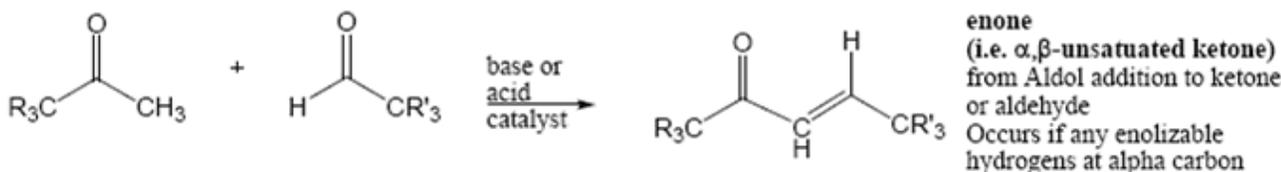
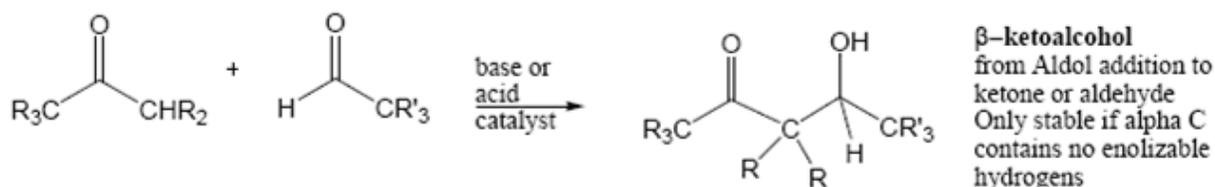
Michael addition – a 1,4-addition of a conjugated ketone

Michael donor is typically a stabilized enolate ion or R_2CuLi

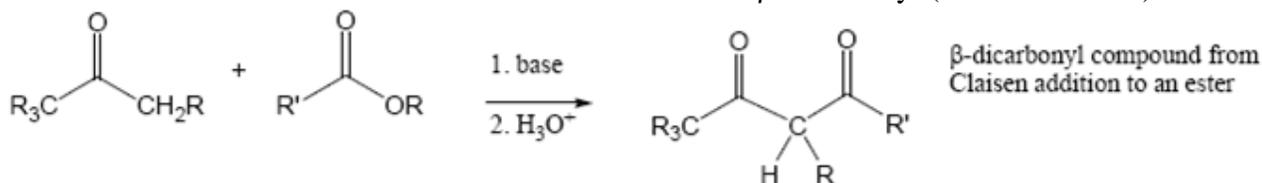
Acceptor is a conjugated carbonyl, cyano, or nitro group

Aldol Condensation – Acid catalyzed – **enol** adds to a ketone or aldehyde

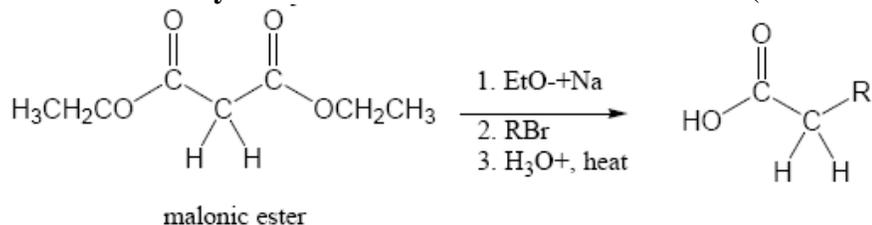
Base-catalyzed - **enolate** adds to a ketone or aldehyde



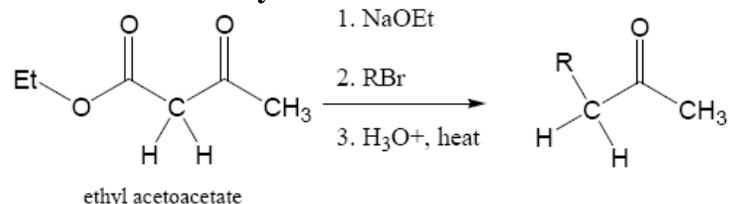
Claisen Condensation – enolate attacks an ester to form a β -dicarbonyl (self and crossed)



Malonic Ester Synthesis – forms a substituted acetic acid (adds 2 carbons)

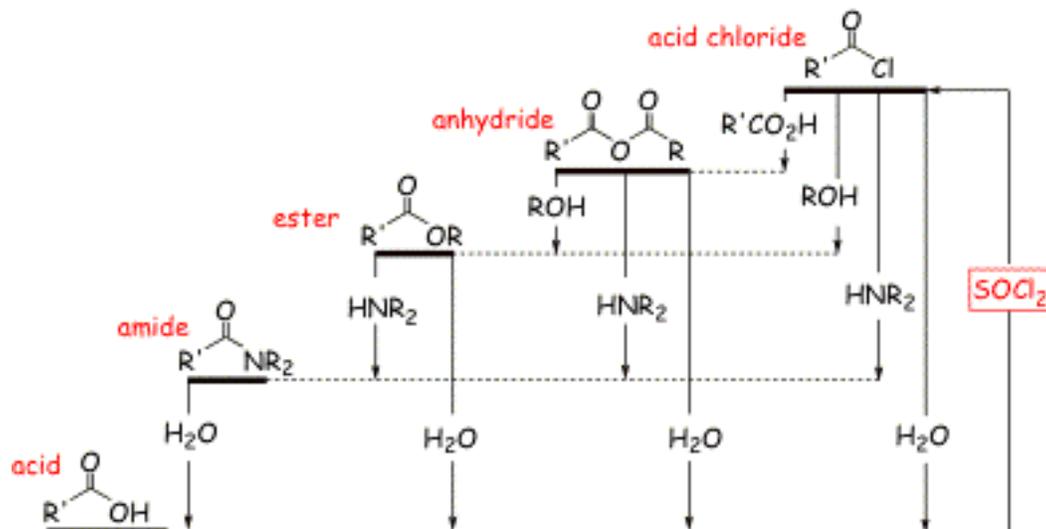


Acetoacetic Ester Synthesis – forms a substituted acetone (methyl ketones)



Nucleophilic Acyl Substitution

-Reactivity (acid chlorides > anhydrides > esters > amides > carboxylates)



• can convert *more* reactive derivatives into *less* reactive derivatives, not the other way around!!

Saponification of Esters

Fischer Esterification

Rxns of Amines

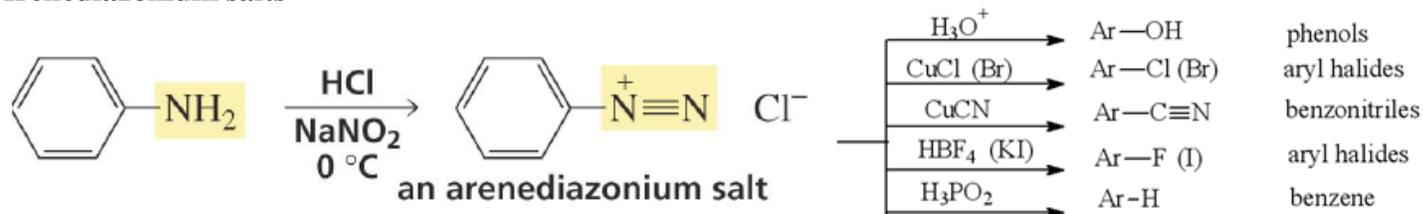
Reductive Amination

HCl, H₂, Pd/C

Hofmann Elimination

(1) Excess CH₃I (2) Ag₂O/H₂O (3) Heat

Arenediazonium salts



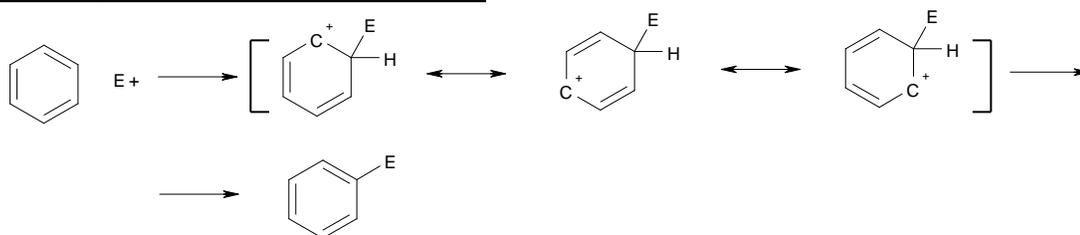
Criteria for Aromatic Compounds

- 1) cyclic and containing conjugated pi bonds
- 2) each atom in the ring must have an unhybridized p orbital (no sp³ atoms in ring)
- 3) planar structure
- 4) delocalization of the pi electrons must lower the electronic energy (4N+2 electrons)

Antiaromatic compounds satisfy the first 3 rules above but delocalization of the pi electrons increases the electronic energy (4N electrons)

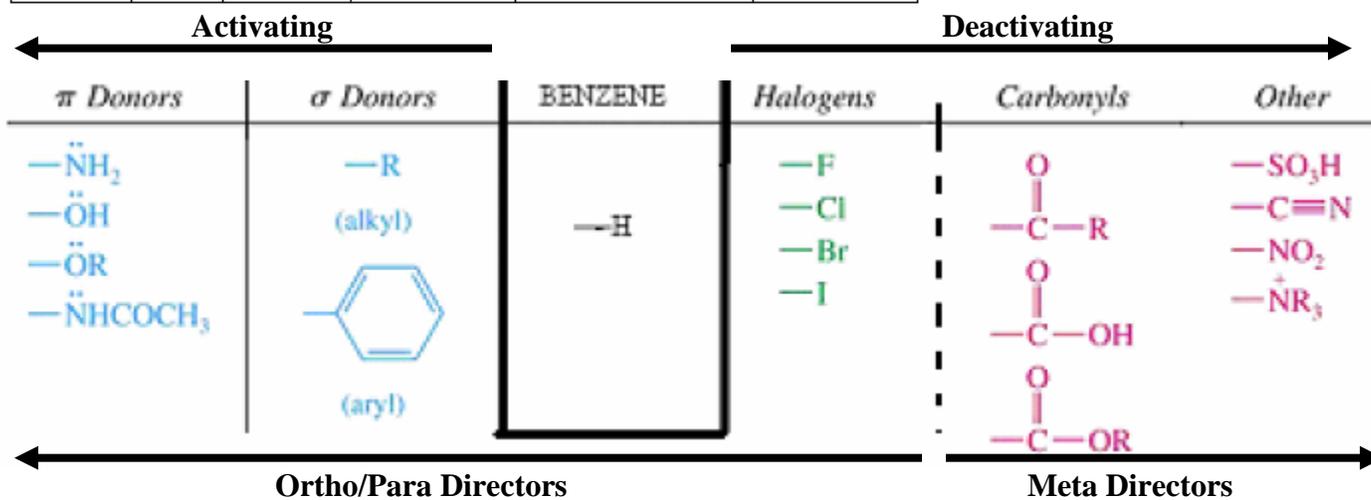
Nonaromatic compounds are those that don't satisfy one or more of the first 3 rules above

Electrophilic Aromatic Substitution



Summary of suitable EAS electrophiles, reagents, and reactions

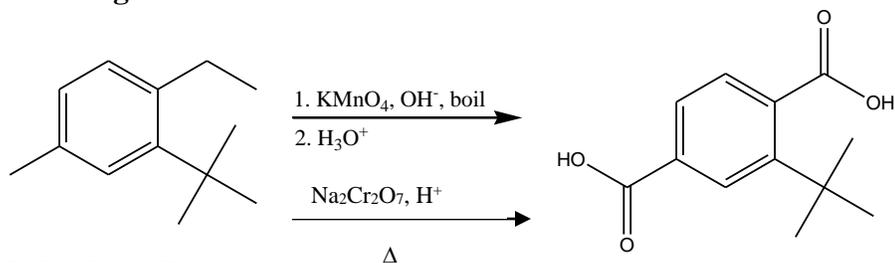
Reactant	E ⁺	Reagents	Catalyst	Product(s)	Type of EAS
	NO ₂ ⁺	HNO ₃ , H ₂ SO ₄	---		Nitration
	SO ₃ H ⁺	SO ₃ , H ₂ SO ₄	---		Sulfonation
	Cl ⁺	Cl ₂	AlCl ₃		Chlorination
	Br ⁺	Br ₂	FeCl ₃		Bromination
	I ⁺	I ₂	HNO ₃		Iodination
	R ⁺	RX or R-OH or alkene	AlCl ₃ or FeBr ₃ H ₂ SO ₄ HF		Friedel-Craft Alkylation Or alkylation
	O=C ⁺ R		AlCl ₃		Friedel-Craft Acylation



Strongest donating group usually directs when there are competing substituents

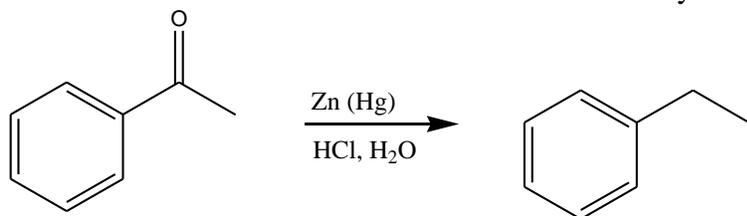
Reactions of Benzenes

Permanganate or Chromic Acid Oxidation



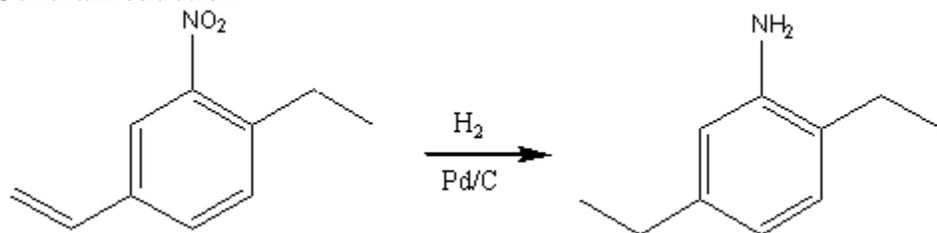
Side-chain Reduction

Clemmenson Reduction – reduces ketones and aldehydes to alkanes



Wolff Kishner
Reduction does the
same thing with
 $\text{H}_2\text{NNH}_2, \text{OH}^-, \text{heat}$

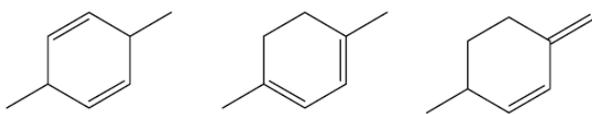
General reduction



Or 1. Sn, HCl for selective reduction of nitro groups to amines
2. OH^-

Conjugated Systems

Relative stability of isolated, conjugated, and cumulative double bonds
heat of hydrogenation



1,2- and 1,4-addition to conjugated dienes
Kinetic vs. Thermodynamic Product

π Molecular Orbitals

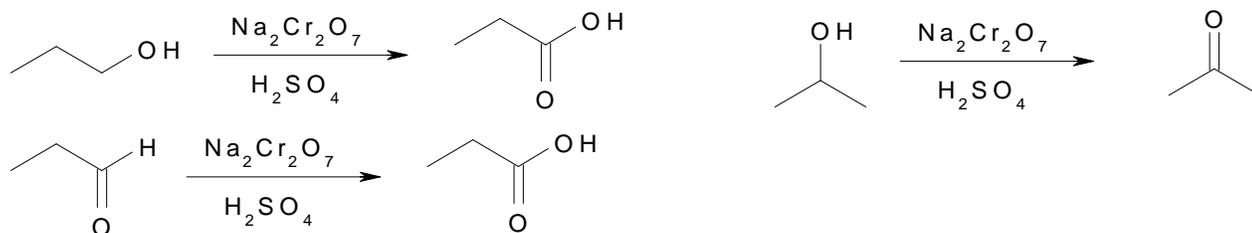
1,3-butadiene
allyl system (cation, radical, and anion)
benzene

Diels-Alder Rxns ([4 + 2] cycloaddition)

concerted syn addition between dienophile and electron-deficient diene
diene must be in the s-cis conformation
only 1,2 and 1,4 products observed with unsymmetrical reagents (relationship of D to W)
Frontier Molecular Orbital Theory (FMO Theory)
Conservation of orbital symmetry

Oxidation Rxns

$\text{Na}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$ oxidizes 1° alcohols to carboxylic acids, 2° alcohols to ketones, and aldehydes to acids

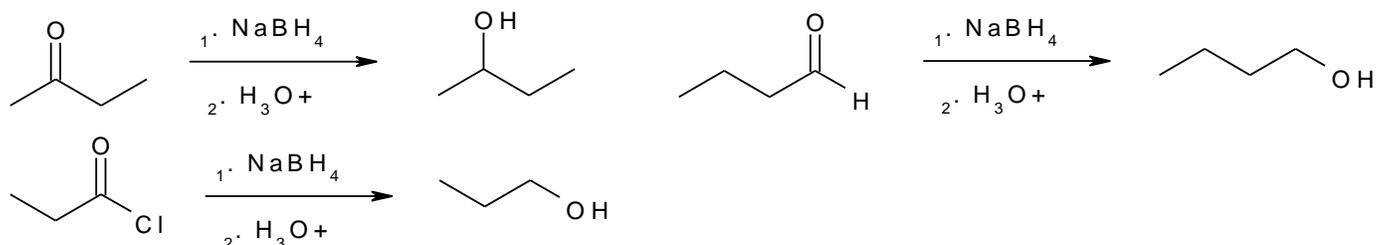


PCC oxidizes 1° alcohols to aldehydes and 2° alcohols to ketones

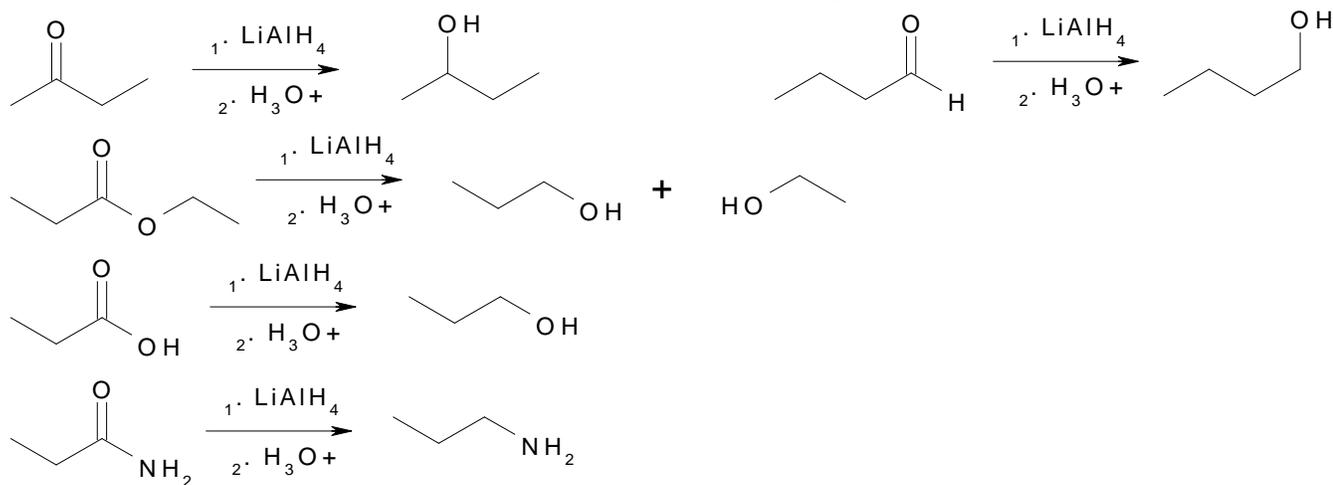


Reduction Rxns

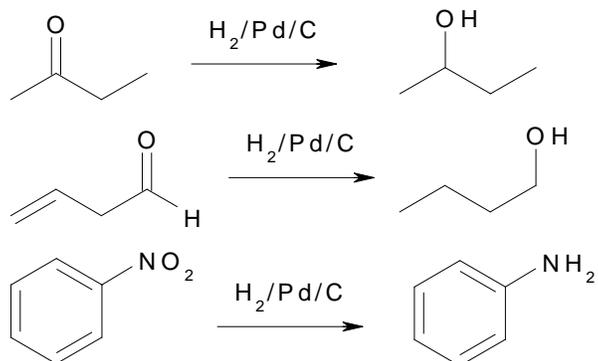
NaBH_4 reduces ketones, aldehydes, and acid halides



LiAlH_4 reduces ketones, aldehydes, acid chlorides, esters, carboxylic acids, and amides (and others)



$\text{H}_2, \text{Pd/C}$ reduces alkenes, alkynes, and nitro groups

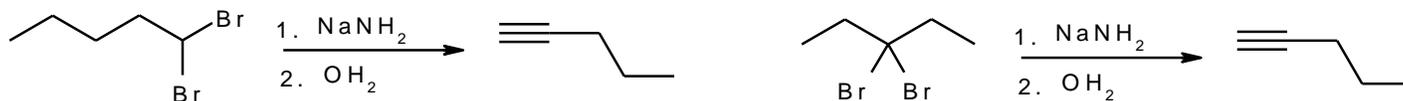


Alkynes

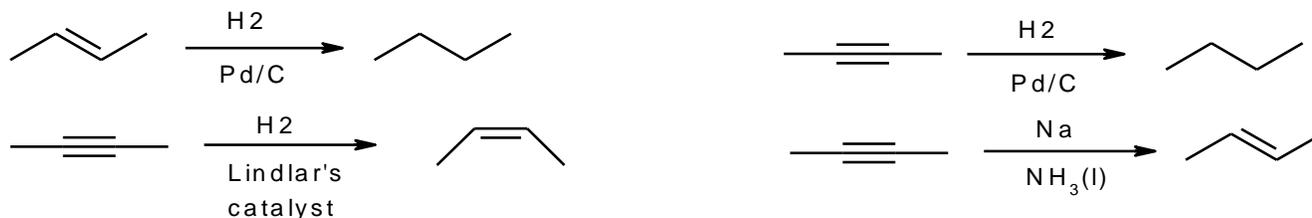
Nomenclature

Acidity (heterolytic vs. homolytic cleavage)

Preparation of Alkynes (E2)

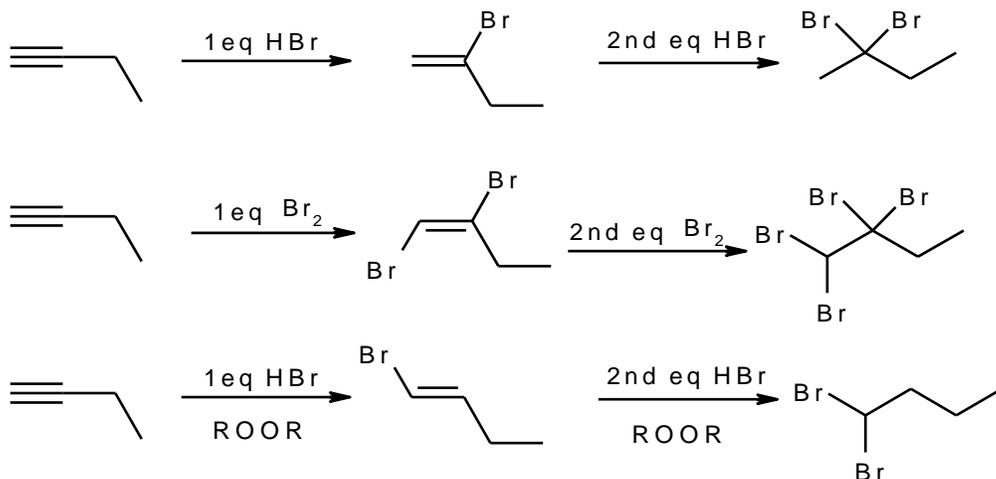


Reduction (Addition of Hydrogen)

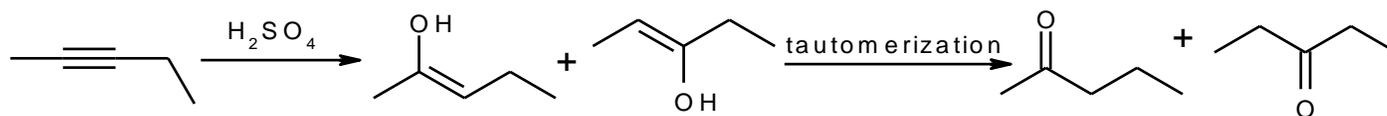


Addition of H-X or X₂

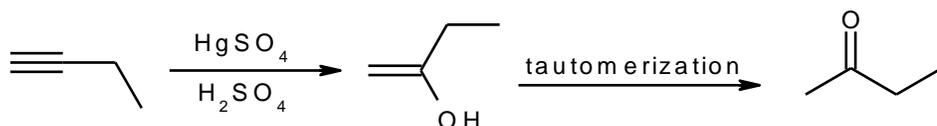
Alkynes are less reactive than alkenes in addition rxns



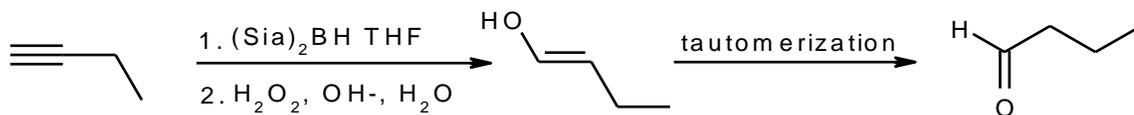
Addition of H₂O



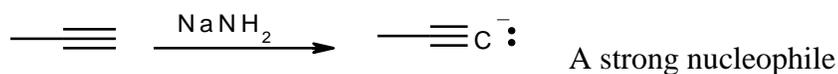
Terminal alkynes require HgSO₄ as a catalyst (Markovnikov)



Hydroboration oxidation with a terminal alkyne produces an aldehyde (anti-Markovnikov)



Nucleophilic Addition of Acetylide Ions

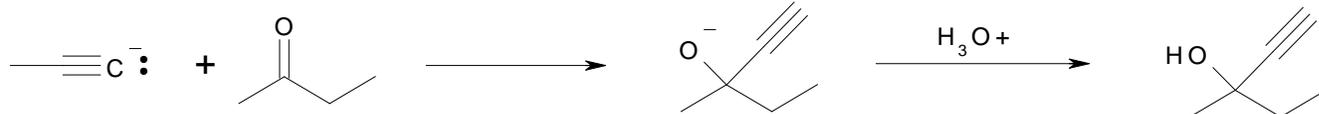


An acetylide ion has 3 typical substrates:

1) an alkyl halide



2) a carbonyl (C=O)



3) an epoxide (adds to least substituted side)



Cycloaddition Rxns

Aromatic Transition State Theory

Huckel – $4n+2$ e^- involved in the transition state

Suprafacial-suprafacial

Mobius – $4n$ e^- involved in the transition state

Suprafacial-antarafacial



Electrocyclic Rxns (Ring Closures/Opening)

Aromatic Transition State Theory

Huckel – $4n+2$ e^- involved in the transition state

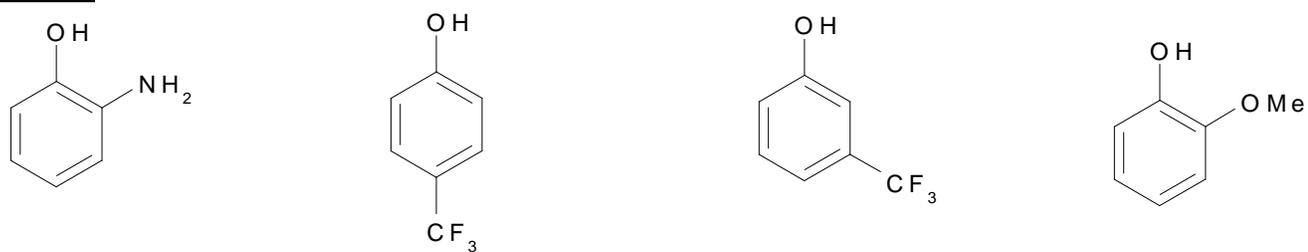
disrotatory

Mobius – $4n$ e^- involved in the transition state

conrotatory



Acidity



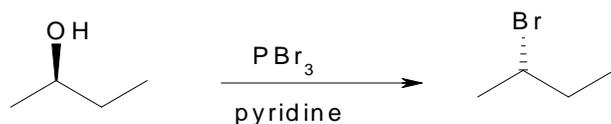
Alcohols

Rxn with H-X

S_N1 for 2° and 3° alcohols

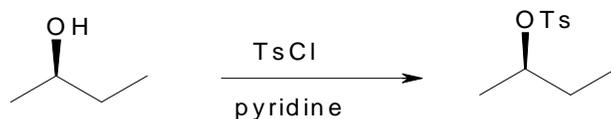
S_N2 for 1° alcohols

Rxn with PBr_3 (for 1° and 2° alcohols)

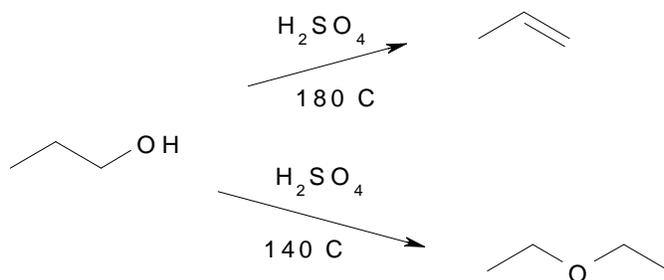


Rxn with $SOCl_2$

Conversion to Sulfonate Esters

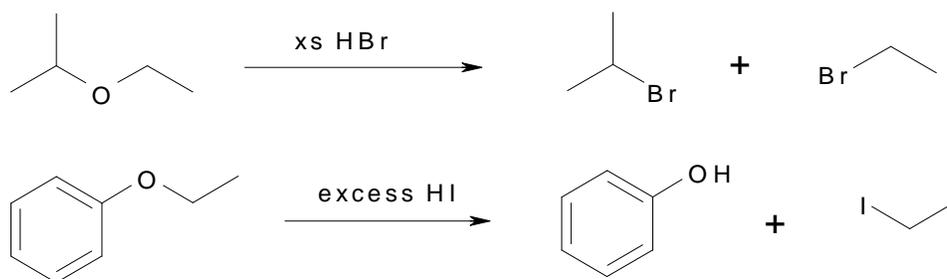


Dehydration with H_2SO_4



Ethers

Rxn with H-X



Epoxydes

Ring opening of epoxydes (in acid or base)