

UNIT XV: ORGANIC CHEMISTRY
(Chemistry IB)

I. Introduction to Carbon Compounds:

- There exists over 6 million carbon compounds, and over _____ new ones are synthesized each year.
- Carbon compounds are the most industrially prolific, present in everything from _____, to _____, to _____.
- Carbon compounds exist naturally in the Earth as _____, or deposits of decaying plants that have accumulated and undergone pressure buildup over the years.
- The vast amount of uses and chemical properties of carbon compounds warrants it to have a special branch in chemistry called _____.

II. Organic Compounds & its Classes:

- C atom has four electrons for bonding and can be covalently shared with _____ other atoms in a _____ configuration.
- This _____ allows for some carbon compounds to be of enormous lengths.
- Other C compounds can also form into _____.

There are 2 classes of organic compounds:

- 1) **Hydrocarbons** – those compounds that contain only _____ and _____.
- 2) **Hydrocarbon Derivatives** – where the H atoms are _____ with other compounds or atoms.

No matter what type of organic compound, all possess a _____ backbone. However, the backbone may be _____ or _____.

Whether the compound is a hydro-carbon or a derivative, there are two forms that it can take:

1) Saturated:

2) Unsaturated:

III. Hydrocarbons- A Closer Look:

- There are 3 families of hydrocarbons:
- 1) _____ : singly bonded hydrocarbon
 - 2) _____ : doubly bonded hydrocarbons
 - 3) _____ : triply bonded hydrocarbons.

A. Alkanes: (C_nH_{2n+2})

- May be _____ or _____.
- Have relatively _____ boiling points due to the molecules' _____.
- Bond enthalpy for alkanes are _____, resulting in _____ stability.
- As # of C increases, boiling point increases due to _____ forces.

i) The First 6 Alkanes: (Straight Chains)

1. _____ (g) :

2. _____ (g) :

3. _____ (g) :

4. _____ (g) :

5. _____ (l) :

6. _____ (l) :

Hept---- (7)
Oct--- (8)
Non--- (9)
Dec--- (10)

NOTE: The above alkanes are examples of a **homologous series** – where successive molecules differ by only CH_2 .

5. Assign a name to each _____ according to its point of attachment to the parent chain:
Change the ending of the substituent to *-yl*.

Also assign the substituent with a number according to its placement on the # of the parent C.

WORKSHEET: Alkanes Worksheet

B. Alkenes (C_nH_{2n})

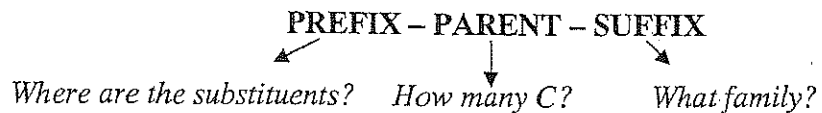
- There is at least _____ double bond along the carbon _____.
- Alkenes are more _____ because the site of the double bond can be _____ to form a single bond.

Nomenclature:

- The double bond gets _____ when naming alkenes. This means that the site of the double bond gets the _____ number possible. Aside from this, all other rules apply when naming alkenes.

SUFFIX: -----ene

ii) Nomenclature: For Branched Alkanes



1. Find the _____ continuous chain of C atoms present in the molecule. This is the _____ name of the molecule.
2. If 2 different chains of *equal lengths* are present, choose the one with the _____ number of branch points as the parent.
3. Beginning at the end nearer the _____ branch point, number each C in the parent chain.
4. If there is branching an *equal distance* away from both ends of the parent chain, begin numbering at the end nearer the _____ branch point.

C. Alkynes (C_nH_{2n-2}):

- There must be at least one _____ bond in the backbone chain of an alkyne.
- Even more reactive than alkenes because the triple bond can be opened to form _____ single bonds.

Nomenclature:

- The site of the triple bond gets _____. This means that the triple bond site gets the lowest possible number.
- All other rules apply when naming alkynes.

SUFFIX: -----yne

WORKSHEET: Alkanes, Alkenes, Alkynes Worksheet
Organic Worksheet #1, #2

IV. Functional Groups in Organic Compounds:

Functional Group: an _____ on an organic compound that tells us which _____ a particular compound belongs to.
All organic compounds that belong in one family behave _____ similar.

There are _____ different functional groups:

- 1) _____
- 2) _____
- 3) _____
- 4) _____
- 5) _____
- 6) _____
- 7) _____ Amine _____
- 8) _____ Amide _____ (HL)
- 9) _____ Nitrile _____ (HL)

1) Alcohols:

Functional Group:

R-OH

Hydroxyl Group

Nomenclature: (a) Numbering of the _____ group takes _____ - It gets the _____ possible number.

(b) **Suffix:** _____

Primary (1^o), Secondary (2^o) and Tertiary (3^o) Compounds:

- To determine the order of the compound, look at the C that contains the _____ group:

Primary (1^o): has one _____ group, aside from the functional group.

Secondary (2^o): has _____ substituted groups, aside from the functional group.

Tertiary (3^o): has _____ substituted groups, aside from the functional group.

2) Aldehyde:

Functional Group:



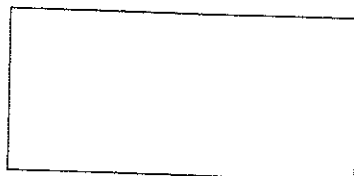
Carbonyl Group

Nomenclature: (a) Functional group gets _____ priority.

(b) **Suffix:** _____

3) Ketone:

Functional Group:



Nomenclature: (a) Site of _____ gets first priority.

(b) **Suffix:** _____

4) Carboxylic Acid:

Functional Group:

Carboxylate Group

Nomenclature: (a) Functional group gets _____ priority.

(b) **Suffix:** _____



5) Halogenoalkanes (Alkyl Halides):

Functional Group:

Halide Group

Nomenclature:

6) Ester:

Functional Group:

Nomenclature:

7) Amine:

Functional Group:

Nomenclature:

8) Amide: (HL)

Functional Group:

Nomenclature:

9) Nitrile (Cyanides): (HL)

Functional Group:

Nomenclature:

Trends in Physical Properties of Functional Groups:

- Melting/Boiling Point:** m.p or b.p. _____ as the number of C bonds increase. This is due to increasing _____ forces and a greater _____ in which that V.d.W. force is exerted.
 The increasing trend in m.p. or b.p. is not _____ however – As more and more CH groups are added, the change in V.d.W. forces become less and less significant.
- Volatility:** how easily a substance _____. There is an _____ relationship between volatility and _____.
 _____ organic compounds have _____ volatility than their _____ chain counterpart of similar composition. This is due to chained structures having a smaller _____ and thus less intermolecular attractive points.
- Solubility:** The degree of _____ attraction dictates the solubility and volatility of a substance.

Functional Group	Type of Intermolecular Force	Relative Boiling Point	Solubility in Water	Volatility
Alkanes	<i>Van der Waals</i>	Very low	<i>no</i>	<i>Highest</i>
Halogenoalkanes	<i>Weak dipole-dipole</i>	Low	<i>no</i>	<i>Moderate</i>
Aldehydes	<i>Dipole-dipole</i>	Moderate	<i>yes</i>	
Ketones	<i>Dipole-dipole</i>	Moderate	<i>yes</i>	
Alcohols	<i>H-bonding</i>	High	<i>yes</i>	
Carboxylic acids	<i>H-bonding</i>	High	<i>yes</i>	

Example: ethane vs. hexane vs. octane

Example:

Ethanal

vs.

Ethanol

vs.

Ethanoic acid

V. Cyclic Organic Compounds:

- Carbon has the special ability to form extremely _____ ring (cyclic) structures that are either _____ or _____ bonded.

_____	_____	_____
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Nomenclature for Cyclic Compounds:

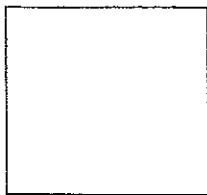
- For substituted cyclic structures, number in a way so that the _____ # results for the substituents. Any functional groups will get _____.

Example:

- If two or more different substituents are present, number the substituents _____.

Example:

Cyclohexane – A Special Cyclic Molecule

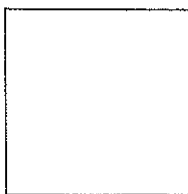


The _____ strain for a six-membered ring structure such as cyclohexane does not allow the molecule to lie in a _____ plane, but rather exist in two formations: (a) *Boat Formation*
(b) *Chair Formation*

(a) *Boat Formation:*

(b) *Chair Formation:*

Benzene (Arene):



- The most ubiquitous cyclic molecule.
- Extremely stable, but also able to bond with _____ to form extremely complex structures.
- Compounds that contain benzene in its molecular structure are often referred to as the _____ functional group.

The _____ exhibit _____ :

Nomenclature of Benzenes:

WORKSHEET: Cyclics Worksheet

VI. Isomerism:

Isomers: two or more molecules that share the same chemical _____, but differ in the way the atoms are bonded, or differ in the way they are _____ arranged.

There are two types of isomers:

a) **Constitutional (Structural) Isomers:** where two molecules share the same chemical _____, but the placement of the atoms differ.

b) **Stereo-Isomers:** two or molecules that share the same physical placement of atoms, but differ in their _____ geometry.

A. Constitutional Isomers:

- Same formulas, but differing placement of the atoms. The isomers must belong to the same _____.
- If the isomers do not belong to the same family, these types of constitutional isomers are called **Functional Constitutional Isomers**.

Example: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$

B. Stereo-Isomers - CIS/TRANS Isomers:

- Exists for _____ bonded and _____ molecules.
- The double bond _____ the rotation of the bonds in space.

Example: cis-2-butene
(Z)

vs.

trans-2-butene
(E)

cis-1,2-dichlorocyclohexane

vs.

trans-1,2-dichlorohexane

NOTE: Some stereo-isomers exhibit different chemical properties due to the placement of their atoms. This placement may cause for repulsive or attractive forces within the molecule.

Example: 2 buten1,4-dioic acid

LAB: Making Isomers Lab

WORKSHEET: Isomerism Worksheet (SL)

VII. Reactions of Organic Compounds:

- Reactions all involve the _____ of bonds, and _____ of e^- .

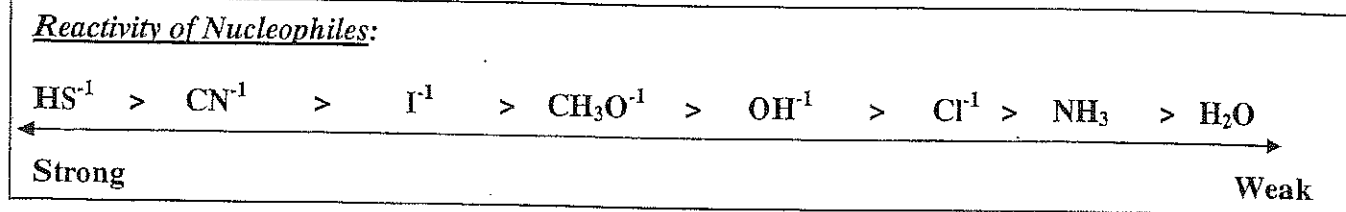
Reaction Mechanism: shows the _____ of _____ movement, from one substance to another.

- In a reaction, a substance (whether _____ or _____), can act as one of the following: a *nucleophile* or an *electrophile*.

(a) **Nucleophile:** a species that "loves" a _____, or e^- deficient partner.

The nucleophile itself is _____, which can then attract an electron-poor partner.

Nucleophiles are e pair _____.
Nucleophiles are often _____.



(b) **Electrophile:** a species that "loves" an _____ partner.
The electrophile itself is _____, which can then attract the e⁻ rich partner.
Electrophiles _____ e⁻ pairs.
Electrophiles are often _____.

Example:

A. Substitution Reactions:

- Radical Substitution Reactions:

Radical (free radical): a species that contains an _____ # of valence e⁻ - In other words, the valence _____ contains one sub-orbital with only _____ e⁻.
Radical substitution rxns. require _____ radiation as E_a.

Mechanism:

Initiation:

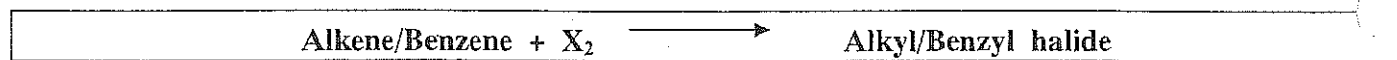
Propagation:

Termination:

Overall:

Example:

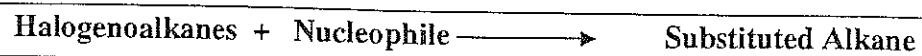
• Substitution of Alkenes/Benzenes:



B. Occurs via _____ formations.

Example: propene + bromine gas \longrightarrow bromopropane

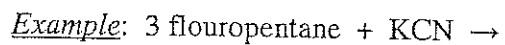
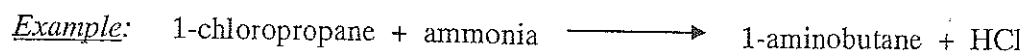
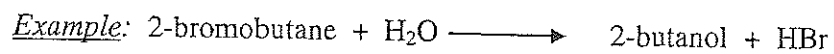
3) Substitution of Halogenoalkanes:



- ***S_N2 Reaction Mechanism:***

Occurs for _____ and _____ alkyl halides.

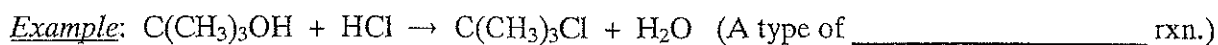
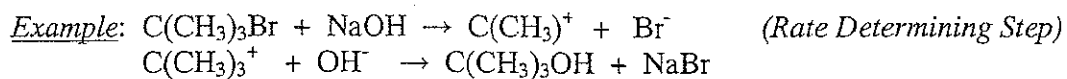
The product is an _____ of the original reactant – Can result in a _____.



Reactivity of Alkyl Halides:

• *S_N1 Reaction Mechanism:*

Occurs for _____ alkyl halides, _____ halides, and _____ halides.
_____ is often used as a solvent instead of water because of ethanol's weak polarity.

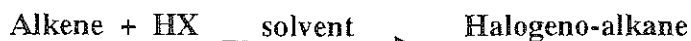


LABS: * Hydrolysis of Halogenoalkane
• Iodination of Propanone

WORKSHEET: Substitution Reaction Worksheet
Reaction Mechanism Worksheet

B. Addition Reactions:

- Addition reactions all involve _____ - Alkenes behave as _____ due to its _____ bond, giving an e⁻ rich area.
- Addition reactions are also known as _____ *Addition Reactions.*
 - Addition of HX (Hydro-halogenation):



Example: 1,1 dimethylethene + HBr \rightarrow

Markovnikov's Rule: The _____ from HX bonds to the _____ hindered alkyl site.

- Addition of H₂O (Hydration):

Example: cis-2-butene + H₂O $\xrightarrow{\text{H}_2\text{SO}_4 \text{ (cat)}}$

NOTE: Hydration reactions follow _____ Rule as well.

- Addition of X₂ (Halogenation):

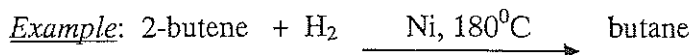
Example: 1 methylcyclopentene + Cl₂ \rightarrow

A Test for Saturation/Unsaturation:

You can determine whether a substance is an alkane or alkene by performing a Halogenation reaction using bromine solution:

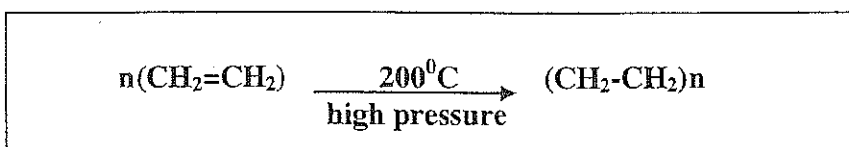
Example: ethene + Br₂ (aq) \rightarrow 2-bromoethane
Yellow colourless

- Addition of H₂ (Hydrogenation):



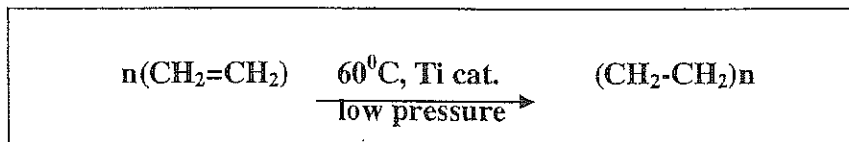
- Polymerization Addition:

a) Low Density Polyethene (LDPE):



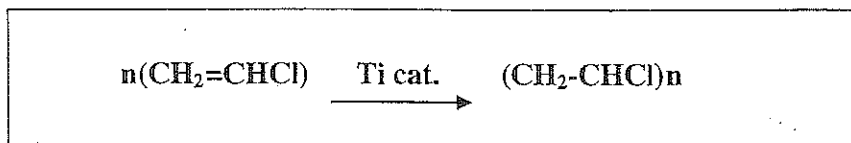
- This type of compound can have anywhere from 2000-20 000 ethene chains joined together.
- There are very chaotic and _____ branching that can occur – This does not allow for the _____ forces to be in one uniform direction, but rather be dispersed. This lowers the _____ of the material and also lowers its _____. Found in everyday plastic bags.

b) High Density Polyethene (HDPE):



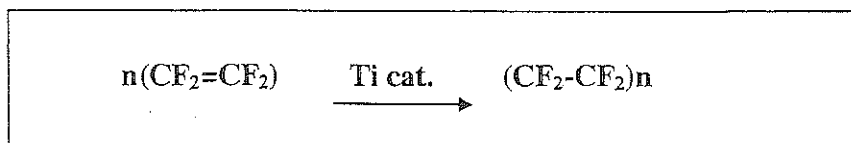
- Minimal branching – This allows for Van der Waals forces to lie in a flat and uniform plane. Thus better _____, resulting in a stronger substance and higher melting point.
- This type of plastic is used for milk jugs or other containers that require stronger plastics that are rigid.

c) Polychloroethene (Polyvinylchloride) – PVC:



Due to the strong _____ created by the chlorines in the structure – PVC are quite _____ plastics.

d) Polytetrafluoroethene (PTFE)



- The extreme _____ of the fluorine groups makes the substance have an incredibly high _____ point. This is why it is a favourite material in _____.
- It also has a very _____ or non-stick property which makes it a favourite "top coat" for stain _____ materials such as carpets or clothing.
- Manufactured under the name *Teflon*®.

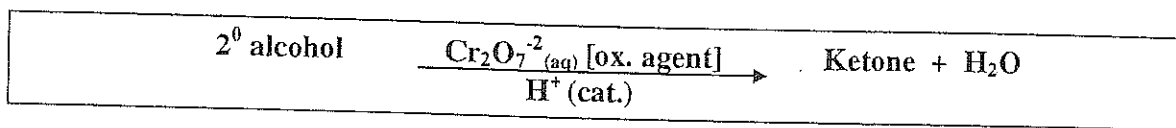
NOTE: Recently, PTFE has been found to be linked to increased probability of _____, _____ cancers. Its compounds have also been found far and wide in places such as _____!

WORKSHEETS: * Nucleophilic Addition Questions
 • Electrophilic Addition Questions
 • Addition Reaction Worksheet

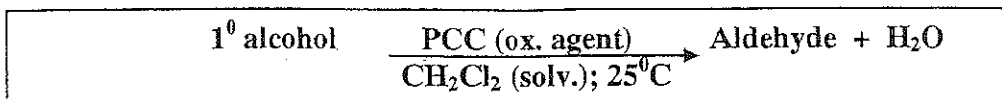
C. Oxidation Reactions:

- Oxidation reaction has occurred when the number of C-H bonds has _____ - The product is less _____ than the reactant. (Usually, the number of C-O, C-N or C-X bonds have increased).

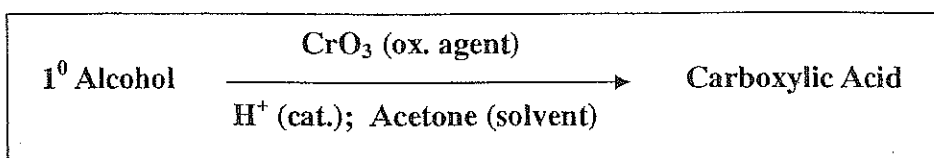
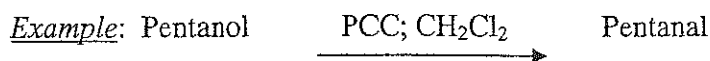
1) Oxidation of Alcohols:



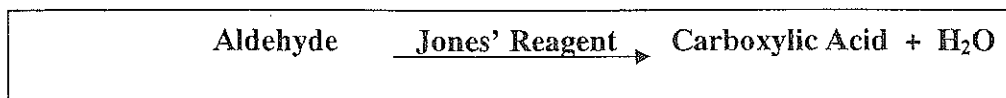
Example: 2-propanol $\xrightarrow{\text{Cr}_2\text{O}_7^{2-} (\text{aq}) / \text{H}^+ (\text{aq})}$ 2-propanone



PCC = pyridinium chlorochromate ($\text{C}_5\text{H}_6\text{NCrO}_3\text{Cl}$)

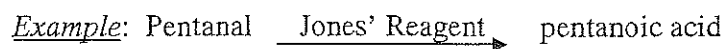


Jones' Reagent = CrO_3 (ox. agent) + H^+ (cat.) + acetone (solvent)



.... OR

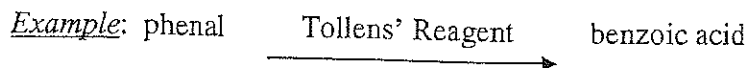
hot HNO_3 (cat.)
 KMnO_4 (ox. agent)



CONCERN! Oxidation of aldehydes tend to take place in strongly acidic media, which can result in unwanted side reactions.

For reactions that have reactive sites such as double bonds and or functional groups that need to be left intact, the milder **Tollens' Reagent** needs to be used.

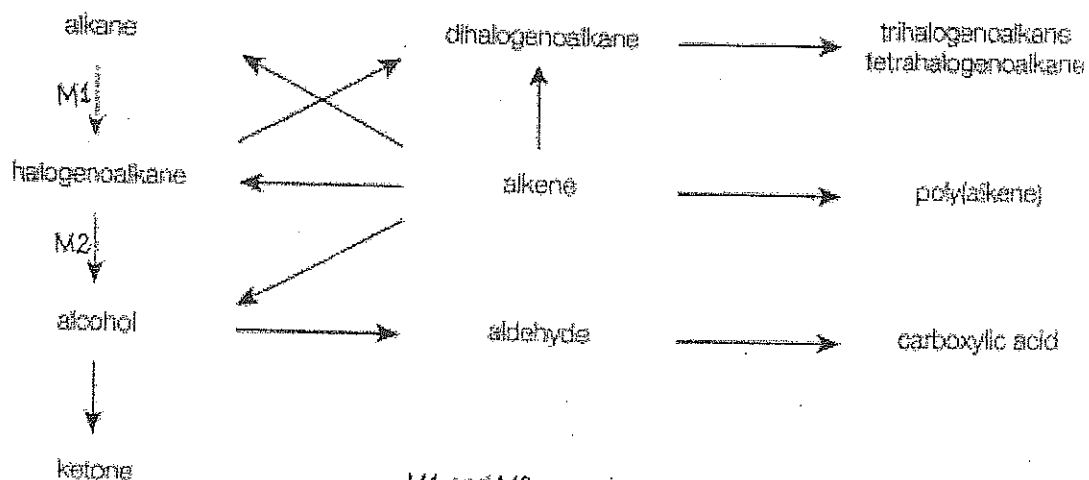
Tollens' Reagent = Ag_2O (ox. agent) + NH_4OH , H_2O (solvent) + Ethanol



NOTE: _____ rxns. are the opposite of oxidation reactions. Reduction rxns. produces more saturated products.

Reaction Pathways for Organic Chemistry SL:

- **Reaction Pathway:** a series of reactions that uses the _____ made from the preceding reaction to react _____ to form new products.



M1 and M2: you should know the mechanisms for these reactions for the IB exam

WORKSHEETS: * Oxidation of Alcohols Worksheet

- Elimination and Addition Elimination Worksheet
- Questions on Reaction Pathways

VIII. Optical Isomerism: (AHL)

Enantiomer: a molecule that is _____ to its mirror image.

A molecule that can have enantiomers **usually** has a _____ site that contains _____ groups attached - This C is called the **stereogenic center**.

Enantiomers have the same _____ properties (eg. Melting point, boiling pt., density), but their _____ properties are different.

A molecule that can form enantiomers is called a _____ molecule.

A molecule that can _____ form enantiomers is called an _____ molecule.

Examples:

a) Achiral Molecules:

Propanoic Acid

Methylcyclohexane

NOTE: Only C that are bonded to _____ groups can be considered as stereogenic centers.

b) Chiral Molecules:

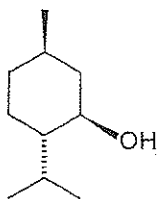
Lactic Acid (CH₃CHOHCOOH)

5-bromodecane

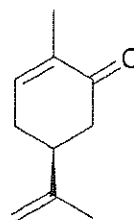
2-methylcyclohexanone

2-butanol

Exercise: Determine the stereogenic center(s) for the following molecules:



Spearmint oil/flavor



carvone (grapefruit oil/flavor)

Sequencing Configuration – Naming Chiral Molecules

- 1) Look at the 4 _____ of a _____ attached to the _____ C. Assign priorities according to _____. The atom **directly bonded** to the stereogenic carbon with the greatest atomic number gets _____ priority.
- 2) If a decision cannot be made by looking at the first atom, move on the _____ or _____ atom, until a decision can be made.
- 3) Place the lowest priority group as the vertical group. Point your thumb upwards, in the direction of this lowest priority group:
 - (i) If you use your **right** thumb pointing upwards, and your fingers curl in the direction of movement, the form is **R**.
 - (ii) If you use your **left** thumb pointing upwards and your fingers curl in the direction of movement, the form is **S**.

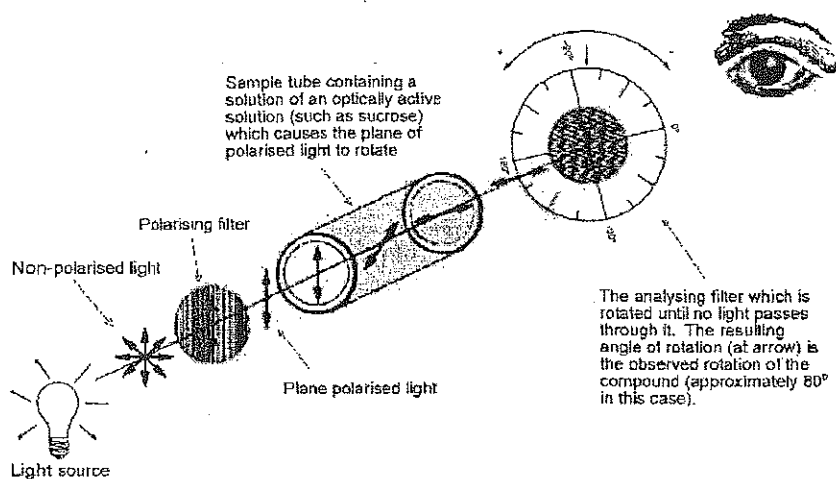
Example: R- lactic acid

S-lactic acid

Optical Activity: Naming Chiral Molecules

• _____ molecules may exhibit _____.

• **Optical Activity:** the ability for a molecular sample to _____ waves of _____.



Levorotatory: where the sample (l)/(+) _____ the polarized light _____.

Molecule's name is designated as _____ form.

Dextrorotatory: where the sample (d)/(-) _____ the polarized light _____.

Molecule's name is designated as _____ form.

Racemic Mixtures: when a solution of any _____ compound is made, usually, _____ (d) and (l) forms are made. The two forms' optical activities _____ out and we end up with a _____ mixture in solution.

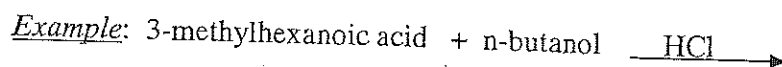
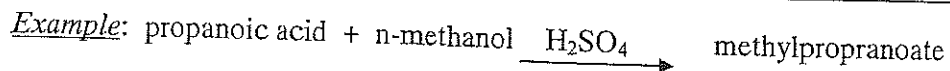
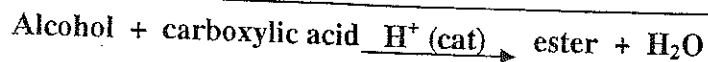
A Case Study: Thalidomide – The Silent Killer

The late 1950's saw the rise of a promising drug that alleviates the terrible morning sickness of pregnant women. Thalidomide grew in popularity so rapidly that it was the drug of choice for pregnant women in most of the developed world. But as the years rolled on, there were increasing cases of babies born with deformities and physical and developmental issues. It was discovered by the mid 1960's that thalidomide was a _____ of two forms of the molecule. One form was helpful in alleviating sickness, while the other form caused the fetal mutations. Today, thalidomide is banned as a prenatal drug but is still used in some developing countries as an aide against _____ and certain types of cancer.

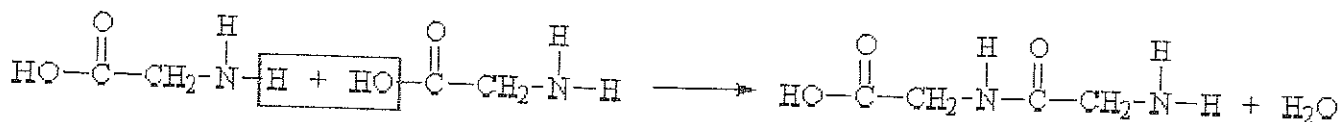
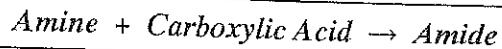
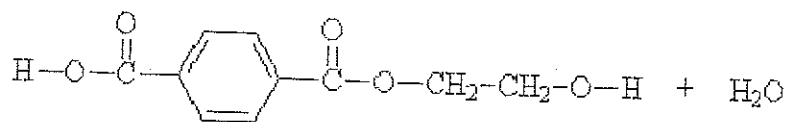
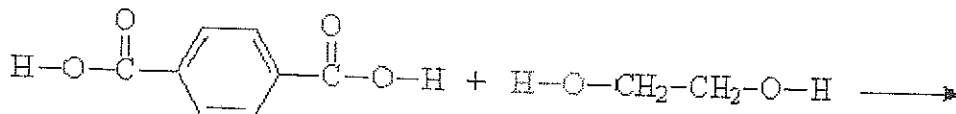
WORKSHEET: * Bonding in Organic Compounds
• Isomerism Worksheet (HL)

1) Condensation Reactions:

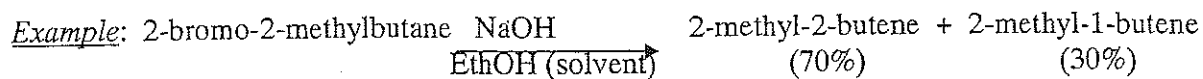
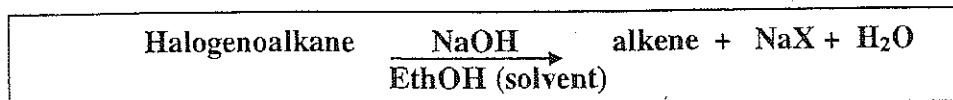
a) *Esterification:*



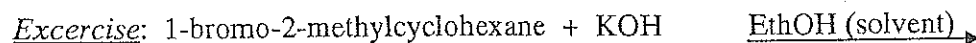
b) *Condensation Polymerization:*



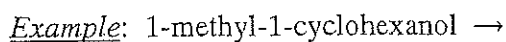
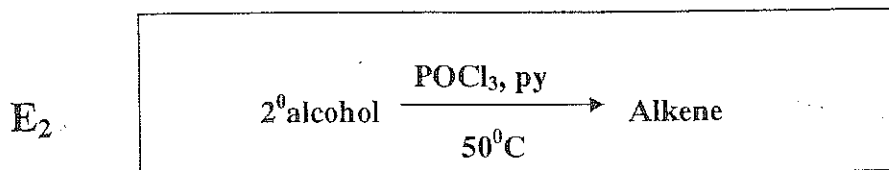
2) Elimination Reaction:



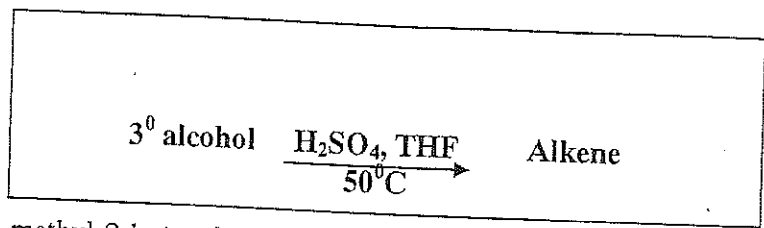
NOTE: The products follow **Zaitzev's Rule** where the more _____ alkene product is formed in _____ quantity.
The more stable form is always the compound where the _____ is " _____ " or _____ from further rxn. by the surrounding groups.



Dehydration of Alcohol:

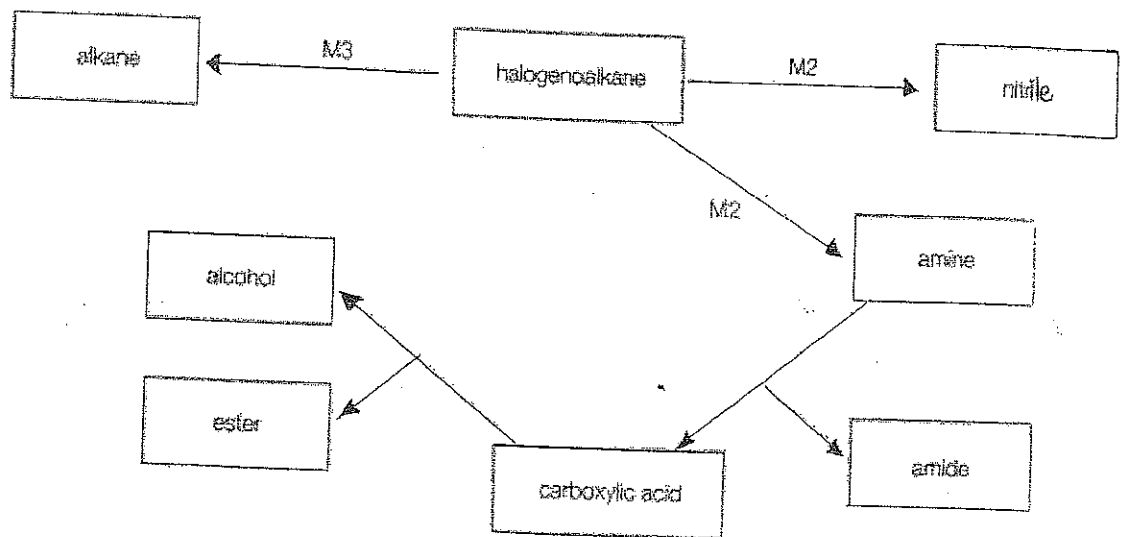


E₁



Example: 2-methyl-2-butanol →

Reaction Pathways for Chemistry IB HL:



M2 & M3: you should know these mechanisms for IB

