Organic Chemistry

Saturday, December 5, 2020 10:48 AM

Terminologies:

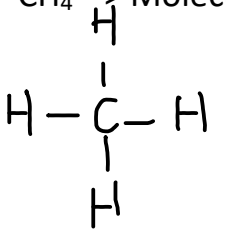
1) Organic compounds are compounds that are naturally occurring in living things
2) Hydrocarbons are compounds that are made up of hydrogen and carbon **only**
3) Homologous series are a family of similar compounds with **similar chemical properties** due to the existence of an identical functional group and shows a **trend in physical properties**
4) Functional group are specific molecules in a compound which is responsible for its unique characteristics

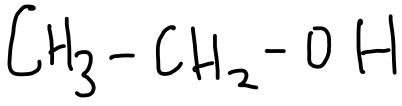
Naming system

# of Carbon	Prefix
1	**Meth**
2	**Eth**
3	**Prop**
4	**But**
5	**Pent**
6	**Hex**
7	**Hept**
8	**Oct**
9	**Non**
10	**Dec**

Types of formula:

CH_4 --> Molecular formula

 --> Displayed formula

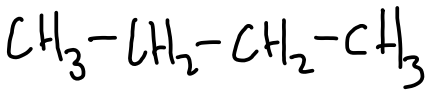
 --> Structural Formula

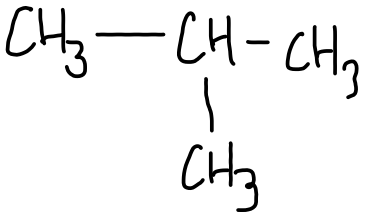
 --> Skeletal formula

Isomerism:
Isomers are molecules that exhibit the same molecular but possess different structural formula.

Eg:

C_4H_{10}



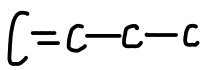


Homologous series {Part 1}:
In the same homologous series, subsequent molecules differ by CH_2

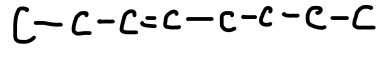
Alkane:
General formula --> C_nH_{2n+2}
Suffix - ane
Simplest alkane --> Methane (CH_4)
Functional group --> None
Properties --> Alkanes are made up of single bonds only -- Saturated

Alkene:
General formula --> C_nH_{2n}
Suffix - ene
Simplest alkane --> ethene (C_2H_4)
Functional group --> None (Special double bond in one pair of carbon atoms) (unsaturated)

Naming
(Here, I am neglecting the H to make it more tidy. However, do not implement this in your own notes and especially your exam)



but-1-ene



oct-3-ene

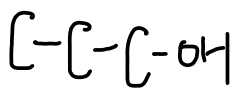
As shown in both examples, the number in the middle represents where the double bond is formed. However, do take note that you should always start counting from the side closest to the double bond.

Alcohol:
General formula --> $C_nH_{2n+1}OH$
Suffix - ol
Simplest alkane --> Methanol (CH_3OH)
Functional group --> -OH (hydroxyl)

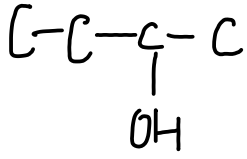
Naming system is similar to that of alkene. The number in the middle will represent where the functional group is found and we should always count from the C closest to the OH.

Types of alcohol(additional):
1) Primary
2) Secondary
3) Tertiary

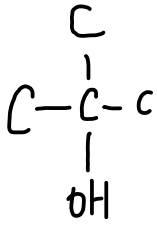
Primary



Secondary



Tertiary



If you noticed, the classification of alcohol is highly dependent on the C-OH bond. In primary, the C in the C-OH bond is only bonded to another C. In secondary, it is bonded with 2. In tertiary, the C in the C-OH bond is bonded with 3 other C.

Oxidation of Alcohol(additional)

*Primary Alcohol
Primary alcohol --> Aldehyde --> Carboxylic acid

*Secondary Alcohol
Secondary alcohol --> Ketone

*Tertiary Alcohol
Cannot be further oxidized

Oxidizing agent is either hot acidified $KMnO_4$ or hot acidified $K_2Cr_2O_7$.

Reactions involving Alkanes, Alkenes and Alcohols:

Alkanes:

1) Combustion (Alkane + Oxygen --> Carbon dioxide + water)
   (Alkane + limited Oxygen --> Carbon monoxide + water + soot)
   Note -- C_1 - C_4 = Gas
   C_5 - C_{17} = Liquid
   $C_{>18}$ = Solid
2) Substitution
   a) Halogenation = Alkane + Halogen --> Halogenoalkane + Hydrogen/Hydrogen Halide

$$CH_4 + Cl_2 \xrightarrow{UV} CH_3Cl + HCl$$

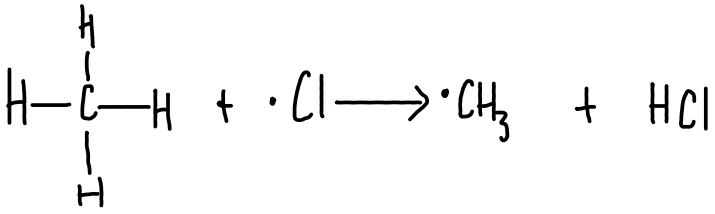
$$CH_4 + Cl_2 \xrightarrow{UV} CH_2Cl_2 + H_2$$

→ Initiation

$Cl{-}Cl \longrightarrow 2\cdot Cl$ radicals eager to react Majority

$CH_4 \longrightarrow \cdot CH_3 + \cdot H$ Minority

→ Propagation



→ Termination

$\cdot CH_3 + \cdot Cl \rightarrow CH_3Cl$ (main)

$\cdot CH_3 + \cdot CH_3 \rightarrow C_2H_6$ (minor)

b) Hydrohalogenation = Alkane + Hydrogen halide --> Halogenoalkane + Hydrogen

→ Initiation

$HCl \xrightarrow{UV} H\cdot + \cdot Cl$

→ Propagation

$CH_4 + \cdot Cl \rightarrow \cdot CH_3 + HCl$

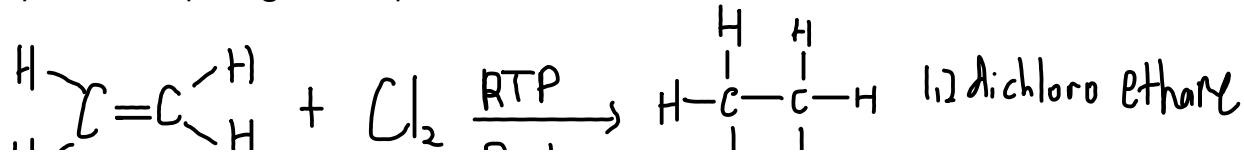
→ Termination

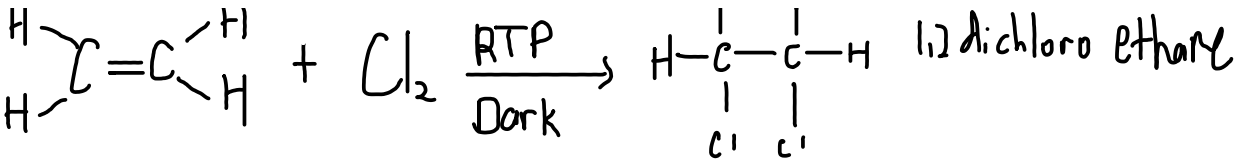
$\cdot CH_3 + \cdot Cl \rightarrow CH_3Cl$

$\cdot H + \cdot H \rightarrow H_2$

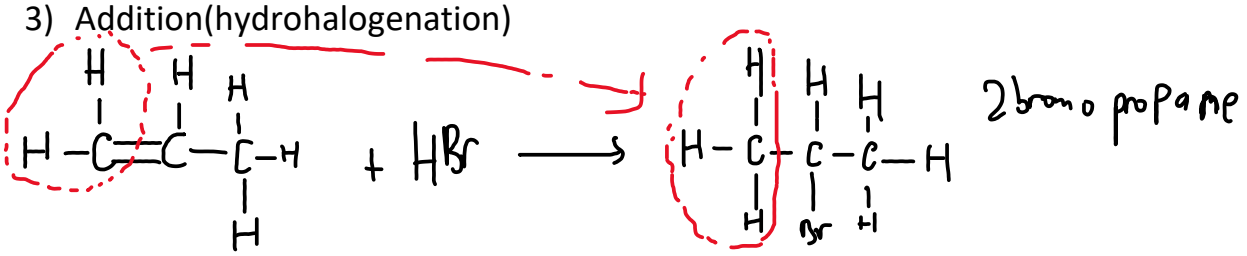
Alkenes:

1) Combustion (Alkane + Oxygen --> Carbon dioxide + water)
   (Alkane + limited Oxygen --> Carbon monoxide + water + soot)
2) Addition(Halogenation)



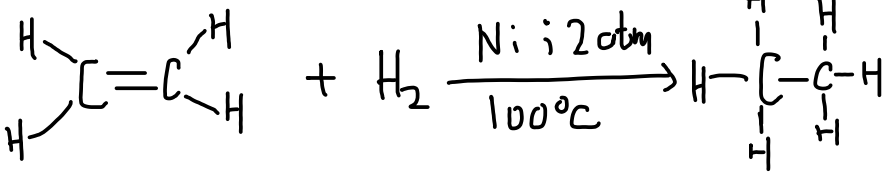


3) Addition(hydrohalogenation)

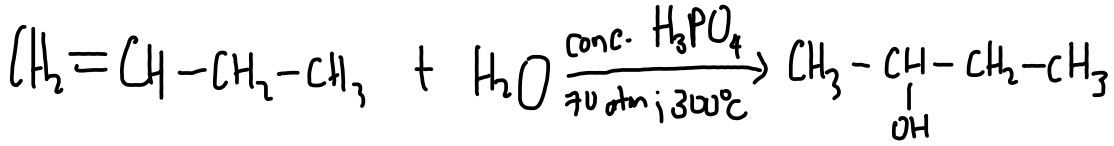


"Markovnikov rule" → The 'C' with more H receives the H

4) Hydrogenation(addition of H_2)



5) Hydration(addition of H_2O --> steam)

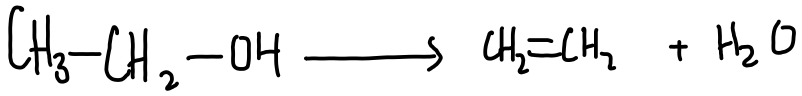


"Markovnikov rule" → The 'C' with more H receives the H

6) Polymerization(discussed at the end of the chapter)

Alcohol:

1) Dehydration(opposite of hydration)



Conc. H_2SO_4/H_3PO_4 (180°C)

Al_2O_3 (300°C)

Broken porous dry pot (300°C)

2) Fermentation

$C_6H_{12}O_6 \xrightarrow[37°C]{Yeast} 2C_2H_5OH + 2CO_2$

If % of C_2H_5OH exceeds 14, yeast will stop multiplying

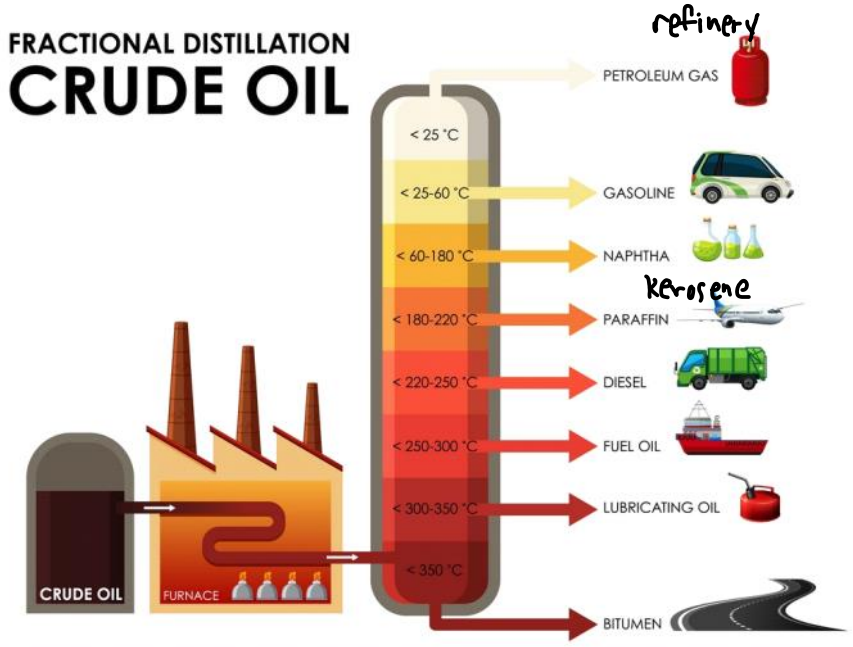
Process	Pros	Cons
Hydration of ethene	Fast and pure	Expensive, dangerous and non renewable
Fermentation	Cheap, safe and uses renewable raw materials	Slow, not pure, produces greenhouse gasses

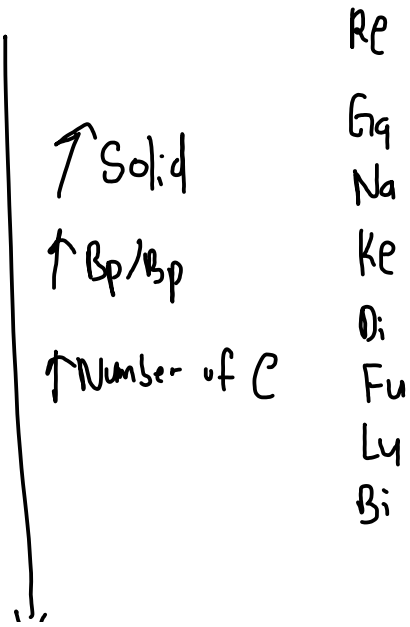
3 types of Fossil Fuels:

1) Coal
2) Petroleum
3) Natural gas(mainly made up of methane)

Coal produces more carbon dioxide emissions per kJ of energy produced compared to the other 2.

Petroleum consists of a mixture of hydrocarbons that can be separated into fractions through fractional distillation. It is separated as each fraction has its own unique uses.





Catalytic cracking:
It is the breaking down of long-chained alkanes to form shorter-chained alkanes and alkene(s) by the presence of a catalyst(zeolite, silica or alumina) and a temperature of 600 degrees Celsius.

$C_8H_{18} \longrightarrow C_2H_{26} + C_6H_{12}$

Note --> If short chained alkanes are cracked, hydrogen will be formed.

$C_5H_{12} \longrightarrow C_5H_{10} + H_2$

* Thermal Cracking
(450 - 800°C)
(70 atm↑)

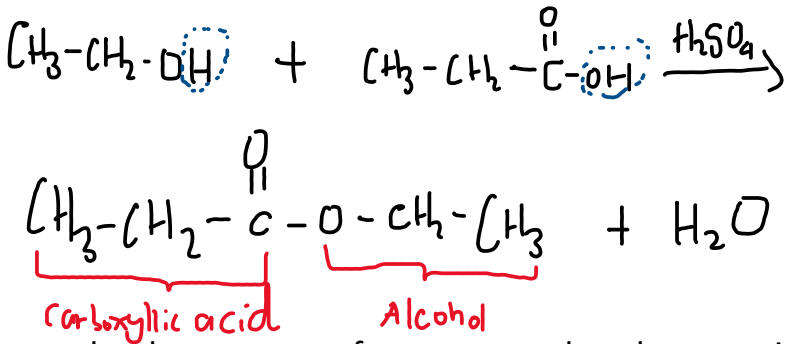
Homologous series(Part 2):

Carboxylic acid:
General formula --> $C_nH_{2n}O_2$
Suffix - oic acid
Simplest alkane --> Methanoate
Functional group --> $-\overset{O}{\overset{\|}{C}}-O-H$ (carboxyl)

Esters:
General formula --> $C_nH_{2n}O_2$
Suffix -yl ___ -oate
Simplest alkane --> Methanoate
Functional group --> $-\overset{O}{\overset{\|}{C}}-O-H$ (carboxyl)

Reactions involving carboxylic acids and esters:
1) Esterification -- Alcohol + Carboxylic acid --> Ester + Water

$CH_3-CH_2-OH + CH_3-CH_2-\overset{O}{\overset{\|}{C}}-OH \xrightarrow{H_2SO_4}$

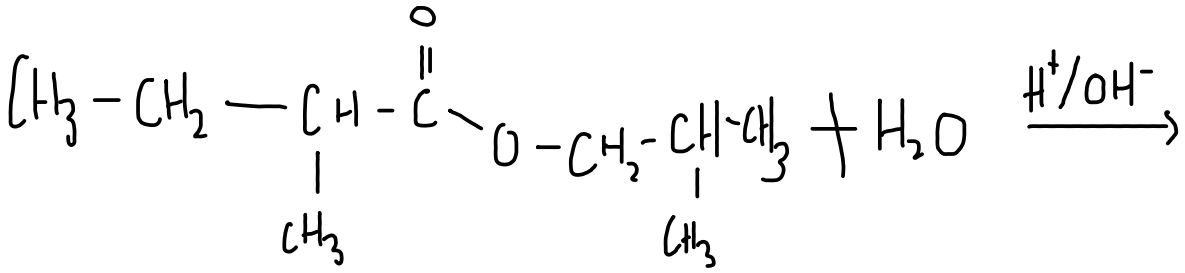


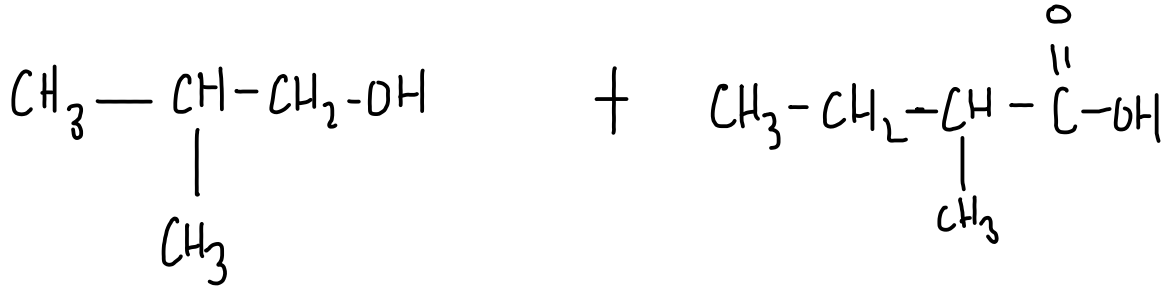
To remember how an ester forms, remember the opposite. If you notice, the alcohol sacrifices H whereas the carboxylic acid sacrifices OH. This is weird because acids are proton donors. That is why remember the opposite. The H and OH sacrificed bonds together to form H_2O.

When naming esters, always name the alcohol part first before the acid. If we see from the ester above, the part with the alcohol has 2 C and with the acid, it has 3 C. Therefore, its name is ethyl propanoate.

2) Hydrolysis of ester -- Ester + Water --> Alcohol + Carboxylic acid

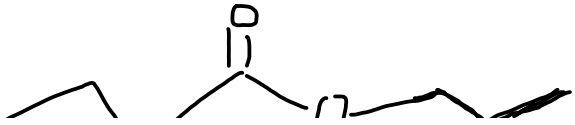
- (Try naming the ester before proceeding)

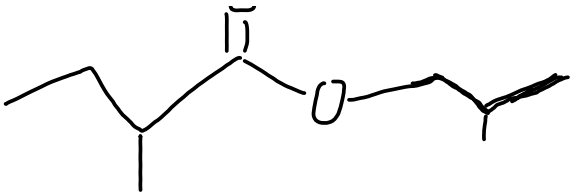




↳ ester → 2-methyl propyl 2-methyl butanoate

↳ skeletal formula





Extra information before proceeding to polymerization:

1) To differentiate saturated from unsaturated hydrocarbons, bromine solution should be utilized. If the hydrocarbon is unsaturated, it will decolorize the bromine solution. Else, there is no change
2) Ethanol is commonly used as a solvent for solute that cannot be dissolved in water. It is also commonly used as a fuel
3) Alcohol, esters and alcohols all have higher boiling point relative to alkanes and alkenes.
4) Realize that all the reactions being discussed above are very closely related to each other. They involve reactants of homologous series to form other homologous series. The tricky part is just with the catalysts and conditions.
5) All carboxylic acids are weak acids. This indicates that they partially ionize in water which accounts for a higher pH in the pH scale relative to strong acids like HCl, H_2SO_4 and HNO_3. However, do not confuse concentration with strength. 1M of CH_3COOH can equally neutralize NaOH just as 1M of HCl can.

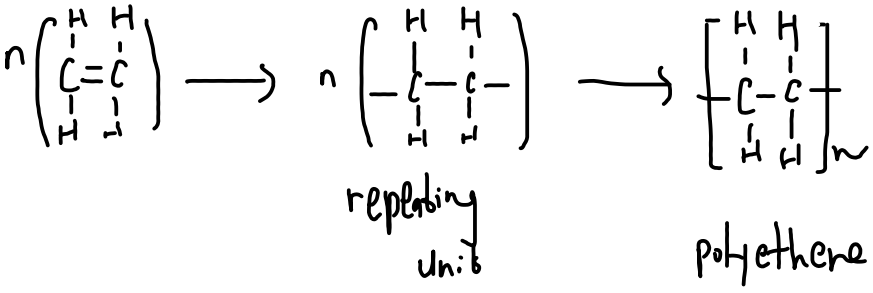
Polymerization:

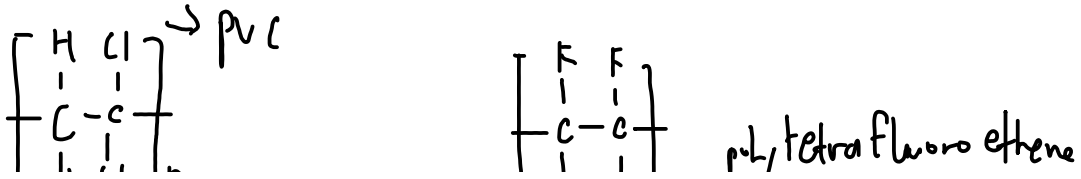
It is a reaction where polymers are produced. Polymers are macromolecules which are composed of monomers polymerized.

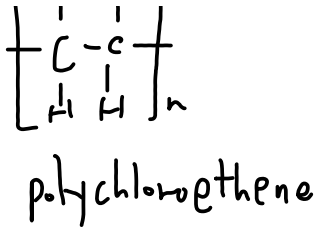
2 types of polymerization:

1) Addition -- Involves the addition of monomers, specifically alkene(only 1 type), and there are no side products.

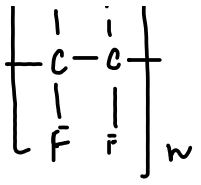
Mechanism:-







polychloroethene



poly(tetrafluoro ethene

Teflon

Polymer	Usage
Polyethene	Plastic bags and gloves
Polypropene	Ropes and crates
Polyvinylchloride (PVC)	Water pipes and electrical cables
Polystyrene	Fast food cartons and packaging
Teflon	Non-stick frying pan

2) Condensation polymerization

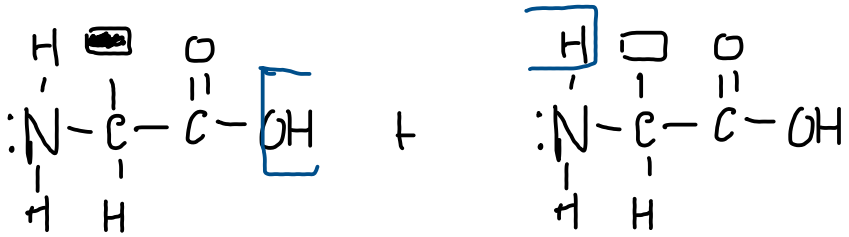
Criteria:

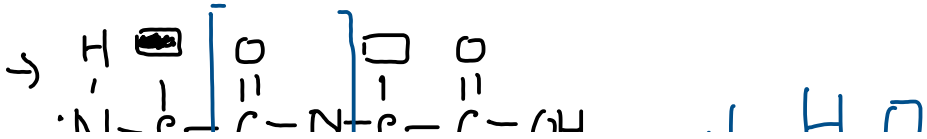
- 2 types of monomers are involve(usually but not always)
- Side products are always produced
- Linkage is present
- Monomers are not required to have the C=C bond

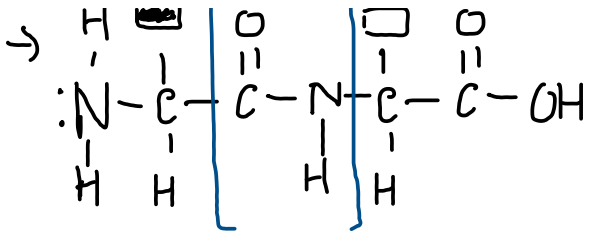
Carbohydrates --> Additional info(more to bio):

1) Monosaccharides --> glucose, fructose and galactose
2) Disaccharides --> Sucrose when hydrolyzed forms glucose and fructose
   --> Maltose when hydrolyzed forms 2 molecules of glucose
   --> Lactose when hydrolyzed forms glucose and galactose
3) Polysaccharides

Protein

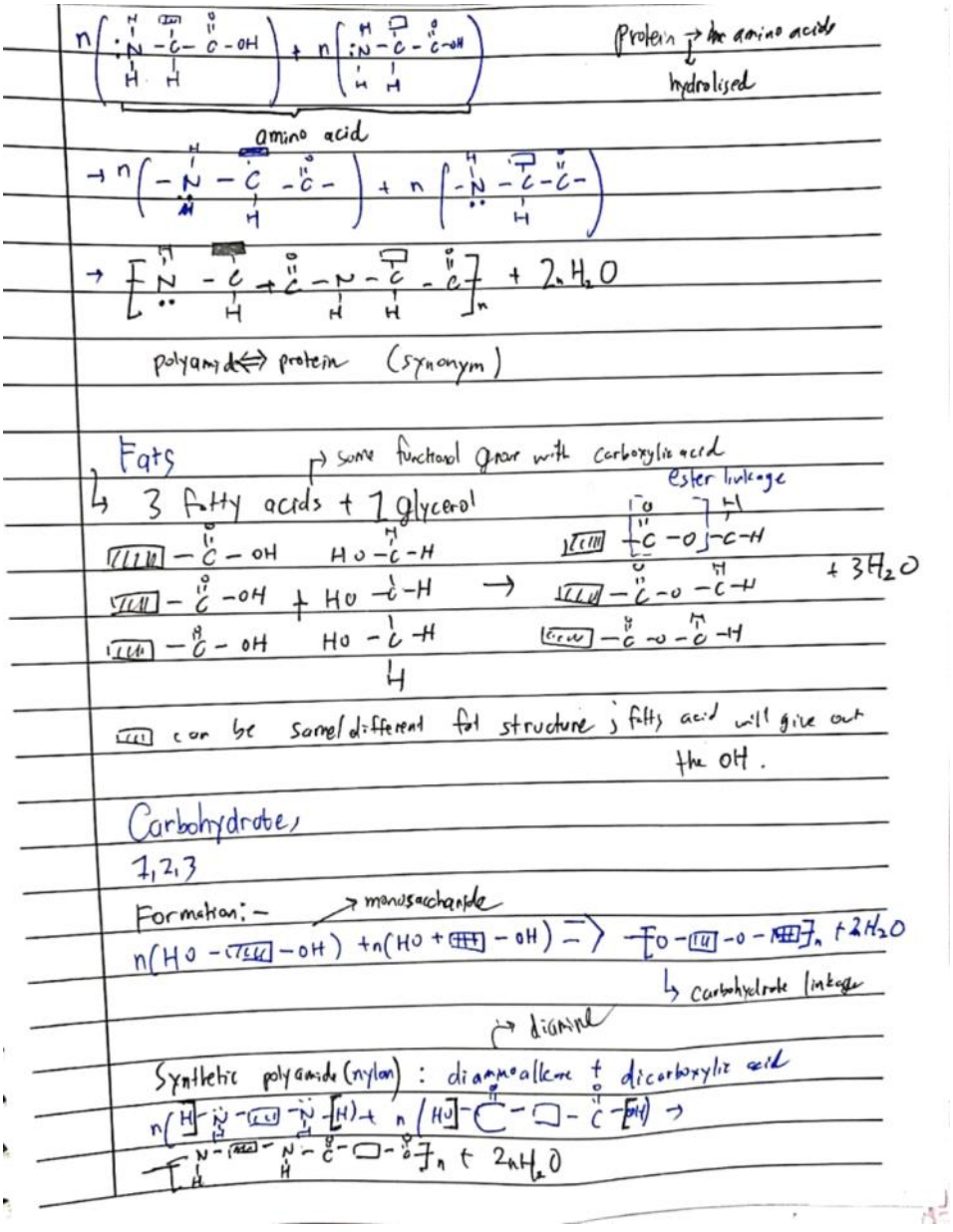




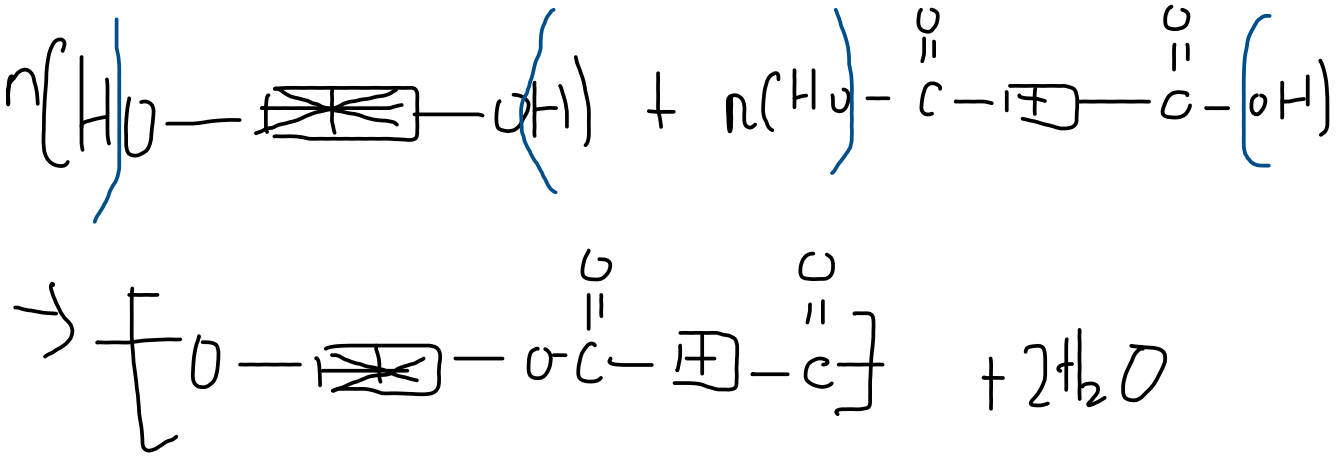


+ H_2O

Amide Linkage



Terylene → diol + dicarboxylic acid



Hydrolysis:

1) During digestions, proteins are hydrolyzed to amino acids
2) Soaps are the products of the hydrolysis of fats. Fats are reacted with hot NaOH. Soap and glycerol is formed
3) --> Sucrose when hydrolyzed forms glucose and fructose
   --> Maltose when hydrolyzed forms 2 molecules of glucose
   --> Lactose when hydrolyzed forms glucose and galactose
4) The above is hydrolyzed under heat with the presence of HCl

Hydrolysis may be incomplete and hence you get a mixture of molecules of different sizes. This mixture can be separated through chromatography. A locating agent is then used as more often than not, they are colorless.

Exam tips:

1) Although organic comprise of a whole lot of components, they are not all assessed. Organic questions usually fall at the last part of your paper 4.
2) Esterification is a must to understand as it is so often asked. Same goes to condensation polymerization
3) Usage and conditions are also commonly asked so it is best to play safe and memorize them
4) Understand the significance of functional groups to identify organic compounds
5) Remember that in a family of a specific homologous series, they exhibit similar chemical properties and a trend in physical properties
6) Fractional distillation of petroleum is also very often asked
7) Develop your own methods of memorizing polymerization. Find patterns such as the removal of either H or OH. This is also true for the reactions involving the other homologous series. They are often interconnected
8) I'm tempted to say know each content thoroughly but you will find out after several years of past papers that this is not necessary. When doing past papers, it is good practice to see which concepts tend to be prioritized. However, **do not conclude after doing only a few sets.** Be able to conclude after doing at least 8-10 yrs of papers or else the sample

size is just not enough