

# Organic Chemistry

## 1 Introduction

All living matter (organic) is made up of chains of carbon atoms, with hydrogen, oxygen and nitrogen as the primary components.

This is the study of Organic Chemistry.  
Carbon chains form the “backbone” of organic molecules.  
Carbon can form four covalent bonds, and make long chains with many atoms connected together.

Carbons in Organic Chemistry:  
Sp, sp<sup>2</sup> or sp<sup>3</sup> hybridized.  
Form long chains.

Primary atoms in Organic Chemistry are: carbon, hydrogen, oxygen and nitrogen

## 2 Hydrocarbons

Hydrocarbons are molecules with only Hydrogen and carbon.  
Hydrogen will normally only form one covalent bond.

Carbon will form four covalent bonds, but can form double and/or triple bonds between carbons.

### 2.1 Alkanes

Alkanes are carbon chains with only single bonds between the carbons. (the “ane” ending indicates single bonded carbons)

The carbons are sp<sup>3</sup> hybridized with a 109.5° angle between bonds.

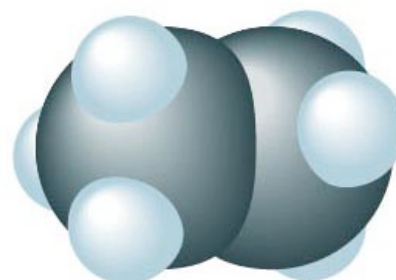
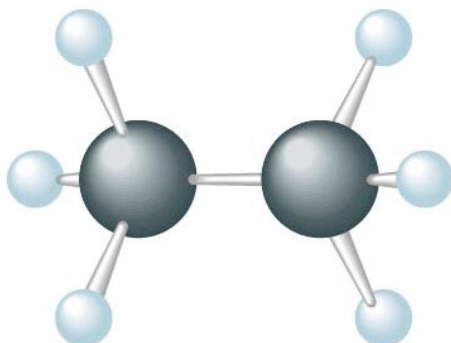
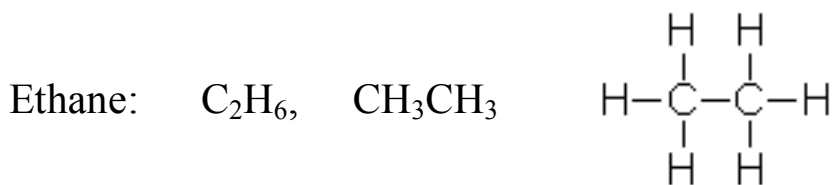
Single bonds are free to rotate, so these molecules are very flexible.

Alkanes are very stable.

The outer C–H bond is very strong: 413 kJ/mol. This is more energy than visible light has, and can only be broken by short wavelength ultraviolet light.

The inner C–C bonds are weaker, (347 kJ/mol), but are shielded by the outer C–H bonds.

Alkanes are very stable in our environment.



## 2.1 Alkanes — Nomenclature

### IUPAC Rules for Naming Alkanes

1. Name the longest continuous chain.
2. Name groups attached to this chain.
3. Number the carbon's in this chain. (so that side groups are given smallest number possible)
4. Designate each group with correct number and name.
5. Assemble name, listing groups in alphabetical order.

Structural formula	Line formula	Formula name	Condensed formula
$\begin{array}{c} H \\   \\ H-C-H \\   \\ H \end{array}$		$CH_4$ Methane	$CH_4$
$\begin{array}{c} H & H \\   &   \\ H-C & -C-H \\   &   \\ H & H \end{array}$	—	$C_2H_6$ Ethane	$CH_3CH_3$
$\begin{array}{c} H & H & H \\   &   &   \\ H-C & -C & -C-H \\   &   &   \\ H & H & H \end{array}$		$C_3H_8$ Propane	$CH_3CH_2CH_3$
$\begin{array}{c} H & H & H & H \\   &   &   &   \\ H-C & -C & -C & -C-H \\   &   &   &   \\ H & H & H & H \end{array}$		$C_4H_{10}$ Butane	$CH_3CH_2CH_2CH_3$
$\begin{array}{c} H & H & H & H & H \\   &   &   &   &   \\ H-C & -C & -C & -C & -C-H \\   &   &   &   &   \\ H & H & H & H & H \end{array}$		$C_5H_{12}$ Pentane	$CH_3CH_2CH_2CH_2CH_3$
$\begin{array}{c} H & H & H & H & H & H \\   &   &   &   &   &   \\ H-C & -C & -C & -C & -C & -C-H \\   &   &   &   &   &   \\ H & H & H & H & H & H \end{array}$		$C_6H_{14}$ Hexane	$CH_3CH_2CH_2CH_2CH_2CH_3$

A hydrocarbon side chain is named similarly: “ane” is changed to “yl”

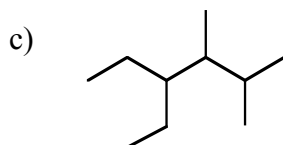
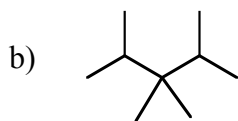
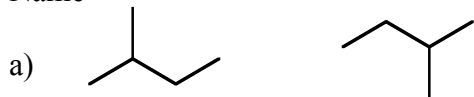
Methyl- $\text{CH}_3$

Ethyl  $-\text{CH}_2\text{CH}_3$

Propyl  $-\text{CH}_2\text{CH}_2\text{CH}_3$

Butyl  $-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$

Name



Draw the structures for the following:

a) methyl butane

b) dimethyl propane

c) 3-ethyl hexane

d) 3-ethyl-2methyl hexane

e) 3,3-dimethyl-4-methyl octane

f) 2,2,4-trimethyl pentane

## 2.1 Alkanes — Isomers

Structural Isomers are two or more molecules with the same chemical formula, but a different structural formula.

Straight chain alkanes have a formula of:  $C_nH_{2n+2}$ .

Because of their different shapes, isomers have different properties and different names.

Example:

Draw and name all the isomers of  $C_5H_{12}$ .

Alkanes can form rings of 3 or more carbons. They will have the generic formula  $C_nH_{2n}$ .

They are named with the ring as the primary structure, and groups added to the ring. (Numbering in on the carbons of the ring.)

Example:

Draw and name alkane isomers of  $C_5H_{10}$ .

## 2.1 Alkanes — Physical Properties

Alkanes are non-polar molecules. They are soluble in non-polar solvents, but not in polar solvents. Intermolecular forces are due to van der Waals attraction.

As molecules are longer, they have more contact with adjacent molecules. There are more places for van der Waals forces to attract, and a higher boiling point (greater volatility) and melting point.

Rationalize the following:

pentane	36 °C	Dimethyl propane	9.5 °C
hexane	69 °C		
heptane	98 °C		
Octane	126 °C	Tetramethyl butane	106 °C

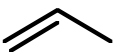
Follow up problems 15.1a, 15.2ab  
Problems 15.3, 14c, 16, 18a, 20, 22

## 2.2 Alkenes — Nomenclature

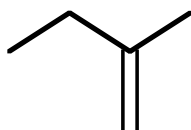
Carbon compounds with double bonds are called alkenes.

Alkenes are named similarly to alkanes. The position of the double bond on the numbered chain is indicated by the first carbon of the double bond. Chains are numbered to give the double bond the lowest number.

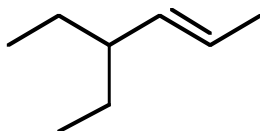
Propene



2-methyl-1-butene  
2-methyl-but-1-ene



4-ethyl-2-hexene  
4-ethyl-hex-2-ene



### Alkynes

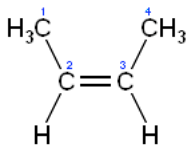
Hydrocarbons with triple bonds between carbons are called alkynes. They follow similar trends for naming and reactivity as alkenes.

They are not covered in the IB curriculum, but you may find them in some questions.

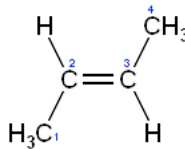
A double bond does not have the free rotation of a single bond. Main groups on the same side of the double bonds are a “cis” isomer, groups on opposite sides are a “trans” isomer.

These geometrical isomers can result in different properties.

cis



trans



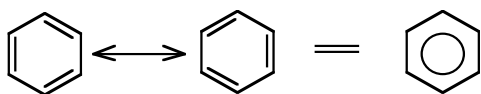
Draw and name the straight chain alkene isomers of  $C_5H_{10}$ .

Alkenes are a much more reactive hydrocarbon than alkanes. The  $\pi$  bond is on the outer part of the molecule and is easier to break (not as strong) than a  $\sigma$  bond.

## 2.3 Benzene

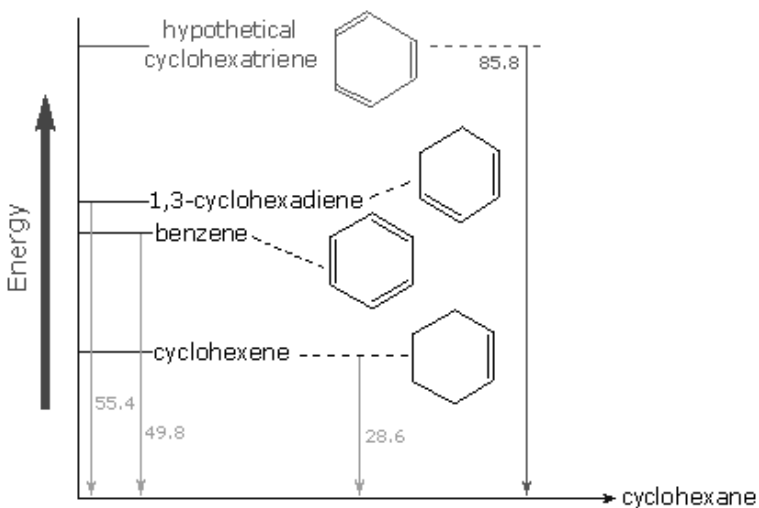
Benzene has a six carbon ring:  $C_6H_6$ . All the carbons are  $sp^2$  hybridized, and  $3\pi$  bonds are delocalized above and below the ring.

Any of the diagrams below can represent benzene.



## 2.3 Benzene

This diagram shows that the delocalization is more stable than three double and three single bonds.



Follow up Problems 15.1b, 15.2cd  
Problems 15.8, 14ab, 16, 18, 28, 30, 32, 35

### 3 Combustion of Hydrocarbons

All hydrocarbons will undergo combustion as an exothermic reaction.

Complete combustion (with excess available oxygen) produce  $\text{CO}_{2(g)}$  and  $\text{H}_2\text{O}_{(g)}$ .

Incomplete combustion (without enough available oxygen) produces many products including:  $\text{CO}_{(g)}$ , misc.  $\text{C}_x\text{H}_x$ , other  $\text{C}_x\text{H}_x\text{O}_x$  compounds, Carbon (soot and ashes), etc...

Enthalpy for complete combustion for some compounds can be found in the IB Chemistry Data Booklet.

Enthalpy can be estimated for other combustions using the enthalpy of bonds broken and formed.

Note: C=O in  $\text{CO}_2$  is an atypical C=O bond. Its bond strength is  $\sim 800$  kJ/mol.

Example:

Estimate the enthalpy of combustion for *n*-propane, *n*-octane and benzene in kJ/mol and kJ/g.

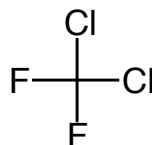
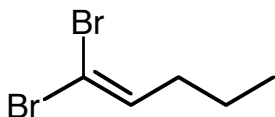
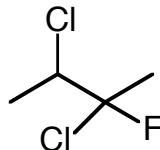
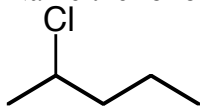


## 4.1 Halogeno-alkanes

An alkane molecule with a halogen (F, Cl, Br, I) is a halogeno-alkane.

The nomenclature of these molecules is very similar al alkanes and alkenes. The halogen is named with an “o” suffix and its place on the longest carbon chain is numbered.

Name the following



Draw the following:  
1,2-dichloro ethane

2,3,4,5-tetraiodo-1-pentene

4,5-dibromo-3-(fluoromethyl)-2-hexene

Halogeno-alkanes usually have a small dipole. Additionally, the larger halogens (Br and I) have substantial London Dispersion Forces because of their large size.

These factors will usually give halogeno-alkanes stronger intermolecular bonds than alkanes, and higher B.P. and M.P.

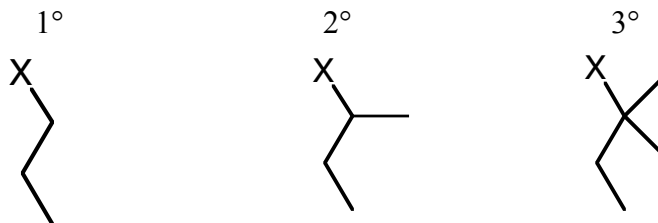
The small dipole makes them mostly insoluble in water.

Explain why the boiling point of cis and trans -1,2-dichloroethane and cis and trans-2-butene are different.

	1,2-dichloroethane (°C)	1,2-dichloroethane (°C)	2-butene (°C)	2-butene (°C)
	b.p.	m.p.	b.p.	m.p.
cis	60	-80	4	-139
trans	48	-50	1	-106

Halogeno-alkanes alkanes are characterized as primary (1°), secondary (2°) or tertiary (3°).

This designation describes the number of carbons attached to the halogenated carbon.



#### 4.2 Halogenation of alkanes

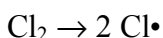
Alkanes are stable molecules. Reactions with alkanes require high initial energies to break the alkane bonds to start a reaction.

A halogen radical has a high enough energy to react with an alkane.

A radical is an atom without a full shell of electrons. It is very reactive.

A halogen radical is produced through the homolytic fission of a halogen molecule.

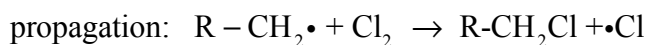
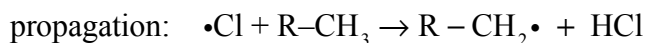
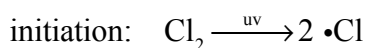
This can be accomplished via *uv* light.



What happened to the electrons?

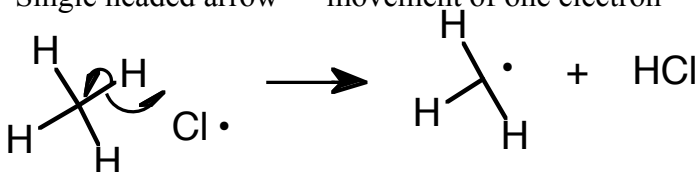
$\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$  is an example of heterolytic fission. Why?

Here is an example of a free radical mechanism.



This is a detailed diagram of step 2 of the mechanism.

Single headed arrow — movement of one electron



Note on Mechanisms.

We are required to understand two mechanisms in detail:  $\text{S}_{\text{N}}1$  and  $\text{S}_{\text{N}}2$ . [elimination of halogenoalkanes](#).

Other mechanism detail is to aid in understanding.

Mechanism detail that will be tested will be noted specifically.

A free radical process would usually not be used in an organic synthesis reaction.

The free radical is too reactive to allow any control over where the reaction occurs. There are multiple possible products.

Example 1:

Describe the possible products of the free radical bromination of butane. (mono and di brominated products only.)

## 5.1 — Alcohols

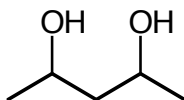
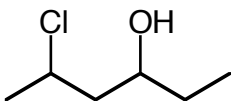
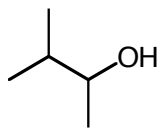
Alcohols are compounds with an —OH functional group.

Alcohols are named similarly to alkanes. The ending of the alkane is changed to “ol”

The alcohol that is consumed in alcoholic beverages is ethane alcohol or ethanol.

Example 1:

Name the following:



Example 2:  
Draw the structure for:  
2-propanol (iso-propanol)

1-bromo-3-hexanol

1,2,3-propan-tri-ol (propylene glycol)

2-methyl-2-propanol

Alcohols can be designated as primary, secondary, or tertiary, by the same criteria as halogen-alkanes. The number of carbons on the carbon with the alcohol determines this.

Example 3:  
Draw an example of a primary, secondary, and a tertiary alcohol.

Alcohols have an OH bond, which produces a hydrogen bond for inter-molecular bonding.

This will generally make the boiling points of alcohols relatively high, compared to an alkane.

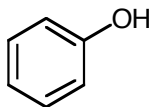
Alcohols are also generally soluble in water. They are polar and the OH of the alcohol will hydrogen bond with water molecules.

Methanol, ethanol, 1-propanol, 1-butanol, 1-pentanol are part of a homologous series, changing by a CH<sub>2</sub> group. As with most homologous series, the molecule becomes less polar, making it less soluble in water.

The molecules also becomes longer, increasing the London Dispersion Forces, and increasing the boiling point.

Acids are compounds that can donate an H<sup>+</sup> ion. Most alcohols are not acidic. The OH bond is strong enough and it does not easily break.

One notable exception is phenol:



Why would phenol be acidic if most alcohols are not?

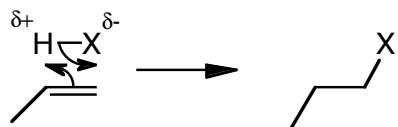
## 6 — Addition Reactions to Alkenes

Alkenes are much more reactive than alkanes. The double bond is made of a  $\sigma$  bond and a  $\pi$  bond. The  $\pi$  bond is easier to break because it is not as strong as the  $\sigma$  bond, and the electrons are physically more accessible.

These are addition reactions because the double bond is broken and replaced with the addition of two other atoms.

### 6.1 — Addition of HX

The hydro-halogen molecule is a polar molecule. The positive H end will react first with the electrons in the  $\pi$  bond.



The “H” and the “X” have been added to the propene molecule.

The halogen could be added to either carbon atom in the double bond.

Example 1:

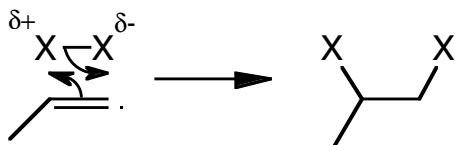
Write the possible products of the addition of hydrobromic acid to 1-butene,

2-butene.

## 6.2 — Addition of a halogen

Halogen atoms can react with an alkene in an addition reaction. The mechanism is very similar to the addition of “HX”.

The temporary dipole that forms in the halogen provides the positive atom to start the reaction.



The reaction will slow as the size of the halogen decreases.

The reaction of bromine with an alkene is a positive test for an alkene. Bromine is a deep purple-brown molecule. If it is added to a substance and the colour disappears, that is a positive test for an alkene.

## 6.3 — Addition of water (hydration)

Water can be added to an alkene to produce an alcohol. This reaction needs to be catalyzed with an acid.



The  $H^+$  is used in the first step and produced again in a later step. It speeds up the reaction but is not used in the overall reaction.

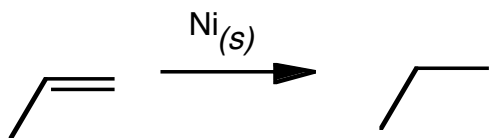
Example 2:

Show a hydration addition reaction to an alkene that produces a primary, secondary, and tertiary alcohol.



#### 6.4 — Addition of hydrogen (hydrogenation)

The addition of hydrogen to an alkene is called hydrogenation. This reaction requires a surface catalyst such as nickel metal. The reactants form a weak bond with the surface of the metal. This weakens their bonds and makes it easier for them to react.



This reaction is most commonly used to produce partially hydrogenated fats.

Unsaturated fats (vegetable oils) have low melting points. They have double bonds (they are not saturated with hydrogens).

Saturated fats (animal fats) have high melting points. They have single bonds (they have as many hydrogen atoms on them as they can).

To make margarine solid at room temperature, it is partially hydrogenated. Some of the double bonds are hydrogenated to increase the melting points and make it solid at room temperature.

Problem: Some of the molecules you eat are not natural and can be carcinogenic.

#### 6.5 Addition reaction with Benzene

Benzene is a very stable alkene. Its delocalization (aromaticity in a cyclic compound) gives it increased stability.

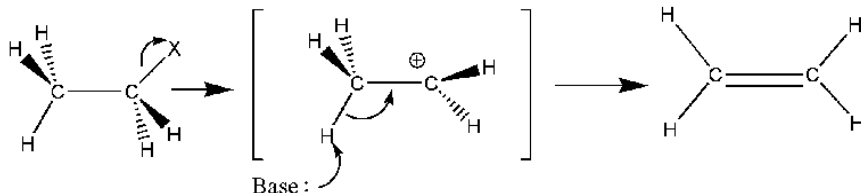
Benzene can undergo addition reactions, but with much more difficulty than regular alkenes. (High temperature and pressure)

Benzene will undergo a substitution reaction, replacing a hydrogen.

An **elimination reaction** is the opposite of an addition reaction.

This reaction is in an ethanol reflux with NaOH. No acid or H<sub>2</sub>O is present. Below is a two step mechanism.

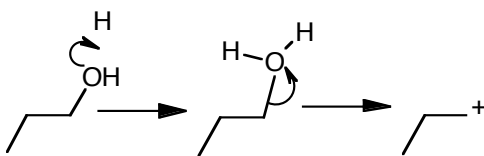
A single step mechanism is also possible.



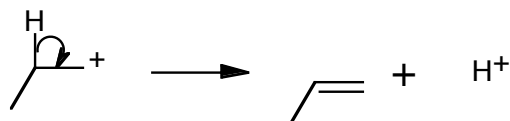
Problems 15.41b, 43

## 7 Reactions of Alcohols

The addition reaction to produce an alcohol from an alkene is a reversible reaction. The reverse reaction reverses the steps of the addition reaction.

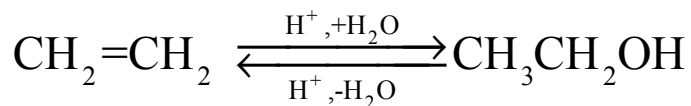


The carbocation takes the electrons from an adjacent C-H bond to form an alkene.



H<sup>+</sup> is produced at the end again. It is a catalyst for the reverse reaction also.

This reversible reaction can be shown by:



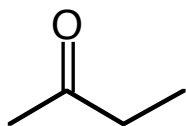
The use of dilute H<sub>2</sub>SO<sub>4</sub> will accomplish the forward reaction. Concentrated H<sub>2</sub>SO<sub>4</sub> will accomplish the reverse reaction, because the concentrated acid will remove excess water.

## 7.2 Carbonyls

Compounds with C=O bonds are carbonyl compounds.

Three classes of carbonyls are Ketones, Aldehydes, and Carboxylic acids.

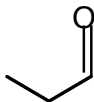
Ketones are carbon chains with one of the interior carbons double bonded to an O.



2-butanone,  $\text{CH}_3\text{COCH}_2\text{CH}_3$

Ketone nomenclature: ending of name is changed to “one”.  
The position of the C=O is numbered.

The C=O on the end carbon is an aldehyde.  
The ending for an aldehyde is “al”. They do not have to be numbered because the C=O must be on the end carbon.  
Propanal, CH<sub>3</sub>CH<sub>2</sub>CHO

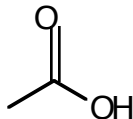


Example 1:  
What is C<sub>3</sub>H<sub>6</sub>O ?

These are functional group isomers.

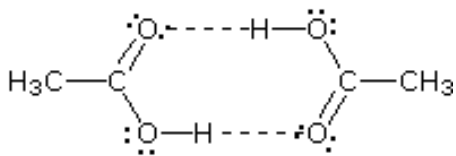
The primary acid in organic chemistry is the carboxylic acid.  
The ending of the name is changed to “oic acid”. They also do not need to be numbered, because they must be on the end of the molecule.

Ethanoic Acid, Acetic acid, CH<sub>3</sub>COOH:



Ketones and Aldehydes have dipoles on the C=O bond. Their b.p. and m.p. are higher than alkanes; however, they are usually not very soluble in water.

The carboxylic acid has much higher inter-molecular bonding because of hydrogen bonding. This also makes many short-chain carboxylic acid soluble in water.



Oxidation is the process of removing electrons from an atom.

For now, we can view oxidation as the addition of oxygen atoms to a carbon. The electronegativity of the oxygen atoms removes the electrons partially from the carbon.

This lowers the amount of electrons around the carbon.

The opposite of oxidation is reduction. This is the removal of oxygen or the addition of hydrogen.

### 7.3 Oxidation of Alcohols

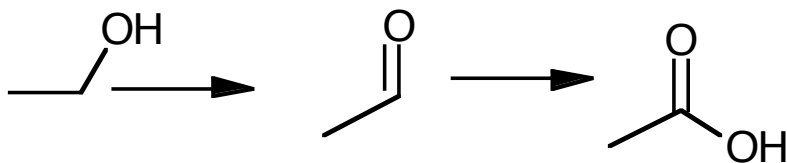
Alcohols can be oxidized to aldehydes, ketones, and carboxylic acids.

The reactant used is acidified dichromate ions ( $\text{H}^+$ ,  $\text{Cr}_2\text{O}_7^{2-}$ ).

This oxidizer is a mild reactant. It is strong enough to oxidize the alcohol, but not other carbons in the molecule. It is a selective reactant.

Acidified dichromate ions can oxidize alcoholic carbons that have hydrogens on them: primary and secondary alcohols.

A primary alcohol can be oxidized to an aldehyde and then to an acid.



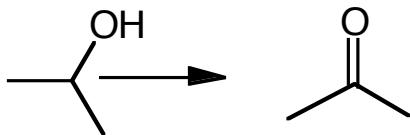
Note that the b.p. of the aldehyde will be markedly lower than the alcohol and the acid.

To recover the aldehyde, the reaction mixture would be distilled. Any aldehyde produced would be boiled and recovered by distillation.

To recover the acid, the reaction mixture would be refluxed. This would keep the easily boiled aldehyde in the reaction vessel, any oxidize it further to the acid.

Sketch the apparatus.

A secondary alcohol will be oxidized by acidified dichromate to a ketone.



A tertiary alcohol will not be oxidized by acidified dichromate. You do need to remember the reactants and conditions for these reactions.

Dichromate ions are a bright orange. As they oxidize the alcohol, the dichromate is reduced to  $\text{Cr}^{3+}$  ions that are a green colour.

This can act as a test for primary and secondary alcohols, as tertiary alcohols will not turn the solution green.

Example 3:

How can you make an acid from 1-butene? From 2-butene?

\

Example 4:

Compound A will react with concentrated sulfuric acid, and the produce will de-colourize bromine. It will not change the colour of dichromate ions. What could compound A be?

Example 5:

How would you make 3-pentanone from an alkene?

## 8 Esters

An ester is a product of a condensation reaction between an alcohol and a carboxylic acid.

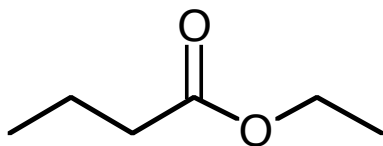
It can be described as a carboxylic acid that has an alkyl group in place of the “H” in the acid.

### 8.1 — Ester Properties

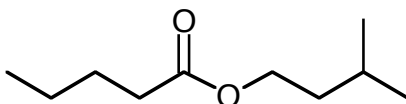
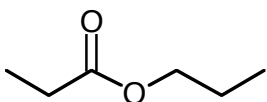
Esters are named after the carboxylic acid from which they are derived.

The ending of the carboxylic acid is changed to “ate”, and the alkyl group that has replaced the “H” is placed before the carboxylic name.

Ethyl butanoate



Name the following:



Draw the following:

Pentyl benzoate

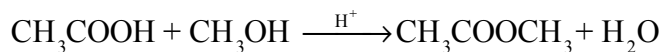
(2-methyl)propyl hexanoate

Esters often have strong odours. Many are used as artificial flavouring in food products. They are also used as solvents and plasticizers.

They have a dipole due to the carbon-oxygen bonds. This usually makes them liquids at room temperatures.

They are usually not very soluble in water.

The reaction to make an ester involves an acid and an alcohol producing the ester and water.



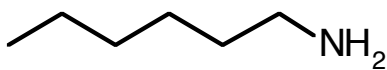
This reaction uses an acid catalyst, and the water produced would condense on the side of the test tube. They were called condensation reactions for this reason.

### 8.3 Amines

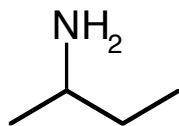
Amines are molecules with nitrogen atoms single bonded to carbons.

They are named by adding “amino” before the alkane name, or ending the compound with amine. The position of the amine on the carbon chain is numbered.

1-aminohexane  
Or 1-hexylamine

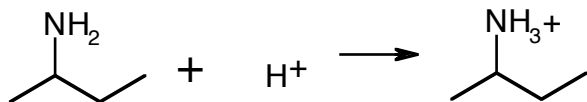


2-amino butane  
Or 2-butylamine



Amines usually have hydrogen bonded hydrogens; they are usually soluble in water and have high boiling points (due to the hydrogen bonding).

Amines are bases. The nitrogen has a lone pair of electrons that can accept a proton.

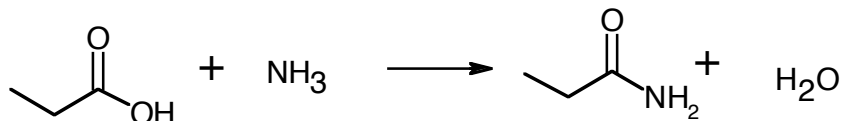




## 8.5 — Amides

Amines can undergo condensation reactions with carboxylic acids.

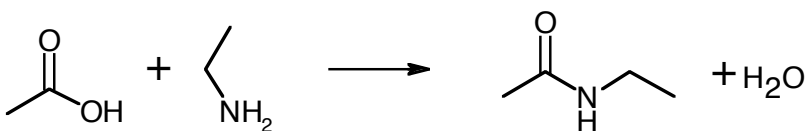
The simplest amine to react is  $\text{NH}_3$ .



Propanoic acid becomes propanamide

The “oic” is replaced with “amide.”

More complex amides can be formed from a carboxylic acid and an amine.



Ethanoic acid and ethyl amine becomes:

*N*-ethylethanamide.

You do not need to name complex amides.

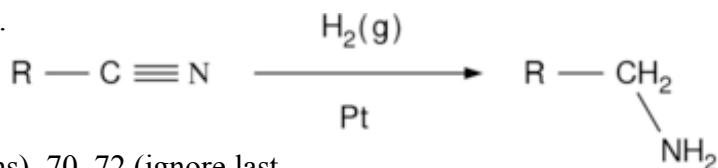
A nitrile is a triple bonded C - N bond. It is also called a cyanide.

They are named similarly to other organic compounds.



Nitriles are very useful organic compounds that can undergo many types of reactions.

We need to know of the reduction of nitriles to form amines with a nickel or platinum catalyst.

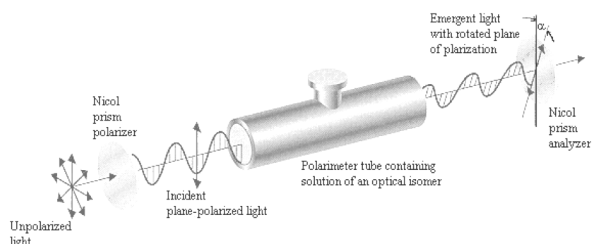


Problems 15.68 (condensation reactions), 70, 72 (ignore last step of b), 74a

## 9.1 Optical Activity

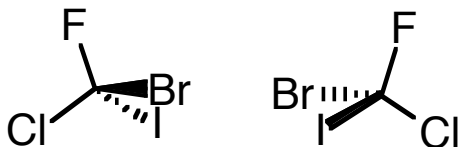
Molecules that are tetrahedrally bonded can exhibit a property called optical activity.

Optical activity means a molecule can rotate the plane of polarized light.



Molecules that are optically active will rotate the polarized light clockwise or counter-clockwise depending if it is left handed or right handed.

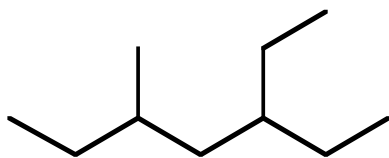
An optically active organic molecule has a carbon atom with four different molecules attached to it - a chiral carbon.



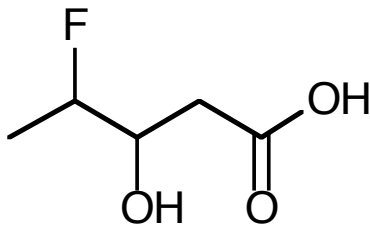
Example 1:

Identify the chiral carbon in the following

a)



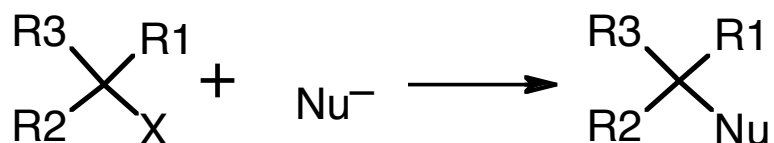
b)



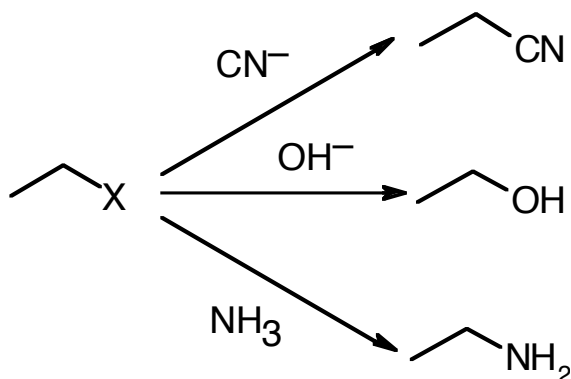
## 9.2 Nucleophilic Substitution Reactions

We will examine nucleophilic substitution reactions of halogenoalkanes.

A nucleophile is a negatively charged species that is attracted to the positively charged carbon bonded to a halogen.



The general form of this reaction will have three possible nucleophiles:  $\text{OH}^-$  to produce an alcohol;  $\text{NH}_3$  to produce an amine;  $\text{CN}^-$  to produce a cyanate.



Example 2:

Explain how you could make ethanoic acid from bromoethane.

Example 3:  
Explain how you make an amide from an alkene.

This reaction can occur through two distinct mechanisms. We will need to learn about these mechanisms in detail.

The nature of optical isomers will allow us to differentiate between these two mechanisms.

### 9.3 S<sub>N</sub>1 Mechanism

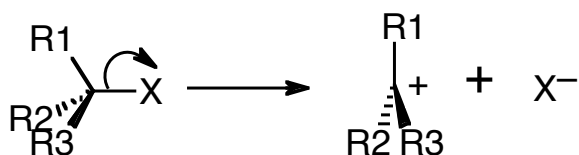
This mechanism takes place in two steps. It is called S<sub>N</sub>1 because the rate of the reaction depends on only one molecule.

In the first step of the reaction, the halogen leaves the carbon, leaving a carbocation. This is a slow step.

In the second step, the nucleophile bonds with the carbocation. This is a very fast step.

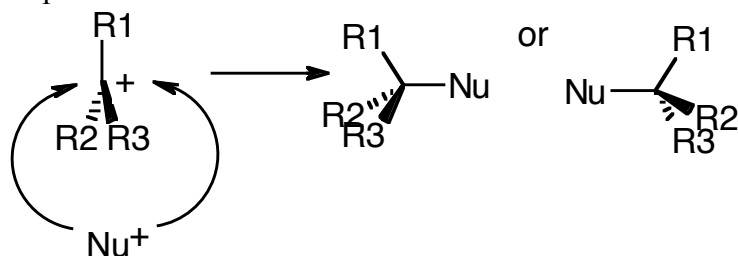
We will examine these reactions using an optically active compound.

Step 1:



In the next step, the nucleophile can attack the carbocation from the right or the left side. The product will end up half left handed and half right handed. (racemic)

Step 2:



The rate of the reaction depends on the slow reaction and therefore on the concentration of the halogenoalkane. That is why it is called S<sub>N</sub>1.

If the reaction is started with a “handed” reactant, the products will be a mixture of left and right handed molecules.

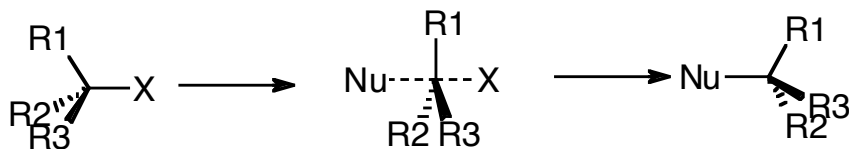
## 9.4 S<sub>N</sub>2 Mechanism

The S<sub>N</sub>2 mechanism occurs in one step. The rate of the reaction depends on two different molecules, thus the “2” in the name.

In this mechanism, the halogen leaves at the same time as the nucleophile bonds with the carbon.

The nucleophile approaches the carbon from the opposite side from the halogen.

The molecule in the middle of this mechanism has half broken the old bond to the halogen as it has half formed the new bond to the nucleophile.



Because the nucleophile must approach the molecule from the other side from the halogen, a handed reactant will result in a handed product.

A **primary** halogenoalkane favours the S<sub>N</sub>2 mechanism.

There is enough room for the nucleophile to approach before the halogen leaves.

The two Hydrogen atoms will not help the formation of a carbocation. (This means the first step in the S<sub>N</sub>1 mechanism will be unlikely.)

A **tertiary** halogenoalkane will favour the S<sub>N</sub>1 mechanism.

The alkane groups on the carbon do not allow the nucleophile to approach until after the halogen has left.

The alkane groups make the carbocation more stable. This favours the first step in the S<sub>N</sub>1 mechanism.

A **secondary** halogenoalkane will usually be a mixture of the two mechanisms.

The rate of these reactions depends on two factors.

S<sub>N</sub>1 is faster than S<sub>N</sub>2.

The larger halogen will leave easier (and faster) than smaller alkanes.

In terms of rate: I > Br > Cl >> F

Problems 15.24, 26

## 10 Polymers

Polymers are long chain organic compounds that are made from smaller molecules that are combined together.

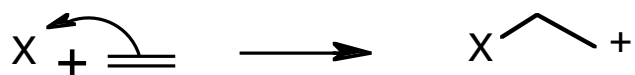
Polymers are made from monomers.

We will look at addition polymers made from alkenes, and condensation polymers: polyesters and polyamides.

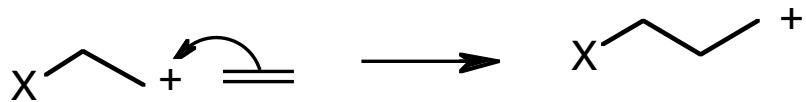
### 10.1 Addition Polymers

Addition polymers are made from addition reactions of alkenes.

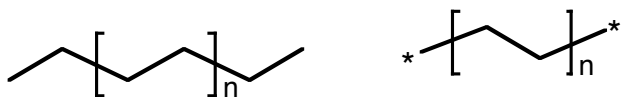
The polymerization reaction is initiated by a chemical that breaks the double bond and leaves a carbocation.



The carbocation will then take electrons from another alkene, producing another carbocation.



A chain will form along the carbons that were in the double bond.



Example 1:

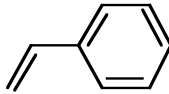
What polymers will form from the following monomers:



Propene

2-butene

Styrene

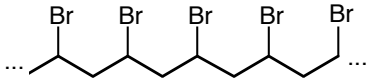


Teflon:  $\text{CF}_2\text{CF}_2$

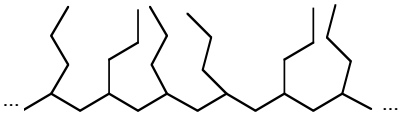
Example 2:

What monomers would form the following polymers:

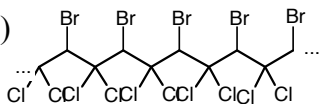
a)



b)



c)

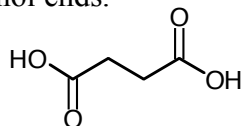




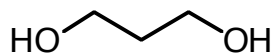
## 10.2 Polyesters

A polyester will be formed from molecules with double acidic ends, and double alcohol ends.

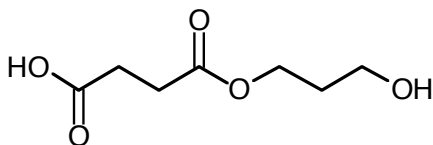
Butan-di-oic acid



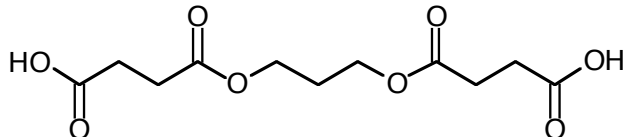
1,3 propan-di-ol



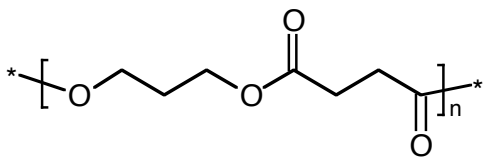
With an acid catalyst the first acid and alcohol will form an ester:



A different acid will now join onto the alcohol end to form another ester.



This process will continue on for up to several thousand units. We only need to indicate one repeating unit:



The C=O is from the acid, the O is from the alcohol.

Example 3:

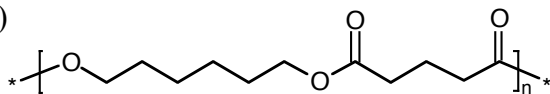
Indicate the polymers formed from:

Benzene-1,4-dicarboxylic acid and 1,2 ethandiol

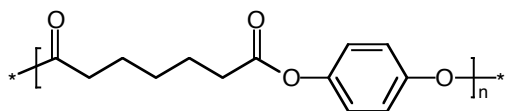
Pentandioic acid and 2,3-dimethyl-1,4-butandiol

Describe the monomers that would produce the following polymers:

a)



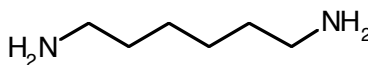
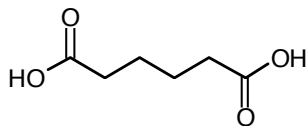
b)



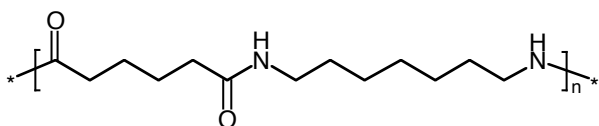
## 10.3 Polyamides

Polyamides are similar to polyesters. The reaction is between a di-carboxylic acid and a di-amine.

The most commonly produced polyamide is 6,6 nylon made from hexanedioic acid and 1,6 diamino hexane. (The 6,6 refer to the 6 member carbon chains)



The polymer is:



This is very similar to the structure of silk. Natural silk has some variation in the arrangement of the molecules, that gives silk its particular properties.

Proteins are made from aminoacids. An aminoacid has an amine group and a carboxylic acid group on every molecule. See IB Data booklet.

Aminoacids are joined with amide bonds between the amine and the acid. These amide bonds are catalyzed by cell enzymes.

In biology these are called peptide bonds. A protein is a poly-peptide.

Example 5:

Draw an example of a tri-peptide with three different aminoacids.

Problems

15.78, 83, 84, 86, 96