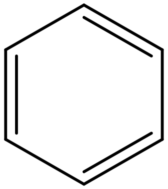
FACULTY OF SCIENCE,QENA
كلية العلوم بقنا

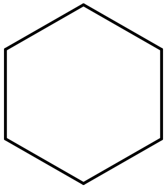
SOUTH VALLEY UNIVERSITY
جامعة جنوب الوادي

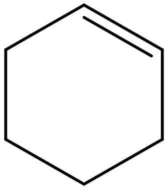
اسم المقرر:كيمياء عضوية (٢)
مركبات عضوية غير متجانسة
Heterocyclic compounds

اعداد
استاذ المادة دكتورة عواطف محمد المغربي
الفرقة الثانية بكلية التربية
شعبة علوم بيولوجية وجيولوجية(لغات)
العام الدراسي ٢٠٢٢-٢٠٢٣

- **Organic compounds are classified into cyclic and acyclic compounds .**
- **Cyclic compounds are classified into homocyclic and heterocyclic.**
- **Benzene ,cyclohexane and cyclohexene are homocyclic examples.**

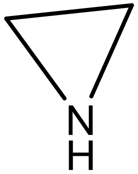

benzene

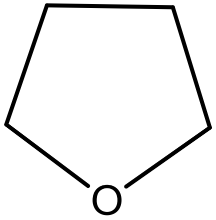

cyclohexane

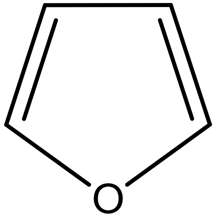

cyclohexene

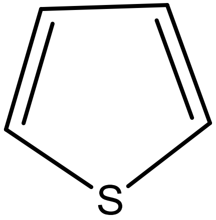
- **Heterocyclic compounds are cyclic compounds with the ring containing carbon and other elements ,heteroatoms like oxygen (O),sulfur, (S) nitrogen(N),phosphorus(P),silicon(Si),boron(B),selenium (se).**

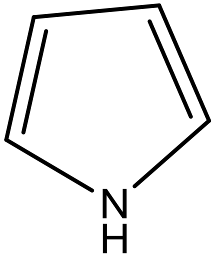
Examples

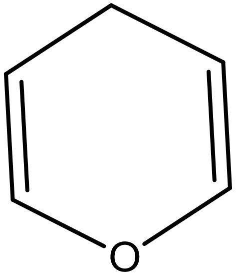

aziridine

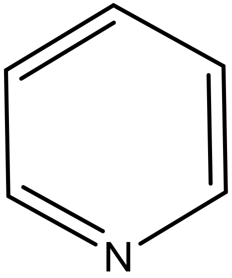

tetrahydrofuran

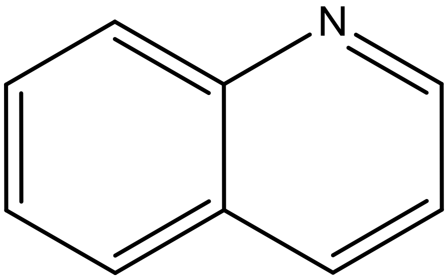

furan

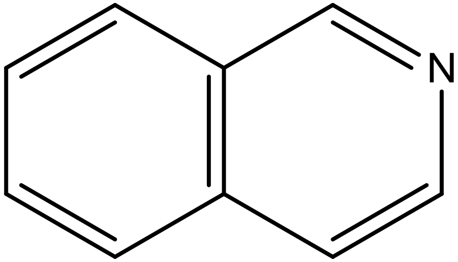

thiophene


pyrrol

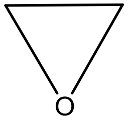

4-H Pyran


pyridine

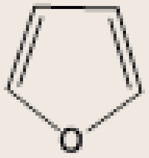

Quinoline


isoquinoline

- **Ethylene oxide less stable and easily opened but five or six membered which contain conjugated double bonds are stable and exhibit aromatic character.**

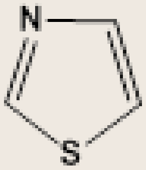


ethylene oxide



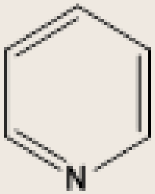
فيوران

furan



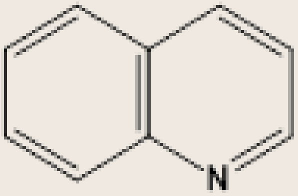
ثيازول

thiazol



بيريدين

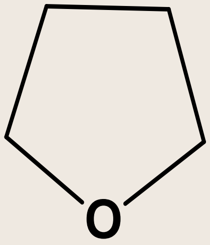
pyridine

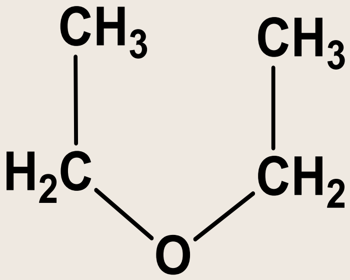


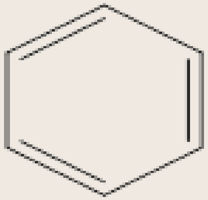
كينولين

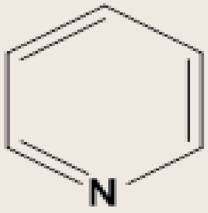
quinoline

- **Tetrahydro furan has a chemical character similar to diethyl ether (aliphatic compound).**


tetrahydrofuran


diethyl ether


Benzene

pyridine


Aromaticity

Any compound to be aromatic ,it must be :

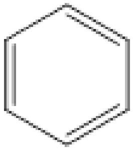
1-Cyclic 2-Planner

3-All atoms must be SP2

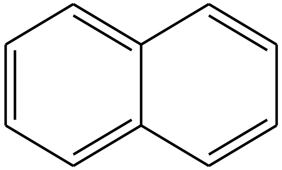
4-All double bond must be conjugated.

5- Obey Huckel rule [any aromatic compound must contain(4n+2) pi electrons]

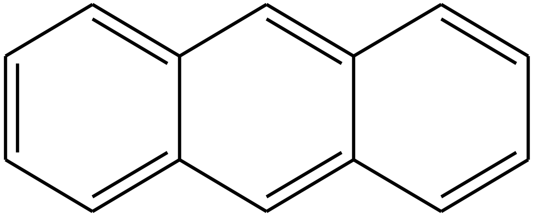
- examples



n=1
6 π electron



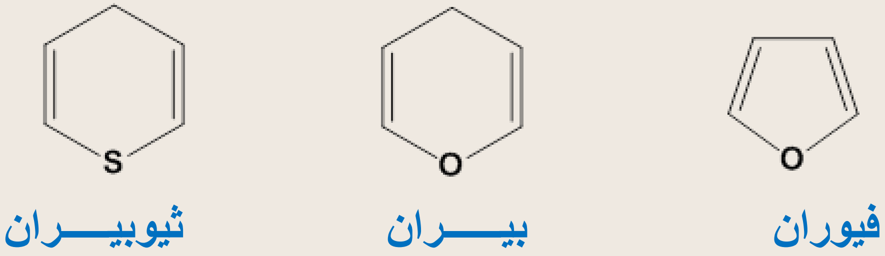
n=2
10 π electron



n=3
14 π electron

Natural sources of heterocyclic compounds

1. Carbohydrates (vitamin c)which contain furan,pyran and thiopyran



2. VitaminB (pyridoxineVB6)related to pyridine ring
3. In alkaloids
4. Antibiotics (penicillin)which contain heterocyclic rings .

Importance and application:

1-Synthesis of drugs .

2-Paper industry.

3- Synthesis of dyes and polymers.

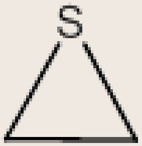
Nomenclature

- **The name of monocyclic compounds are derived by a prefix (or prefixes) indicating the nature of the hetero atoms present , oxygen اوكزا Oxa, sulfur, ثيا Thia, nitrogen ازِا Aza .**
- **In case of two oxygen (dioxa), in case of two sulfur (dithia) , in case of two nitrogen (diaza) if the hetero atom is different the order O –S – N .**
- **In a monocyclic compound containing only one hetero atom numbering starts at the atom .**
- **The size of monocyclic ring from 3 to 10 indicated by 3 ir and 4 et ……. (See the table).**
- **The ring is numbered to give substituents or other hetero atoms the lowest number possible**

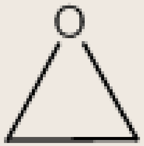
The table indicate ring size ,saturation and unsaturation

		Containing Nitrogen		**Containing no Nitrogen**	
Ring size	symbol	Unsaturation	Saturation	Unsaturation	Saturation
3	ir	-irine	-iridine	-iren	-iran
4	et	- ete	-etidine	-et	-etan
5	ol	-ole	-olidine	-ole	-olan
6	in	-in	perhydro	-in	-ane
7	ep	-epine	perhydro	-epin	-epan
8	oc	-ocine	perhydro	-ocin	-ocan
9	on	-onine	perhydro	-onin	-onan
10	ec	-ecine	perhydro	-ecin	-ecan

Three membered ring الحلقات الثلاثية

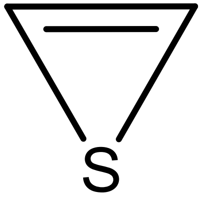


Thiiran

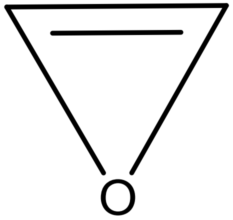


Oxiran

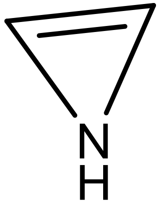
Aziridine



thiiren

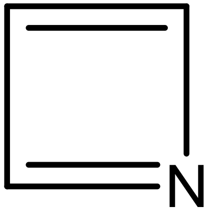


oxiren

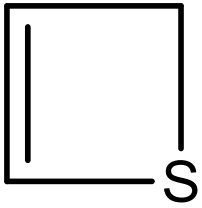


azirine

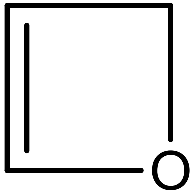
Four membered ring الحلقات الرباعية



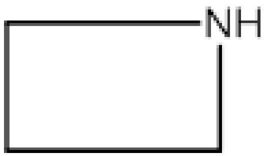
Azete



Thiet



Oxet



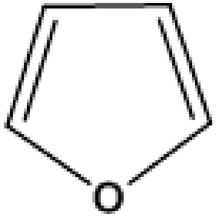
Azetidine
ازيتيـــدين

Thietan
ثييتان

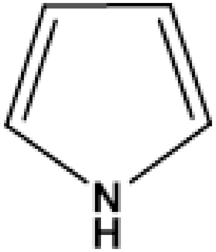
Oxetan
أوكزيتان

Five membered ring الحلقات الخماسية

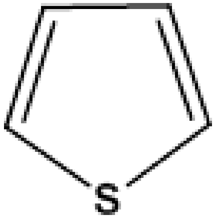
- :



(فيوران) اوكزول



(بيرول) ازول

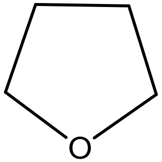


(ثيوفين) ثيول

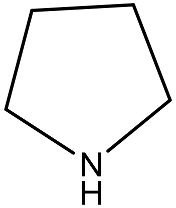
Furan)
Oxole

(Pyrrole)
Azole

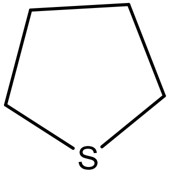
(Thiophene)
Thiol



tetrahydrofuran
oxolane

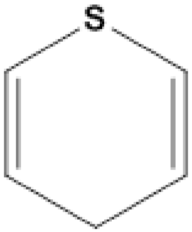
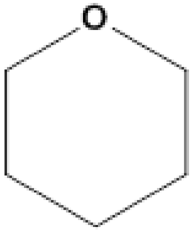
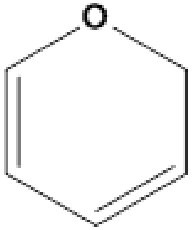


pyrrolidine
azolidine

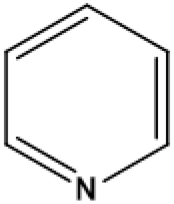
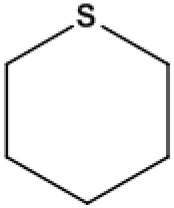


thiolane
tetrahydrothiophene

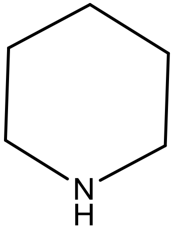
- Six membered ring with one hetero atom .

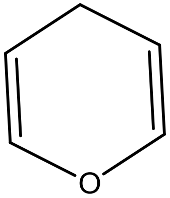
١،٤-ثيوبيران	رباعي هيدروبيران	١،٢-بيران
4-H thiopyrane	tetrahydropyrane	2-H pyrane
4-HThiin	Oxane	2-H Oxin

بيريـــدين	رباعي هيدروثيوبيران
Pyridine	tetrahydrothiopyrane
Azine	thiane

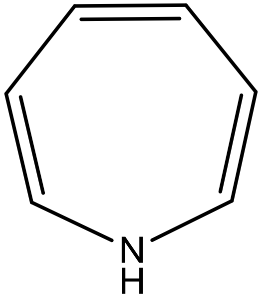


piperidine
perhydroazine

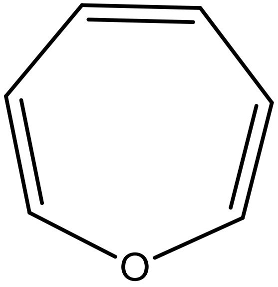


4-H Pyran
4H-Oxin

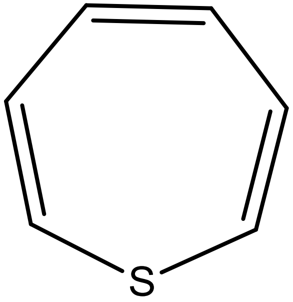
الحلقات السباعية ذات ذرة واحدة غير متجانسة
Seven membered ring with one hetero atom



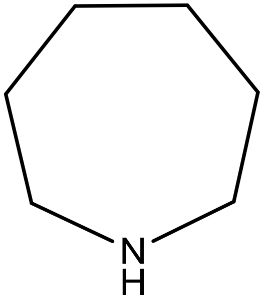
Azepine



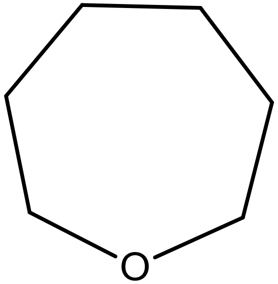
Oxepin



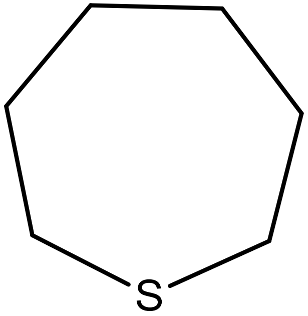
Thiepin



perhydro azepine



Oxepan

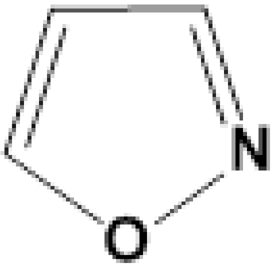


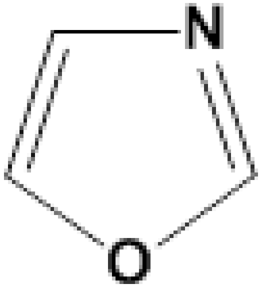
Thiepan

Five membered ring with two hetero atom (O- S- N)
الحلقات الخماسية ذات ذرتين غير متجانستين

In case of different hetero atom the priority O- S- N ,oxygen and nitrogen (oxaza) ,in case of S and N (thiaza)

في حالة اختلاف الذرتين الغير متجانستين تكون الافضلية O- S- N .



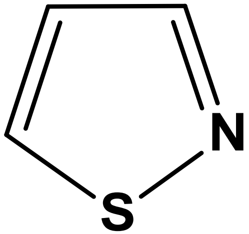


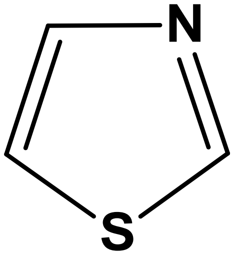
1,2 oxazole
أيزوكسازول(Isoxazole)

1,3Oxazole أوكسازول
(Oxazole)

Five membered ring with two hetero atom (O- S- N)

O>S>N



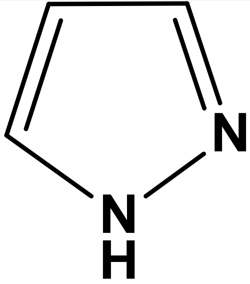


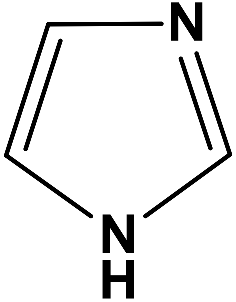
ايزوثيازول ثيازول

1,2Thiazole 1,3 (Thiazole)

Thiazole

(Isothiazole)



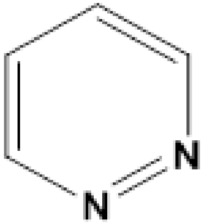


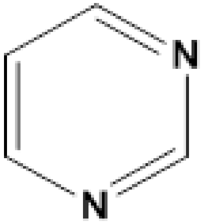
pyrazole بيرازول **imidazole ايميدازول**

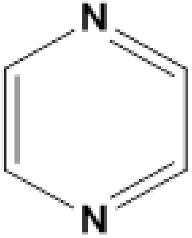
1,2 Diazole ١،٢-ثنائي الأزول **1,3 Diazole١،٣-ثنائي الأزول**

الحلقات السداسية التي تحتوي على ذرتين غير متجانستين

Six membered ring with two hetero atom



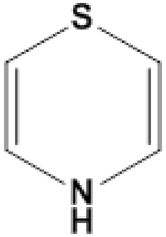


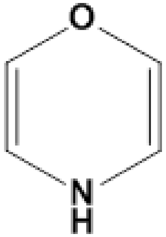


بيرازين بيريميدين بيريدازين

١،٤-ثنائي الأزين ١،٣-ثنائي الأزين ١،٢-ثنائي الأزين

Pyridazine	pyrimidine	pyrazine
1,2diazine	1,3diazine	1,4diazine

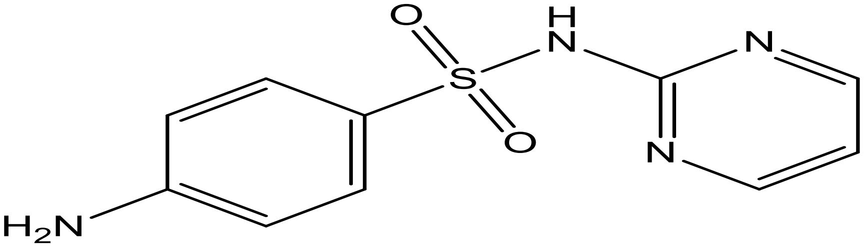




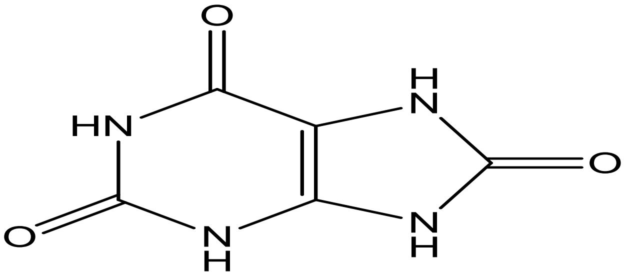
١،٤-اكسازين ١،٤-ثيازين

1,4-thiazin	1,4-oxazine

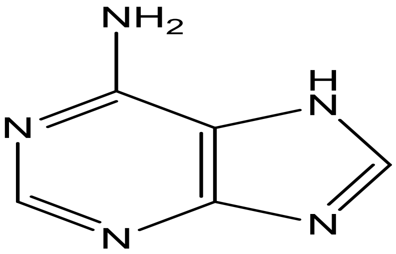
امثلة هامة علي مركبات البيريميدين ذات اهمية بيولوجية
Biologically active Important examples on pyrimidine nucleus



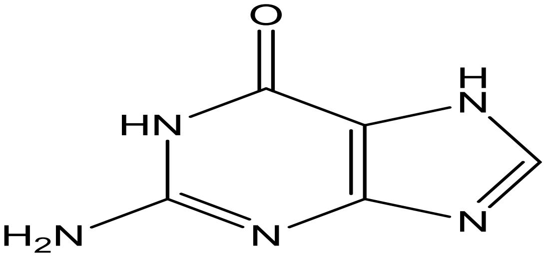
sulphadiazine



Uric acid



Adenine

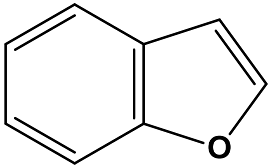


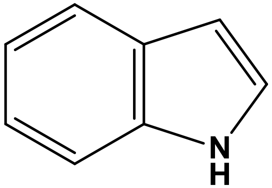
Guanine

سلفاديازين (مضاد للبكتيريا) وادينين -جوانين – حمض اليوريك هي امثلة علي مركبات محتوية علي حلقة بيريميدين.

Pyrimidine is used in the synthesis of sulpha diazine (antibacterial). Nucleic acids (adenine, guanine and uric acid) are also considered important examples.

Benzo derivatives of furan, thiophene ,pyrrole and pyridine مشتقات البنزو لكل من فيوران ، ثيوفين ، بيرول و بيريدين



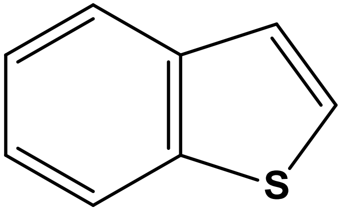


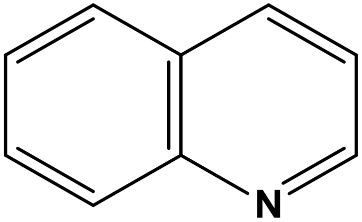
بنزو[b]فيوران

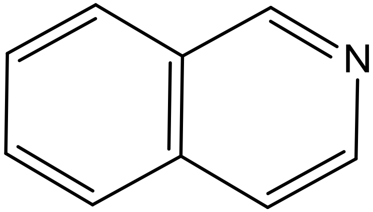
بنزو[b]بيرول

Benzo[b]furan

benzo[b]pyrrole
Indol







بنزو[b]ثيوفين

بنزو[b]بيريدين

بنزو [c] بيريدين

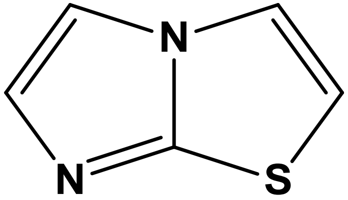
benzo[b] thiophene

benzo[b] pyridine
Quinoline

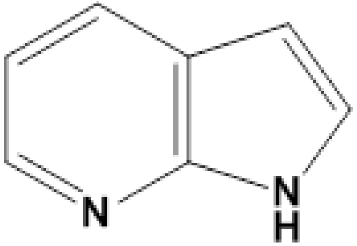
benzo[c]pyridine
isoquinoline

تسمية المركبات الغير متجانسة الحلقة متعددة الحلقات Nomenclature of polycyclic heterocyclic compounds

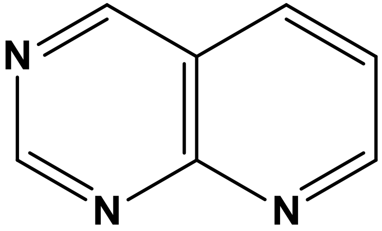
(imidazo[2,1-*b*]thiazole) ايميدازو[2,1-*b*]ثيازول

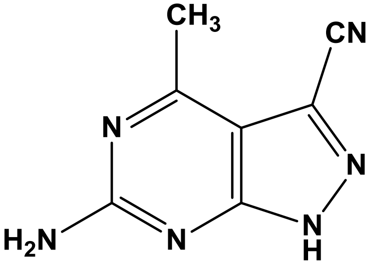


بيرولو[2,3-*b*]بيريدين
(pyrrolo[2,3-*b*]pyridine)



(pyrido[2,3-*d*]pyrimidine) بيريدو[2,3-*d*]بيريميدين





6-amino-4-methyl-1*H*-pyrazolo[3,4-*d*]pyrimidine-3-carbonitrile

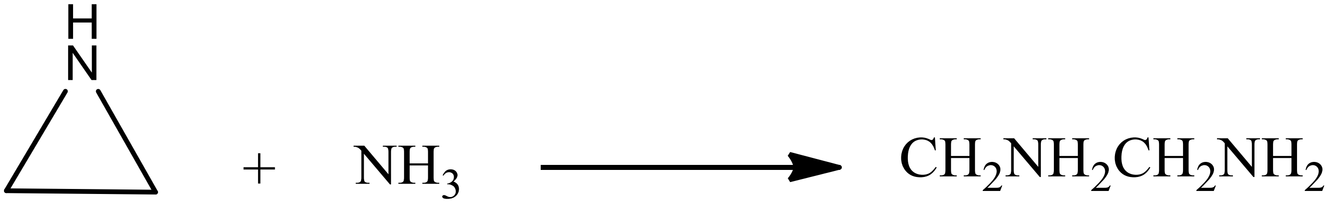
ازيريدين Aziridine

Preparation

Chloroethylamine

Aziridine

with ammonia

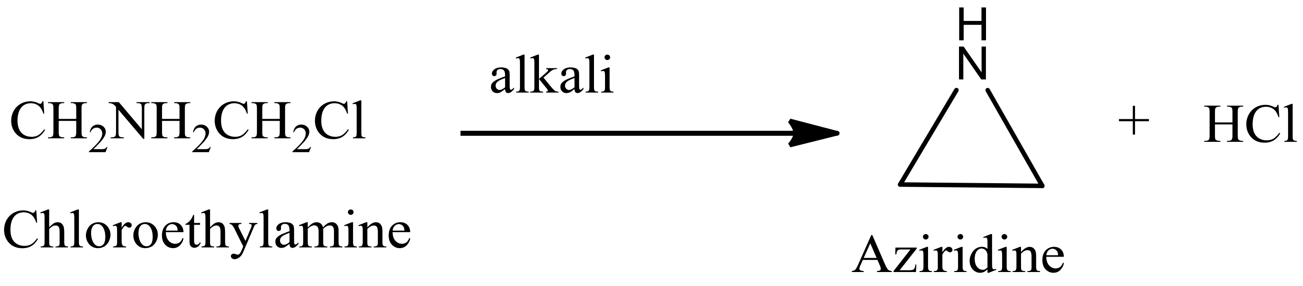


Aziridine

ethylenediamine

Aziridine ازیریدین

Preparation

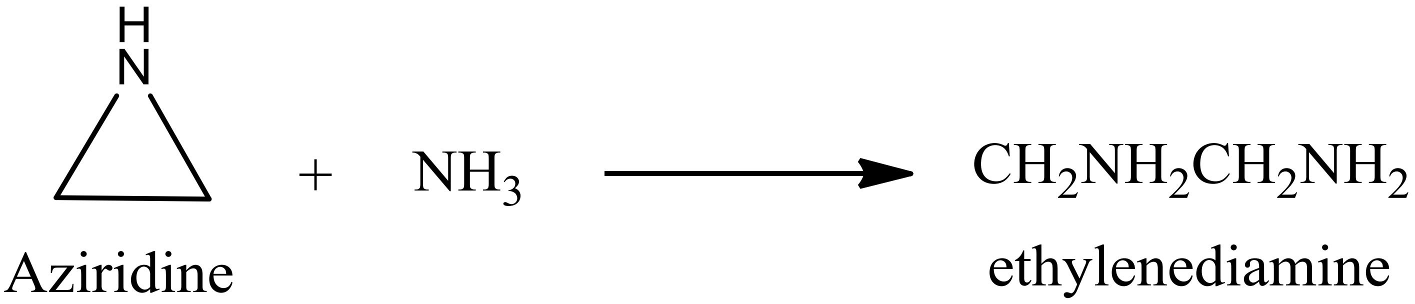


$CH_2NH_2CH_2Cl \xrightarrow{\text{alkali}}$ + HCl

Chloroethylamine

Aziridine

With ammonia



\+ $NH_3 \longrightarrow CH_2NH_2CH_2NH_2$

Aziridine

ethylenediamine

Oxirane

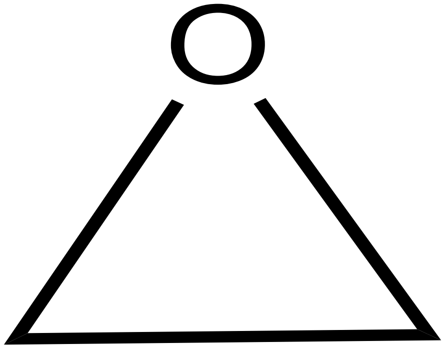
oxirane

Ethylene oxide

epoxyethane

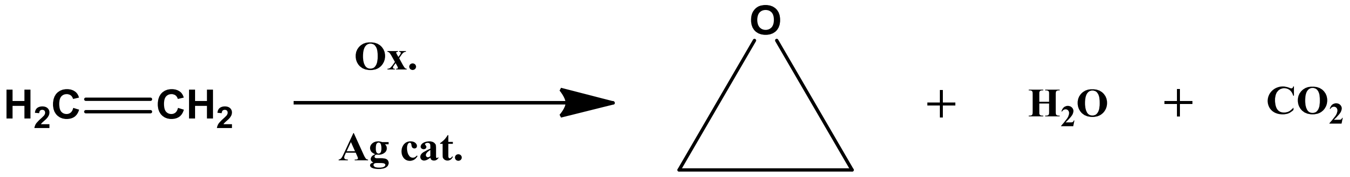
oxacyclopropane

1,2- or beta oxidoethane

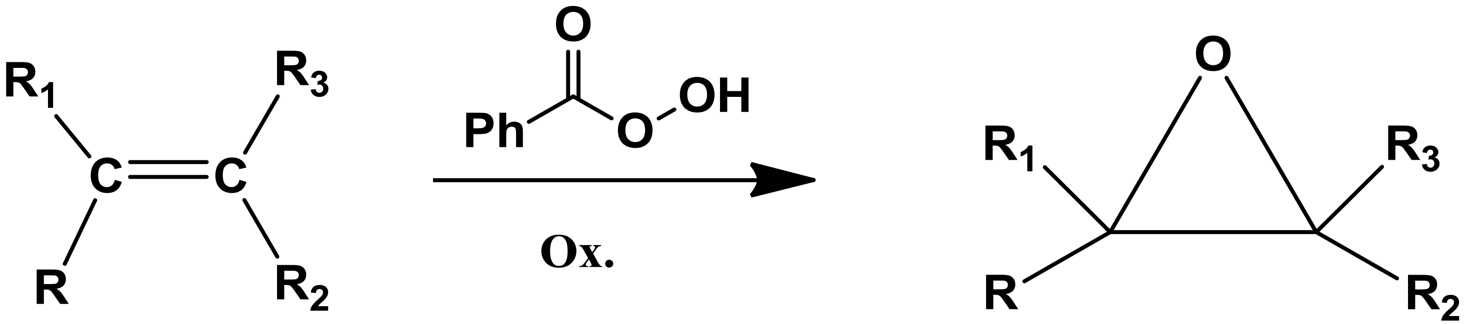


Preparation

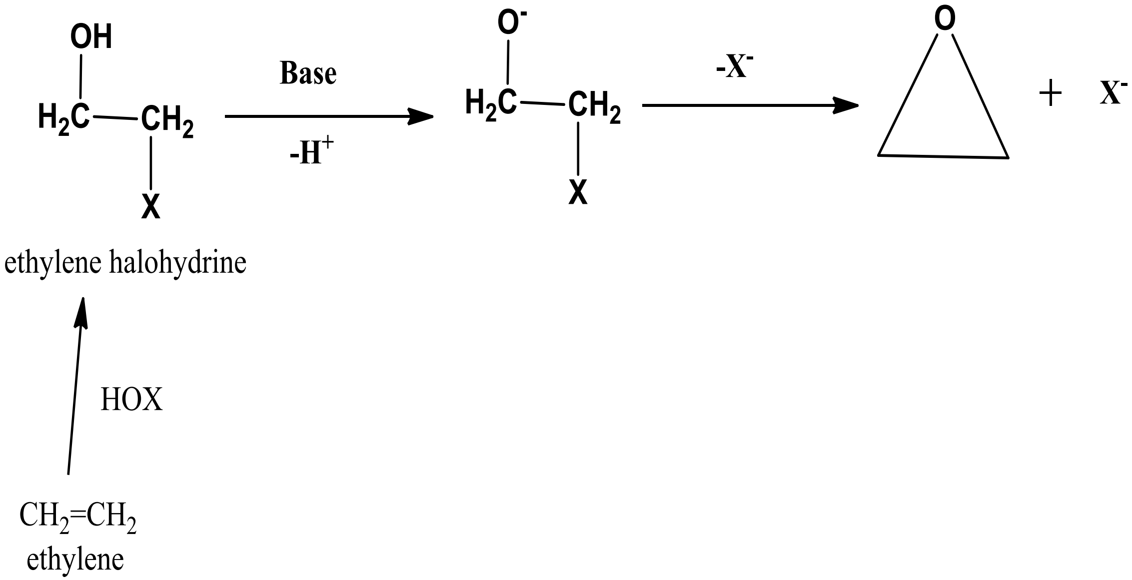
1-Oxidation of ethylene ١.



- 2-Oxidation of olefins by using per benzoic acid :



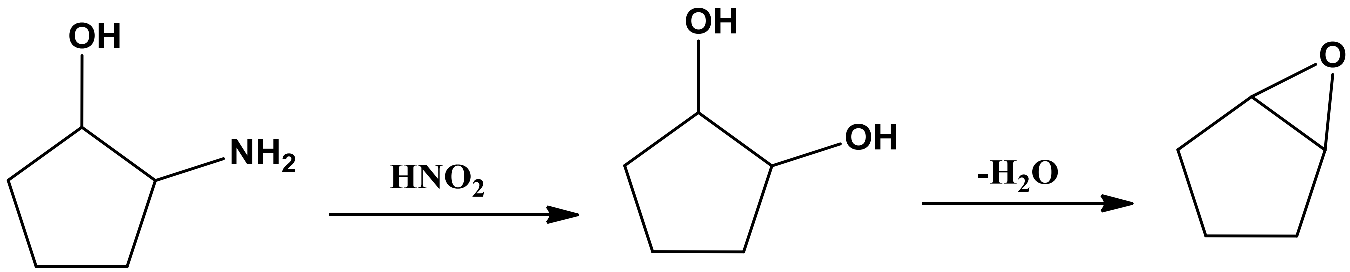
3- Elimination of HX from halo hydrine derivatives



ethylene halohydrine

$CH_2=CH_2$
ethylene

4-Effect of nitrous acid on amino alcohols



2-aminocyclopentanol

1,2dihydroxy cyclopentane

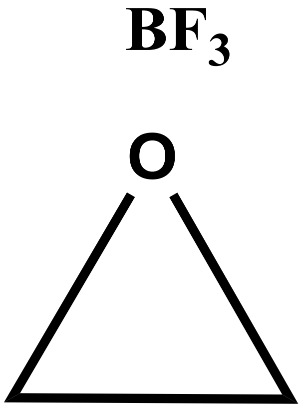
6-oxabicyclo[3.1.0]hexane

Reactions

Ethylene oxide b.p 10.7

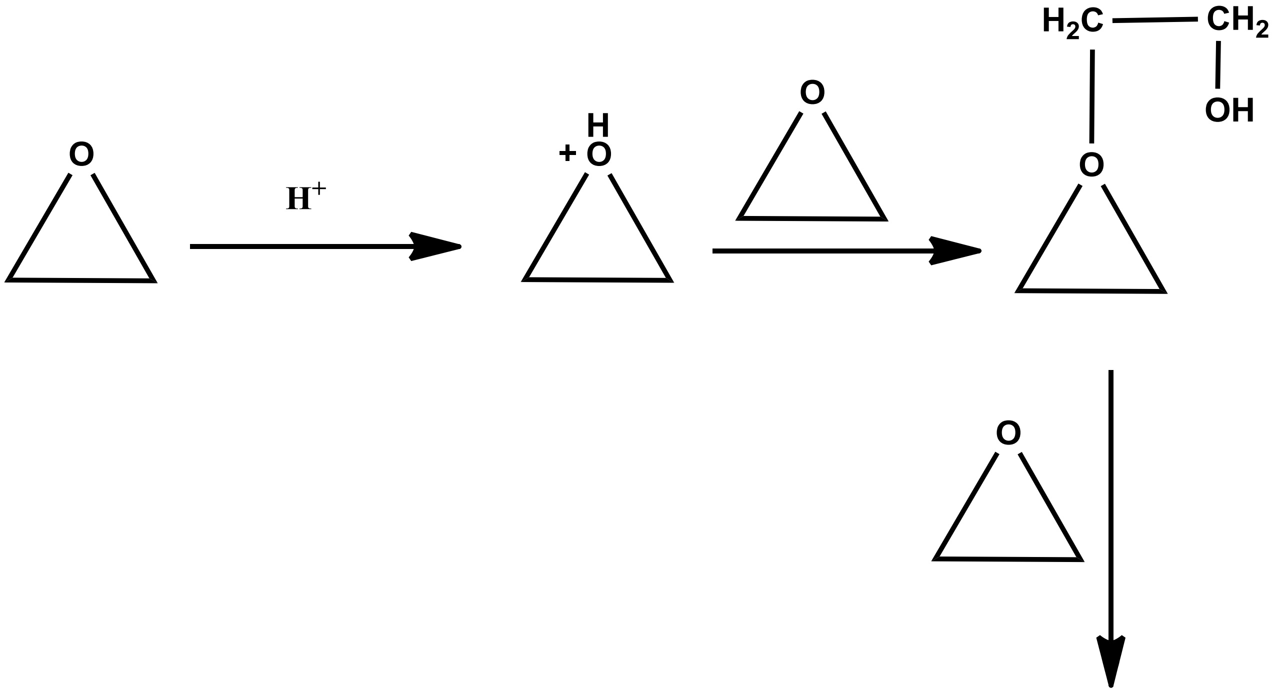
It is kept in welded glass ampoules or in metal cylinders, and great care must be taken when using it, as it is in contact with the skin as it causes severe burns.

Ethylene oxide is unstable but with boron trifluoride gave the corresponding addition product



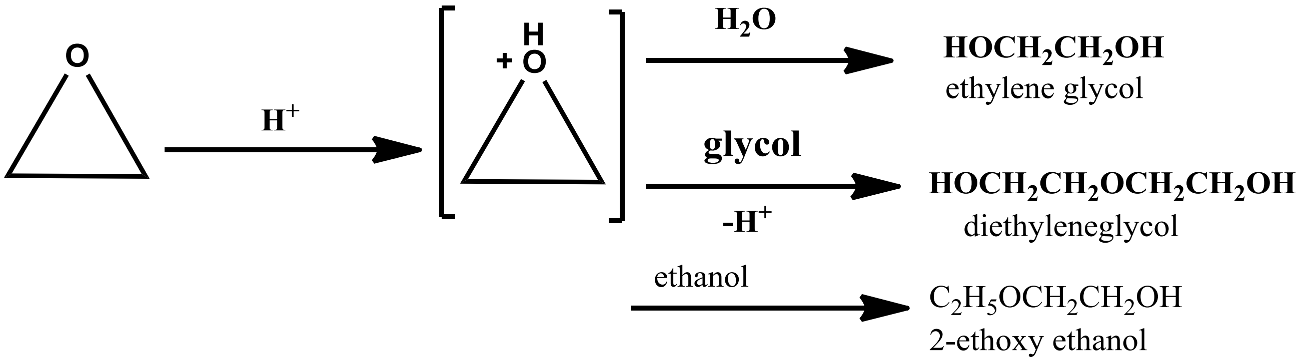
Polymerization

Polymerization of oxiran is slow in the presence of sodium hydroxide and fast in the presence of stannic chloride (mechanism by free radical).



Polymer substance

-With water and alcohols



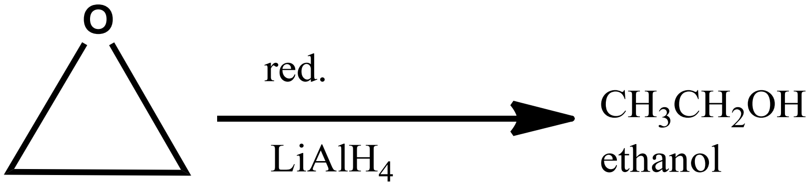
H^+

H_2O $\rightarrow$ $HOCH_2CH_2OH$ ethylene glycol

glycol, $-H^+$ $\rightarrow$ $HOCH_2CH_2OCH_2CH_2OH$ diethyleneglycol

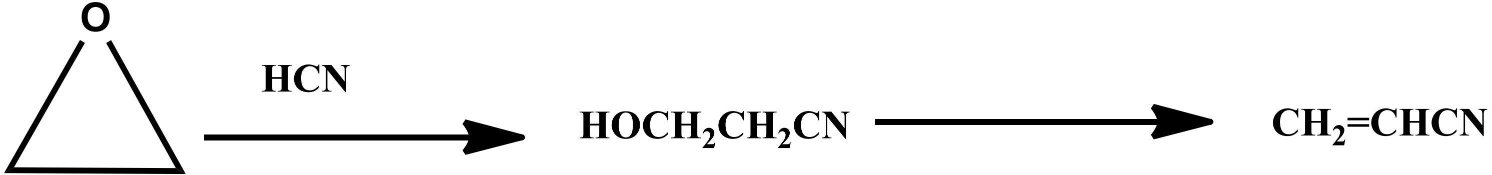
ethanol $\rightarrow$ $C_2H_5OCH_2CH_2OH$ 2-ethoxy ethanol

Reduction using lithium aluminum hydride



red. $LiAlH_4$ $\rightarrow$ CH_3CH_2OH ethanol

With HCN



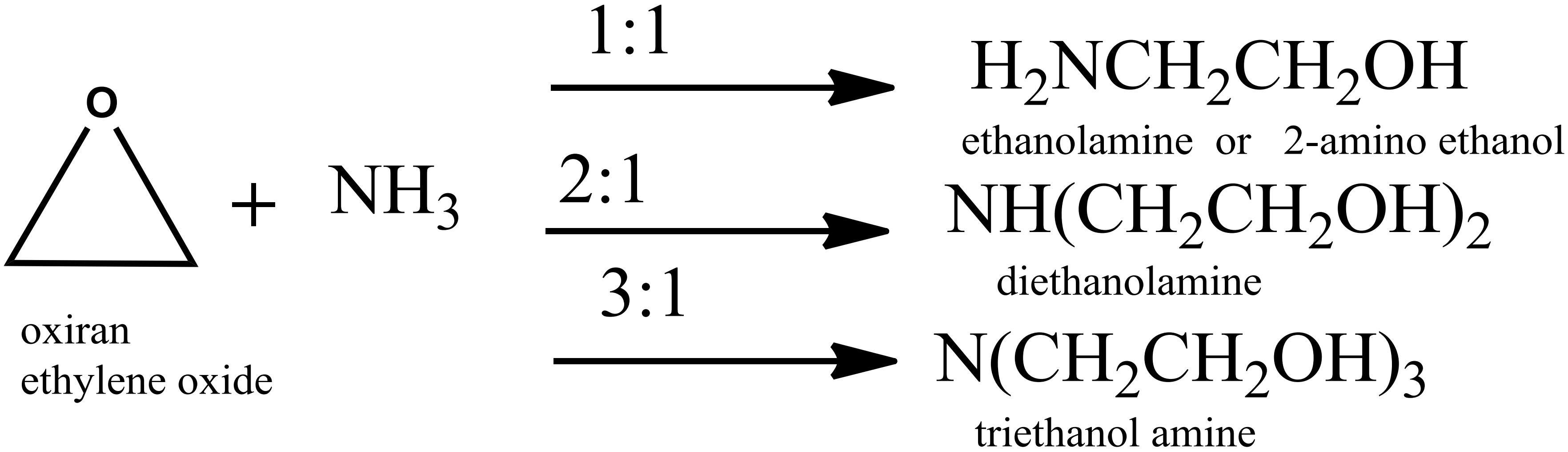
HCN $\rightarrow$ $HOCH_2CH_2CN$ $\rightarrow$ $CH_2{=}CHCN$

Oxiran

2-cyano ethanol

acrylonitrile used in manufacture of Orlon

With ammonia



oxiran
ethylene oxide

$+ NH_3 \xrightarrow{1:1} H_2NCH_2CH_2OH$

ethanolamine or 2-amino ethanol

$\xrightarrow{2:1} NH(CH_2CH_2OH)_2$

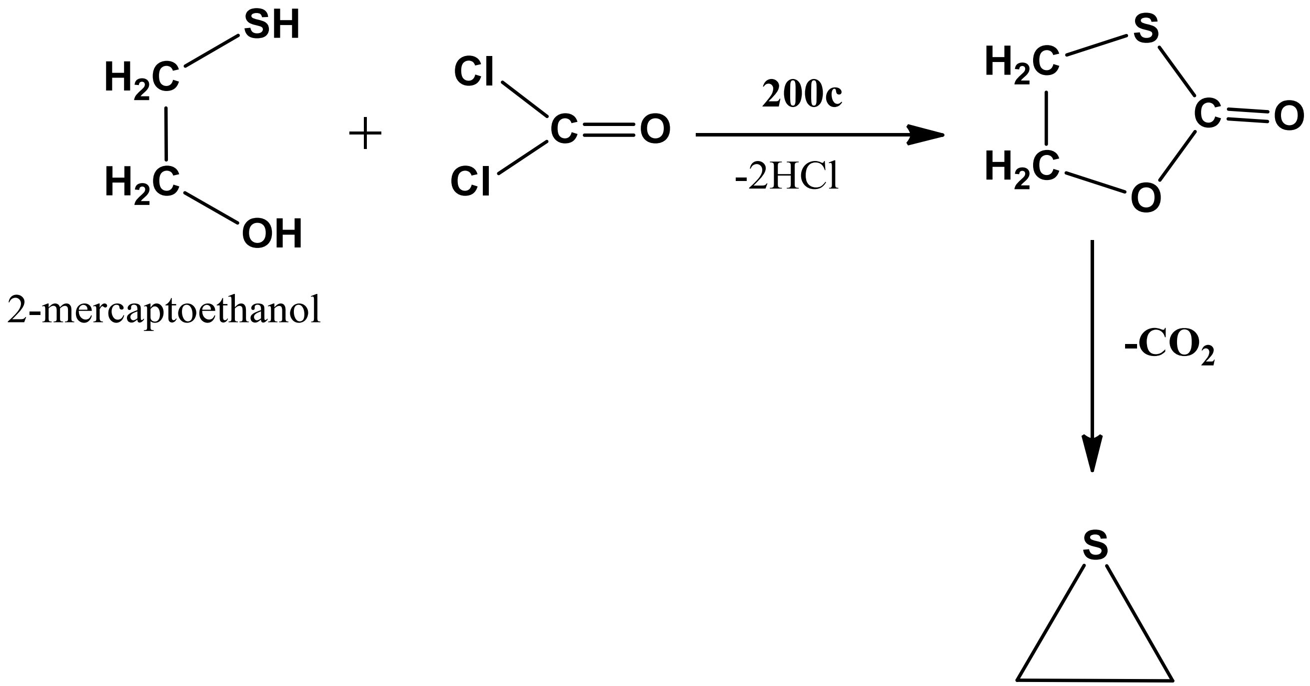
diethanolamine

$\xrightarrow{3:1} N(CH_2CH_2OH)_3$

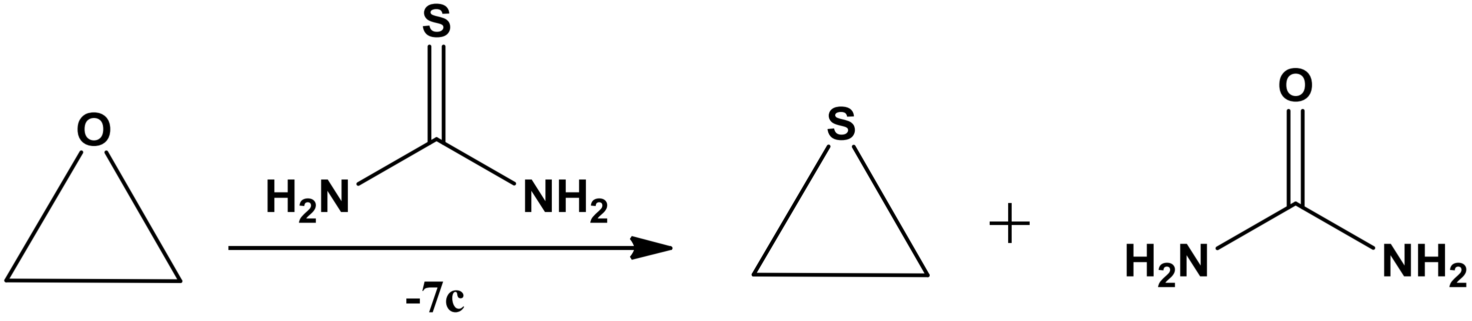
triethanol amine

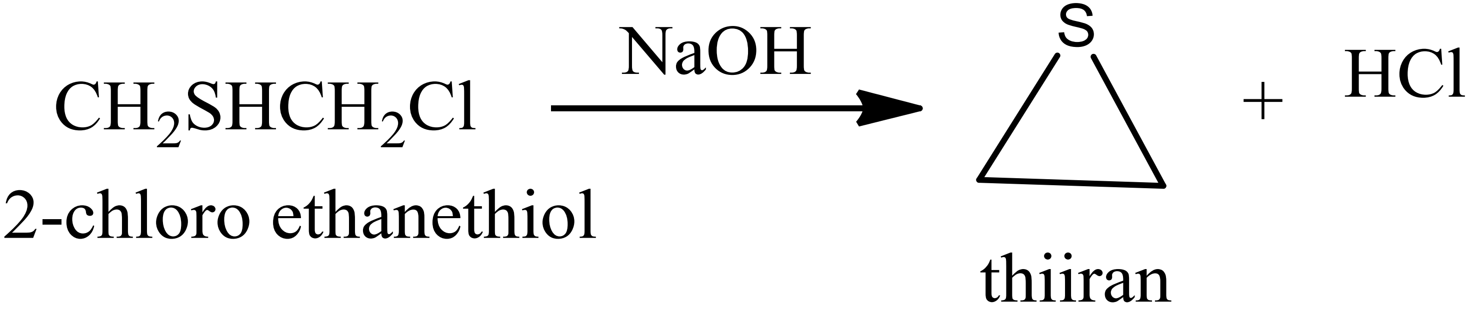
Thiiran

- Preparation
- Reaction between $COCl_2$ and 2-mercaptoethanol in the presence of ethyl acetate and pyridine ,then monothio ethylene carbonate produced and elimination of carbon dioxide to form thiiran.



Conversion of oxirane into thiiran using thiourea



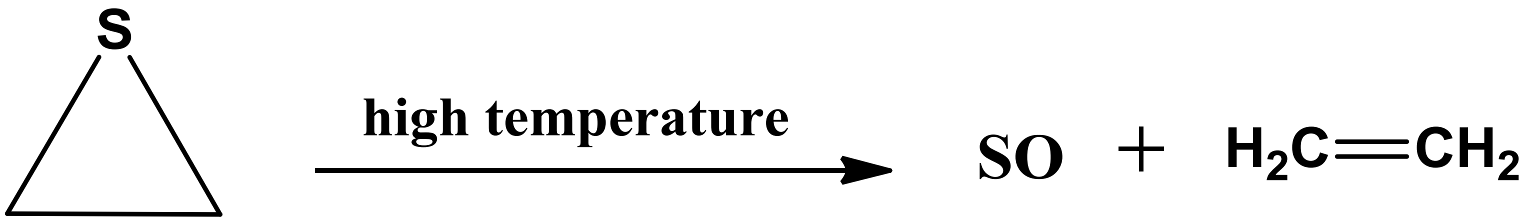


Properties

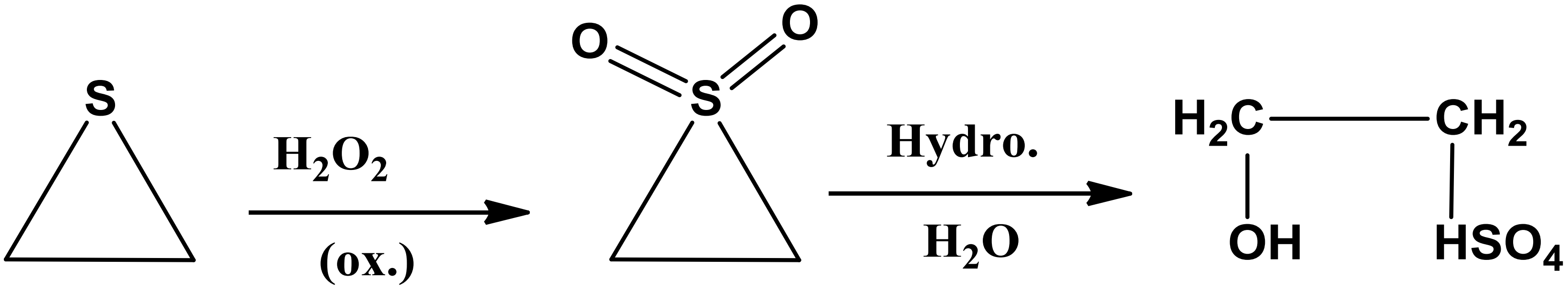
Thiiran is less stable than oxiran

Thiiran can be polymerized in dark or by using ionic catalyst such as mineral acids and bases, also free radicals can be utilized for polymerization.

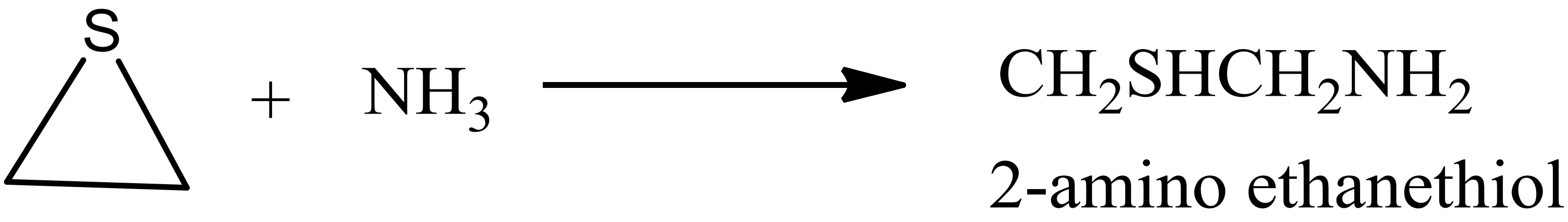
Thermal decomposition



Ring opening

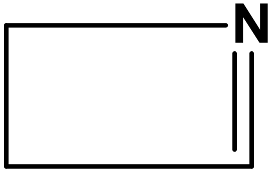


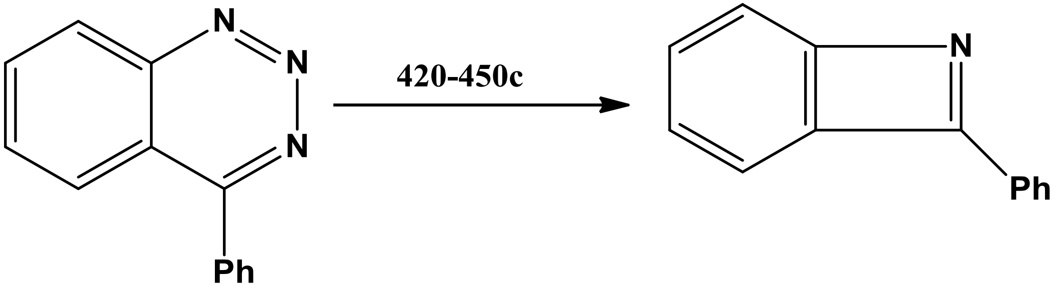
With ammonia



thiiran

المركبات الغير متجانسة الرباعية الحلقة Four membered ring
ازيت Azete

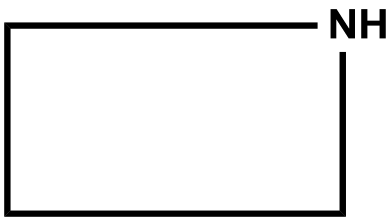




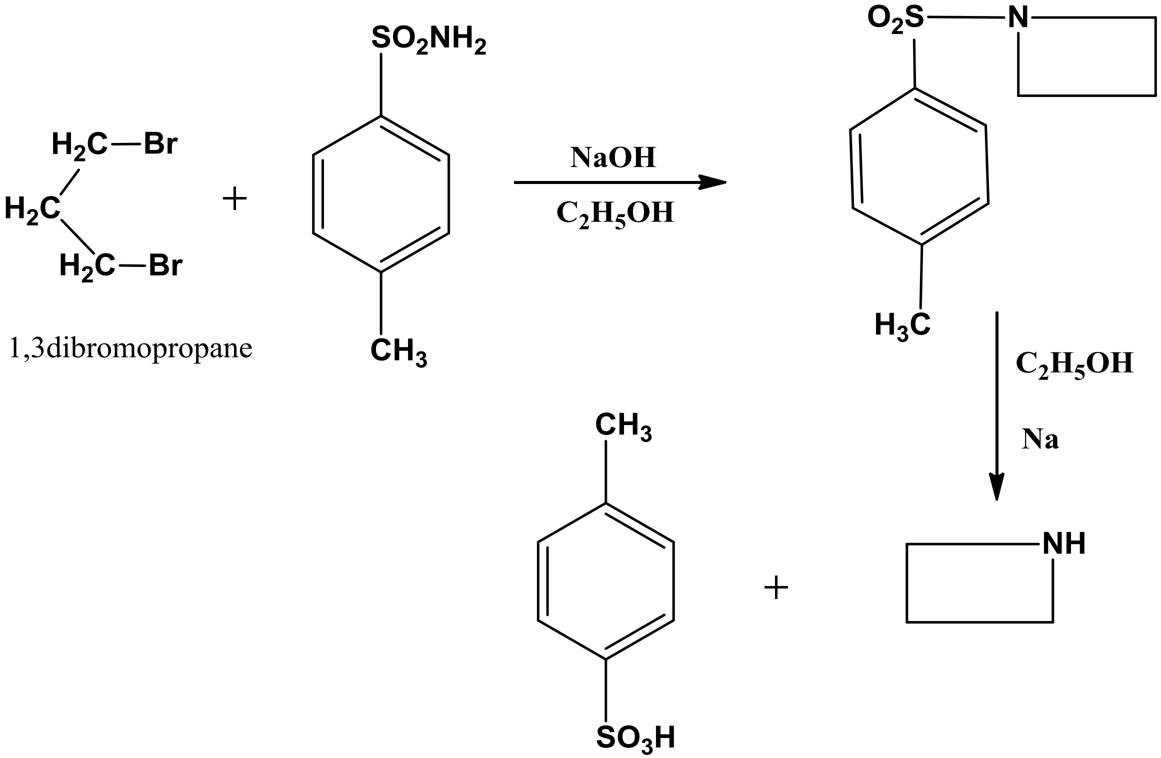
Benzotriazoline 2-phenyl benzo azete

بنزوتريازولين ٢-فينيل بنزوأزيت

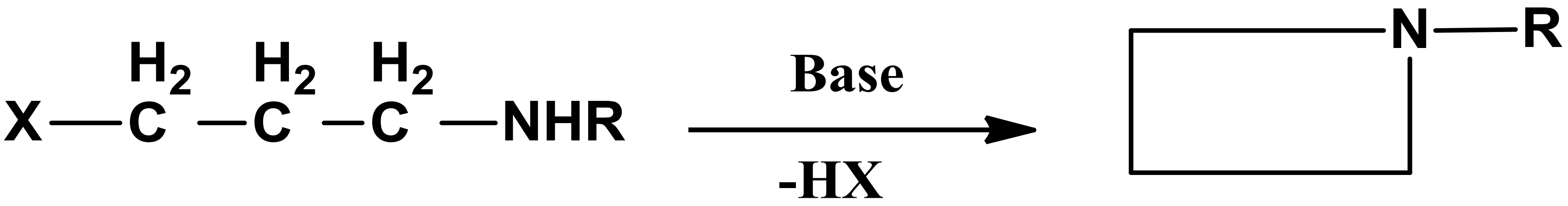
Azetidine , trimethyleneimine or azacyclobutane



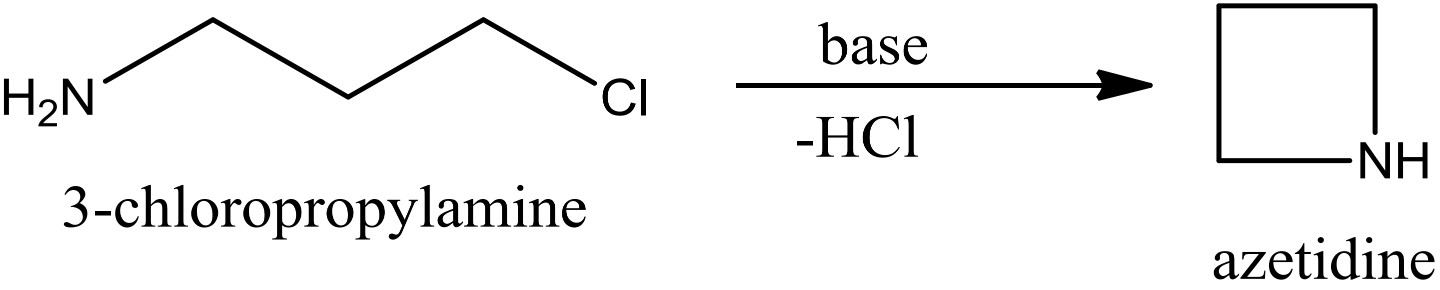
Preparation :



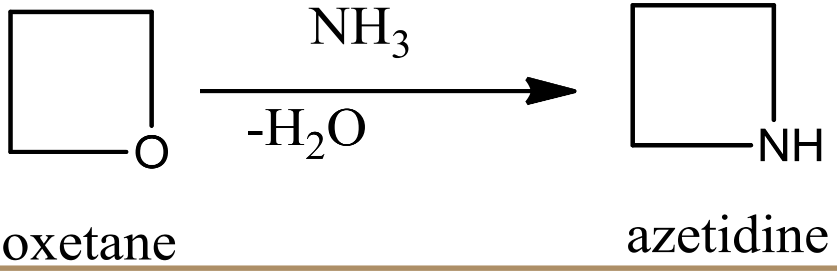
2. By using 3-halopropyl amine , 1-alkyl azetidine is formed .

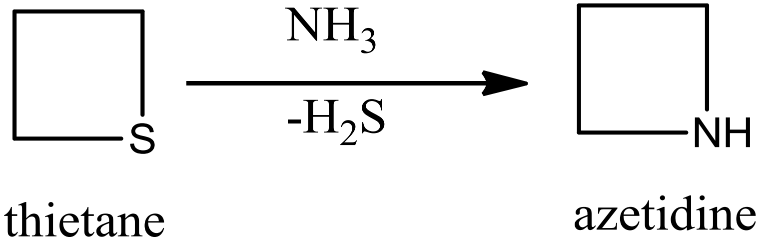


$$X-\overset{H_2}{C}-\overset{H_2}{C}-\overset{H_2}{C}-NHR \xrightarrow[-HX]{Base}$$



3- From other heterocycles

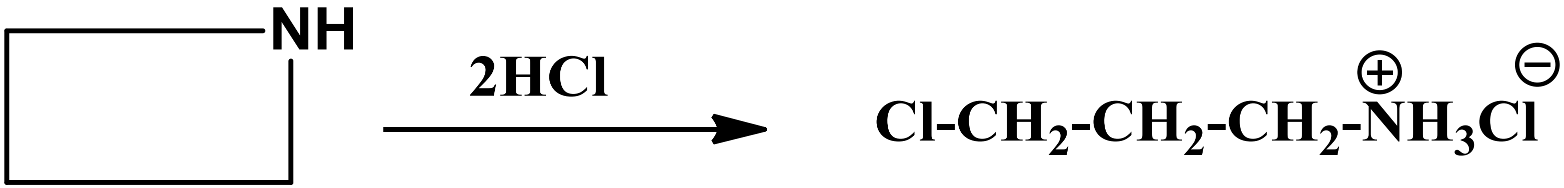




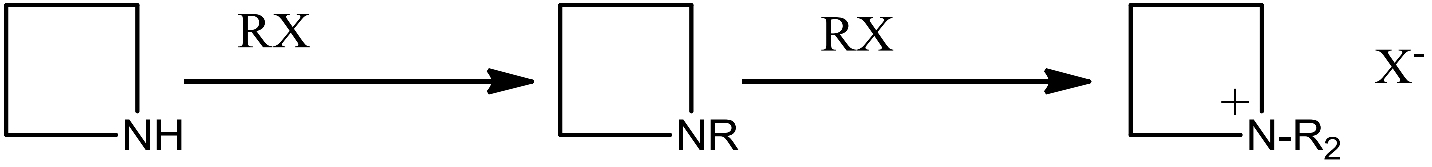
Chemical properties

Aziridine more active than azetidine,azetidine miscible with water and more basic and more stable than aziridine.

Effect of HCl and alkyl halide (quaternary amm. Salt)



$$Cl\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}\overset{\oplus}{N}H_3\overset{\ominus}{Cl}$$

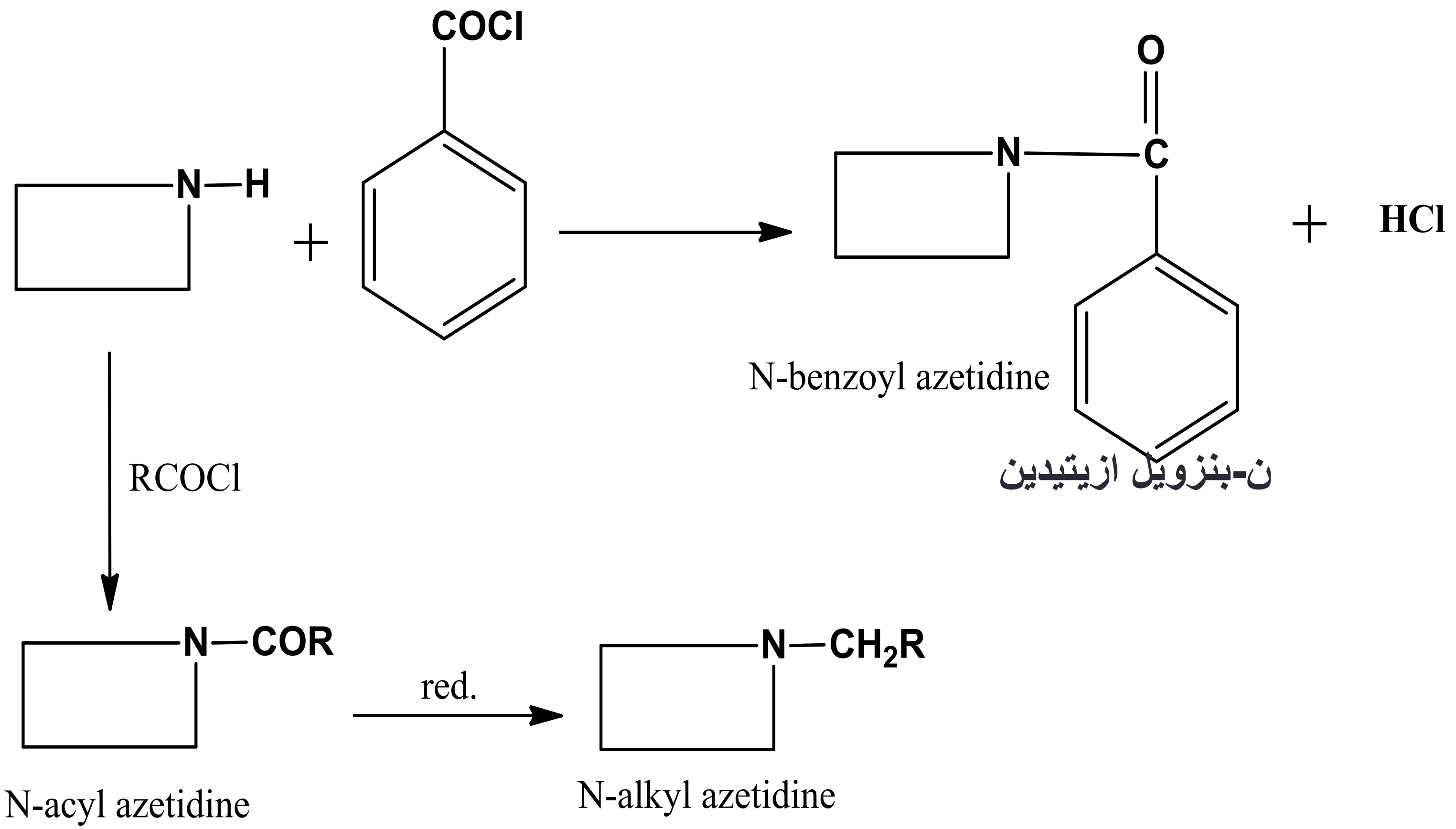


azetidine

N-alkylazetidine

N,N dialkylazetidinium halide

3. Benzoylation and acylation .



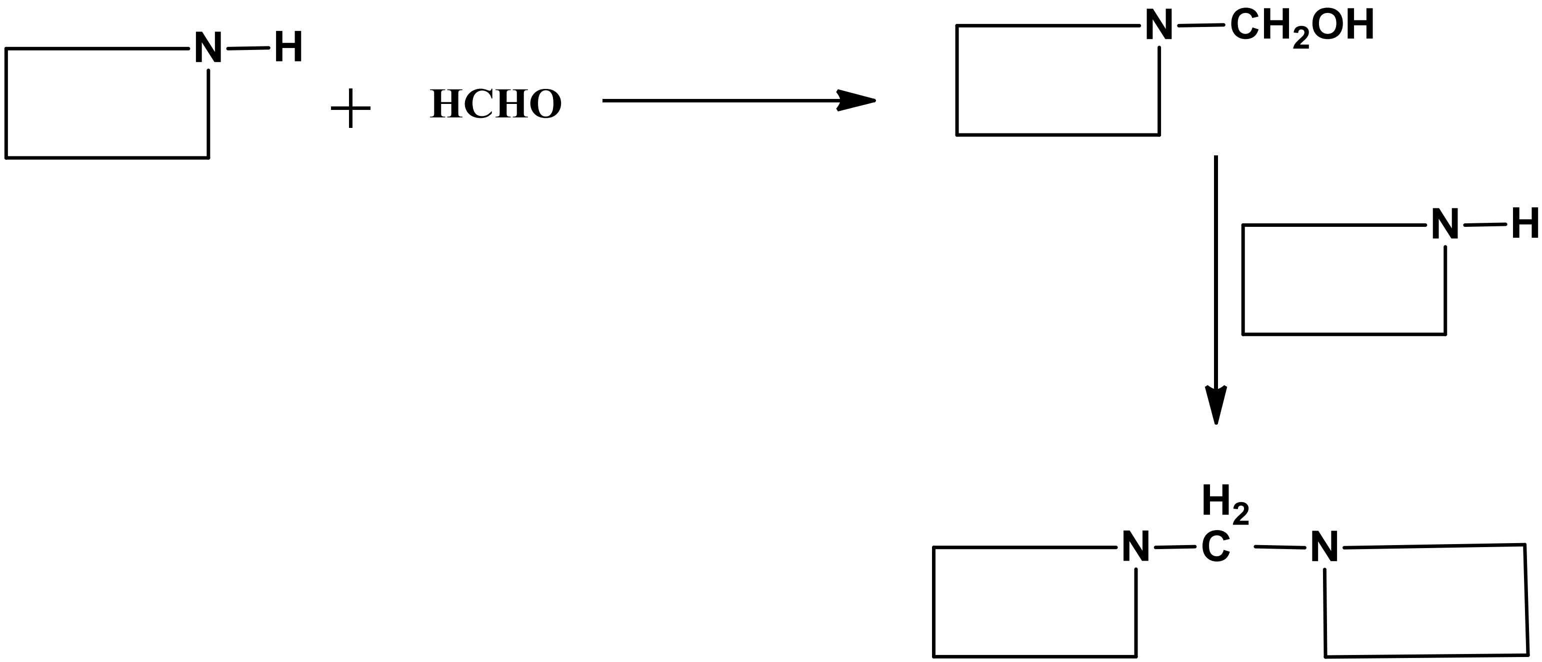
N-benzoyl azetidine

ن-بنزويل ازيتيدين

N-acyl azetidine

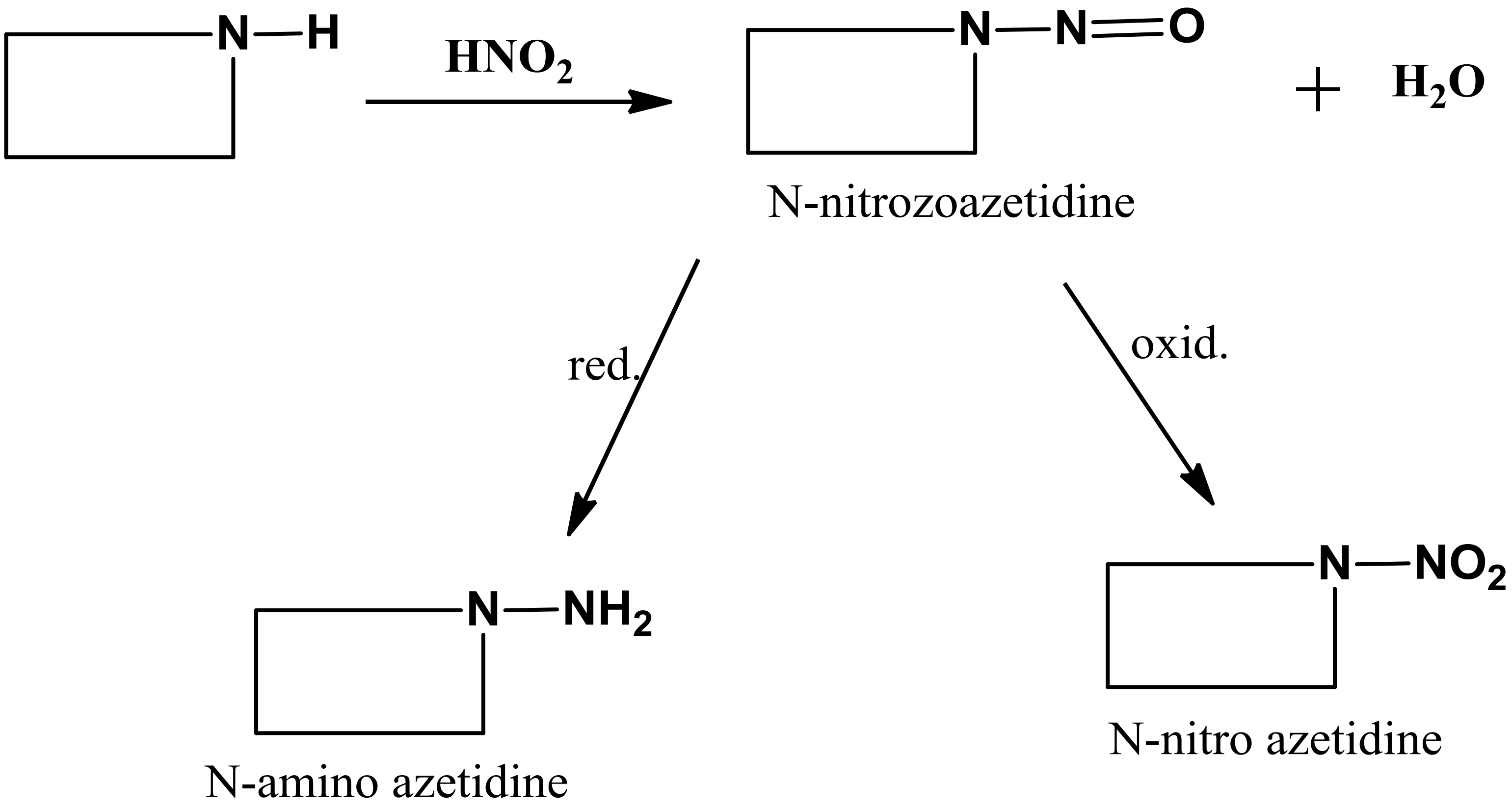
N-alkyl azetidine

4. with formaldehyde



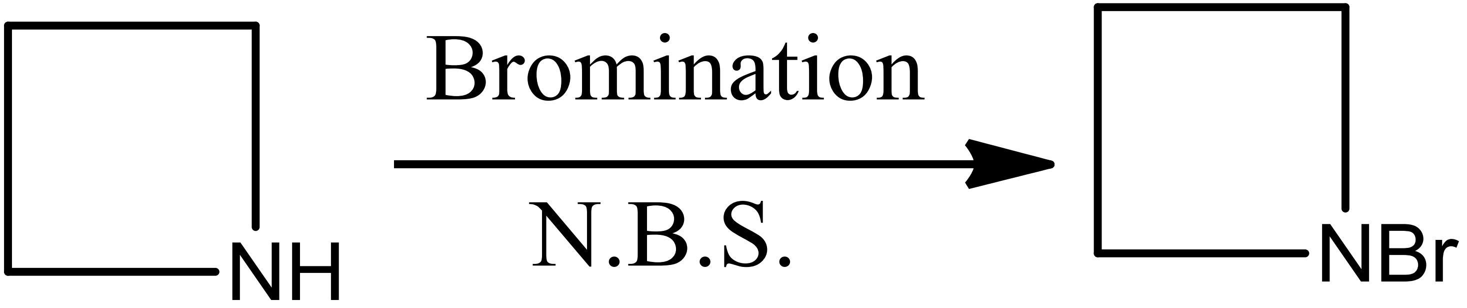
diazetidinylmethane

5. Effect of nitrous acid:



Nitroso azetidine is a viscous yellow oil that boils at 197°C.

with (N.B.S.),N-bromo azetidine is formed



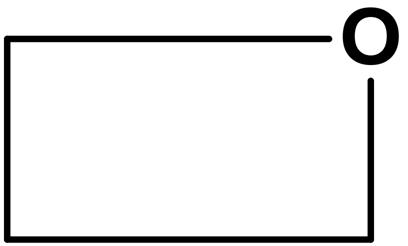
azetidine

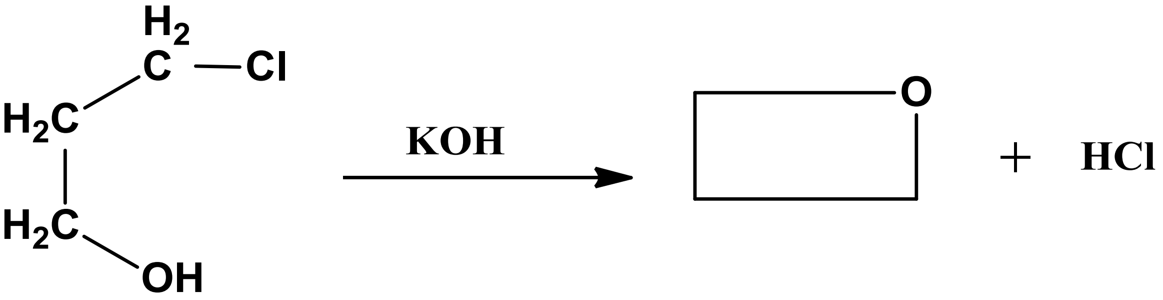
N-bromo azetidine

penicillin

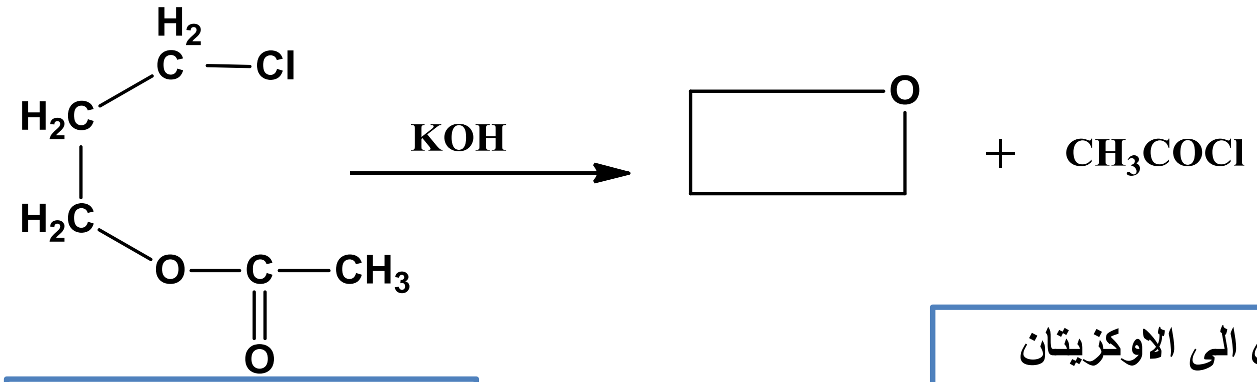
Also, the azetidine ring is found in a keto form, and it is the azeton that is found in the well-known antibiotic penicillin combined with the .thiazole ring.

Oxetan
(trimethylene oxide) - preparation



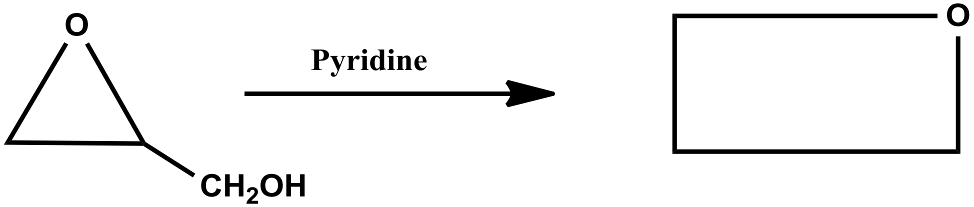


٣-كلوروبروبانول
3-chloro propanol

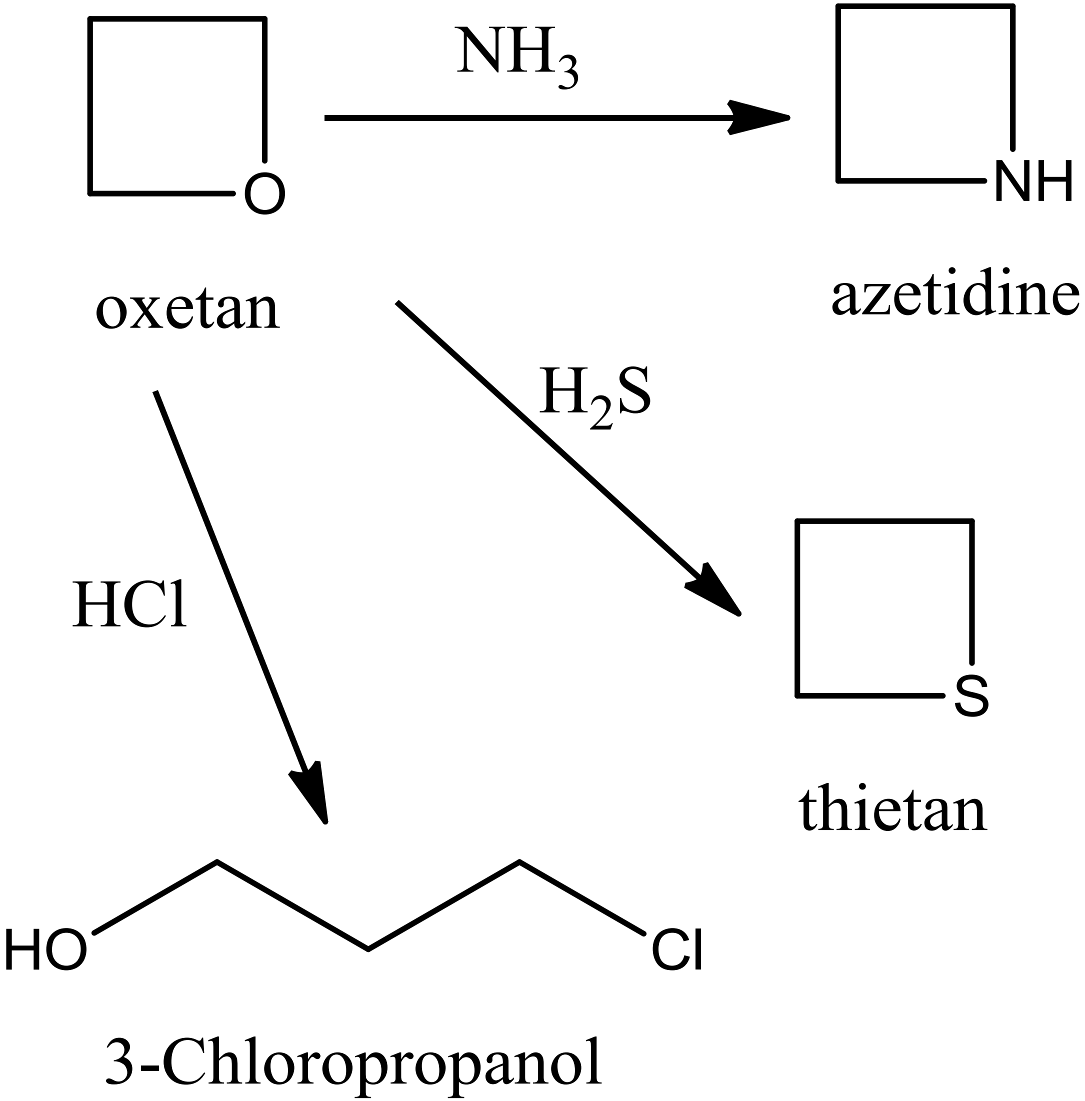


كلورو خلات البروبيل
Chloro propyl acetate

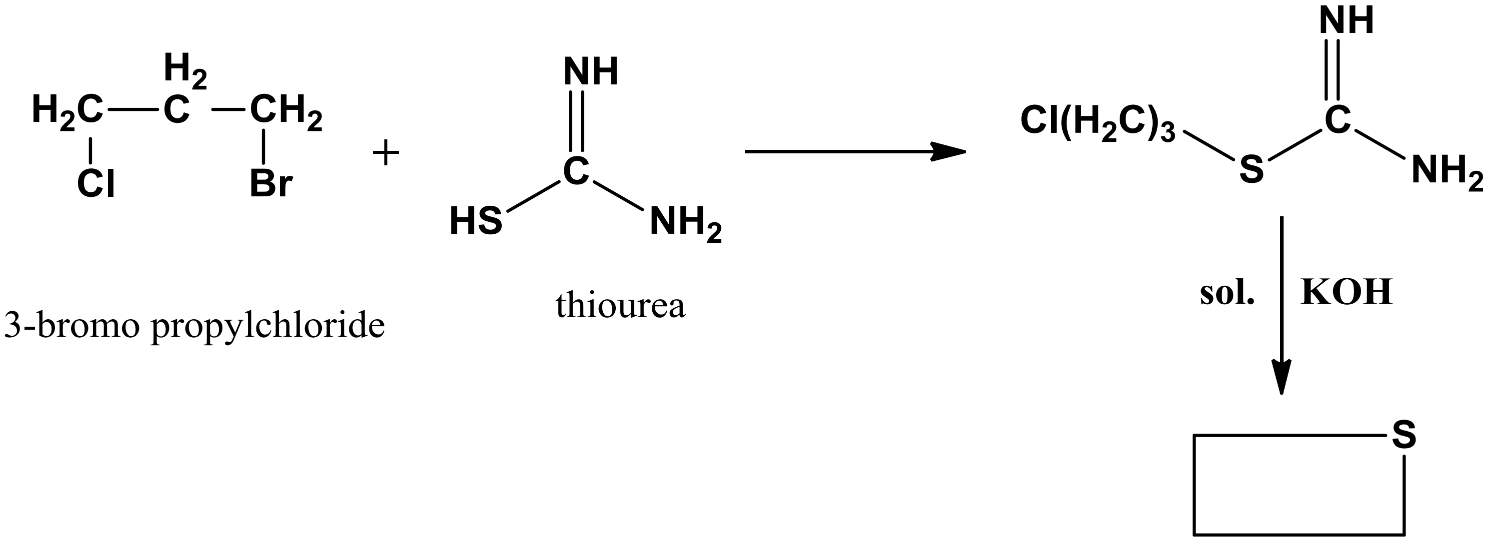
التعديل الجزئي لحلقة الاوكزيران الى الاوكزيتان
Rearrangement of oxiran into oxetane



Reactions of oxetan
تفاعلات اوكزيتان

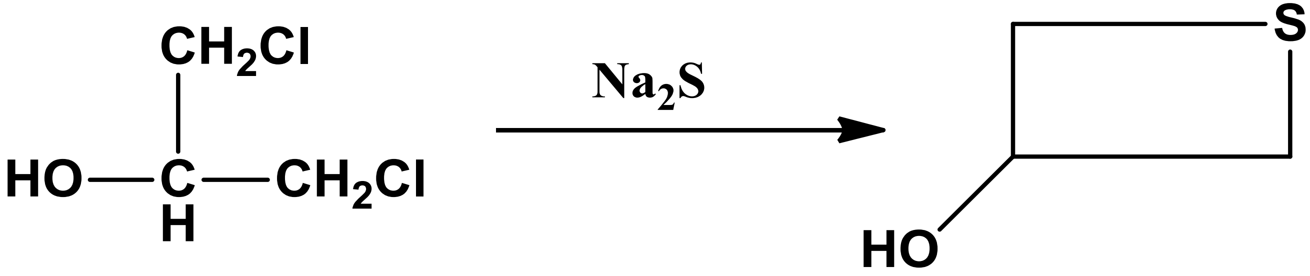


Thietan ,trimethylene sulphide ,1,3propylene sulphide



3-bromo propylchloride

thiourea

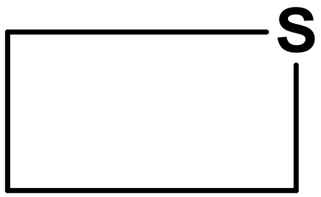


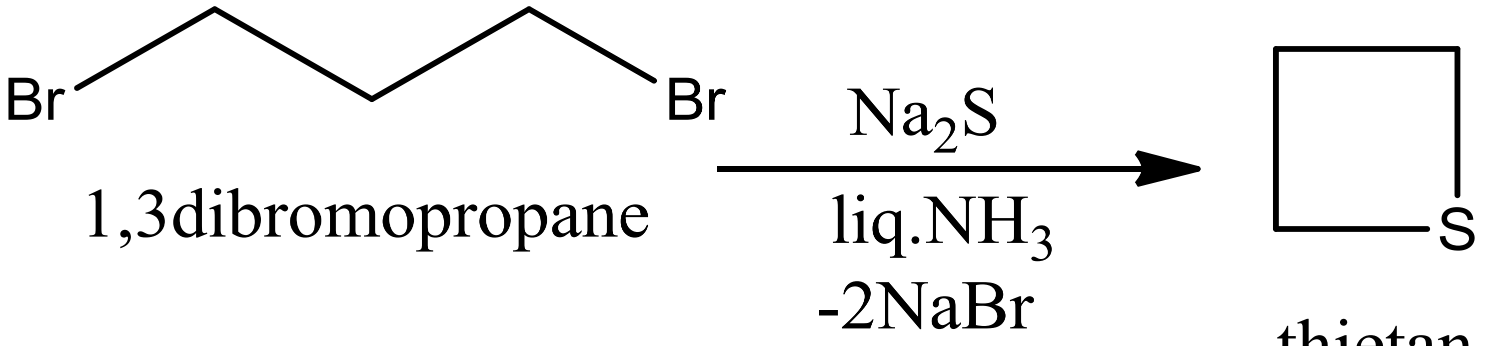
$$\begin{array}{c} CH_2Cl \\ | \\ HO-\underset{H}{C}-CH_2Cl \end{array} \xrightarrow{Na_2S}$$

١،٣-ثنائي كلورو٢-بروبانول
1,3dichloro 2-propanol

٣-هيدروكسي ثييتان
3-hydroxy thietane

Thietan - **prep. Reactions** ثييتان - التحضير –التفاعلات



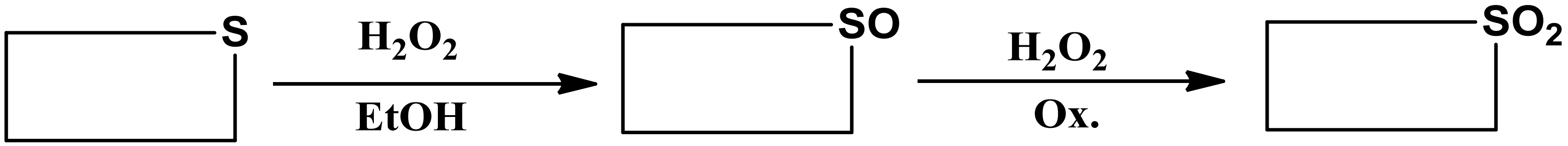


1,3dibromopropane

$\xrightarrow[\text{liq.}NH_3 \;\; -2NaBr]{Na_2S}$

thietan

oxidation الاكسدة



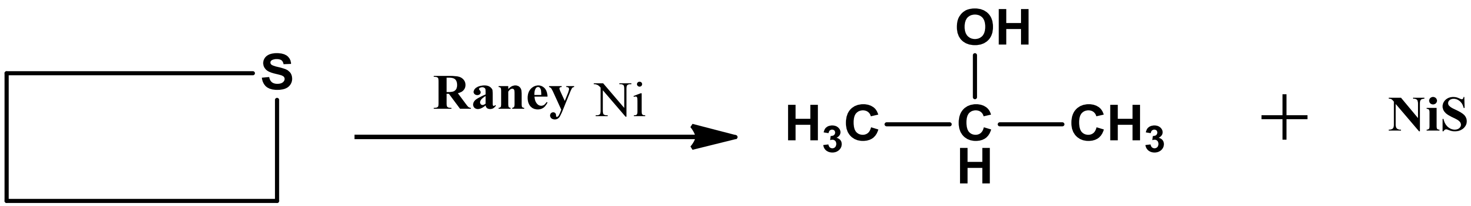
$\xrightarrow[EtOH]{H_2O_2}$ $\xrightarrow[Ox.]{H_2O_2}$

sulphone سلفون

stable oxide أكسيد ثابت

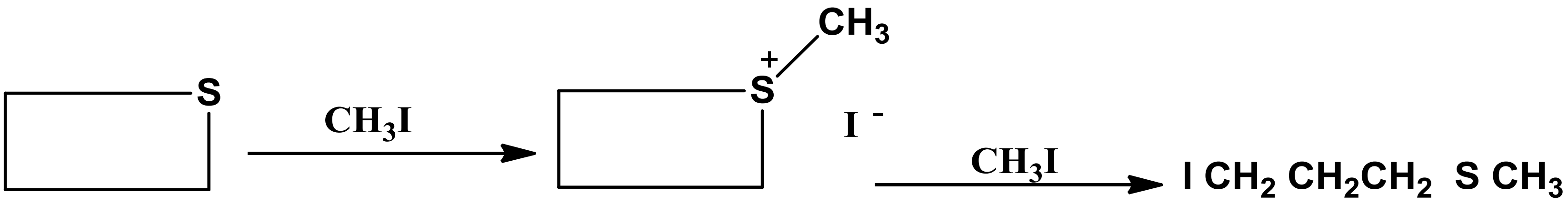
ثييتان – التفاعلات   thietan -   reactions

Removal of sulphur by using raney nickel (alloy from nickel and aluminum with sodium hydroxide)

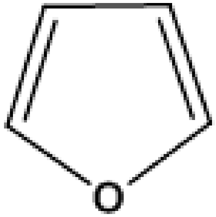


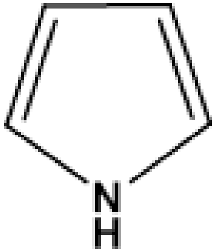
كحول ايزوبروبيلي
Isopropyl alc.

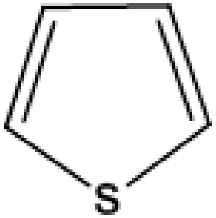
Ring opening:

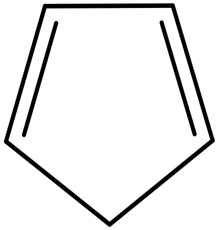


Five membered ring المركبات الغير متجانسة خماسية الحلقة









(Furan)
Oxole

(Pyrrole)
Azole

(Thiophene)
Thiol

cyclopentadiene

- These compounds are the most common and are the simplest heterocyclic compounds as they contain a single heterocyclic atom. And these compounds are Furan, pyrrole, thiophene. It is also expected that the basic reactions of these compounds will be the same for the conjugated dienes of ethers, amines and sulfides (or thioethers). The properties of these compounds deviate greatly from what is expected for conjugated dienes (except for some addition reactions), as well as in their reactions as ethers or as amines, for example thiophene does not oxidize like other sulfates, as well as pyrrole lacks the basic properties characteristic of amines.

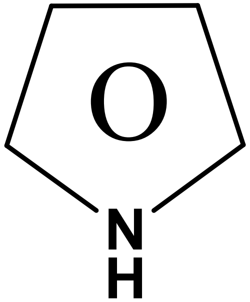
- The heat of combustion of the previous compounds showed a resonance stability in the range of 22 to 28 kilocalories/mole, which is a value less than the resonance energy of benzene (36 kilocalories/mol) and at the same time much greater than the values Conjugated Dienes (within 3 kilocalories/molecule) and based on these facts, we can say that these compounds (furan, pyrrole, thiophene) have aromatic properties.

We can verify this by looking at the picture of the molecular orbitals in one of these compounds, and let this compound be pyrrole, where each atom in the pyrrole ring, whether it is a carbon or nitrogen atom, is linked by a sigma bond (σ) with the other three atoms using three orbitals of The type (sp2), which is located in one plane, and each two orbitals diverge from each other at an angle of 120 degrees. And these orbitals intertwine among themselves, producing pi clouds (cloudsπ) one above the other below the plane of the ring, and these pi-type clouds contain a total of six electrons, i.e. the hexagonal aromatic system

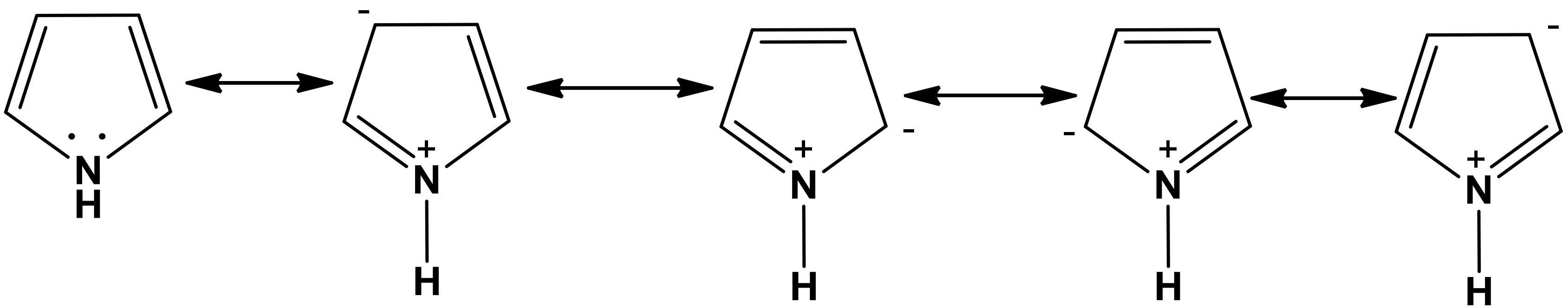
- It is now clear that the electron pair of the nitrogen atom in the pyrrole ring (which is responsible for the basic property in nitrogenous compounds) has become included in the pi cloud and thus becomes unavailable to share with acids. Kb = 2.5 x 10-14).

- Due to the presence of a high electronegativity on the pyrrole ring, this compound becomes highly active towards electrophilic substitution reactions such as nitration or coupling with diazonium salts, and these reactions characterize active benzene derivatives such as phenols and aromatic amines

- **pyrrole**

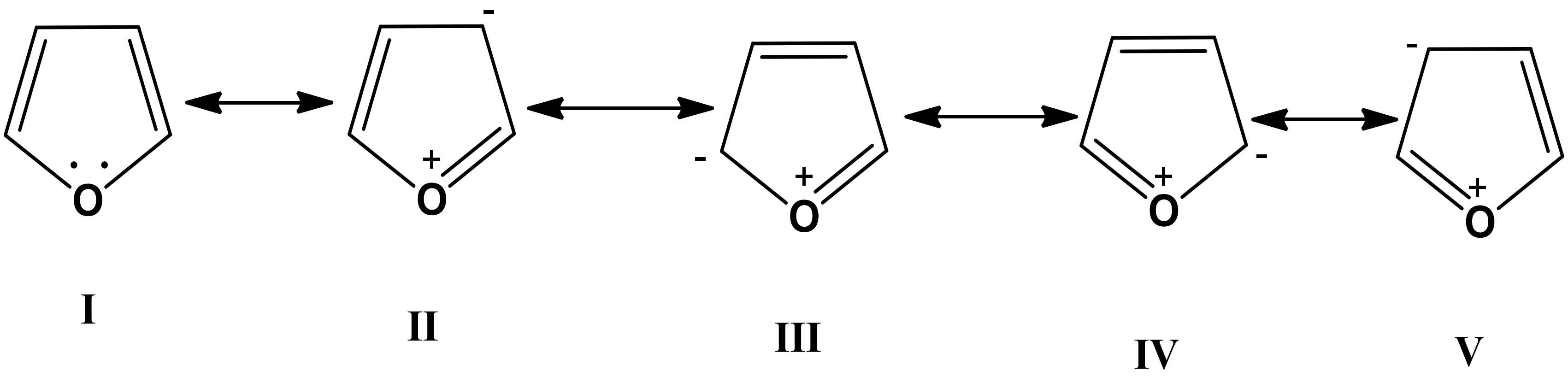


The circle inside the ring represents the hexagonal aromatic system, and the previous structural form can be illustrated by the following resonance images, where nitrogen gives a pair of electrons to the ring, and thus the nitrogen becomes positive and the carbon atoms are negative.



I II III IV V

These resonance images result from the transfer of the electron pair from the nitrogen atom to any of the two adjacent carbon atoms, then the double bonds are modified to get the two forms II, III, we get the two forms IV, V. , II, III, IV, V, and the majority of this mixture consists of two forms II, III, and by applying the same previous rules to the furan compound, we obtain resonance images similar to those of pyrrole as follows:

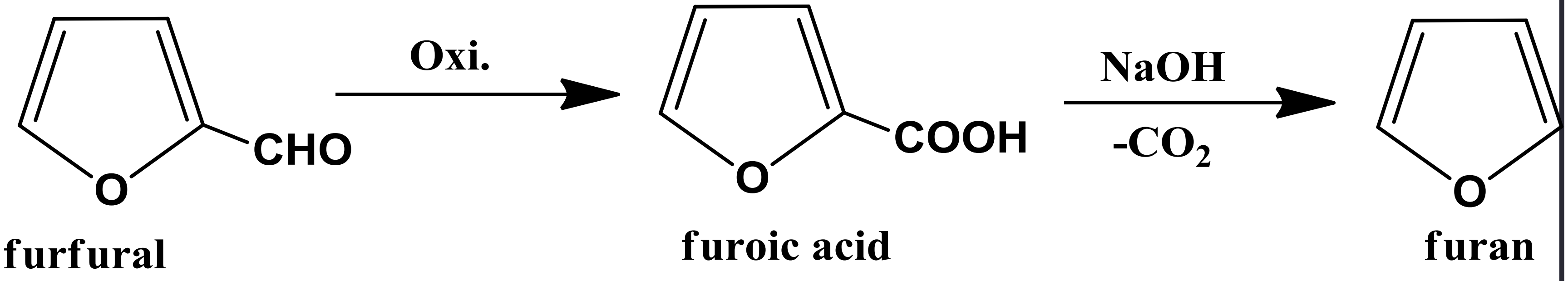


Furan الفيوران

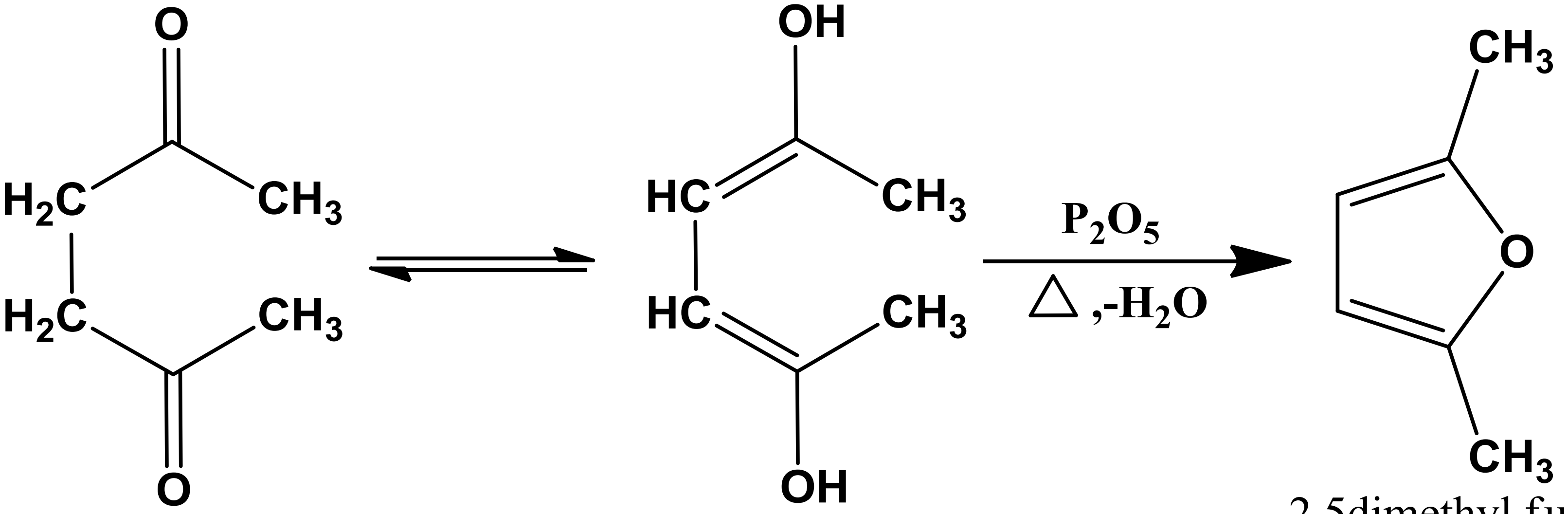
- Furan is a colorless liquid with a low boiling point of 31°C.

- **Preparation**

1. From the oxidation of furfural to furoic acid and then the removal of the carboxyl group from this acid:



2,5-Dimethylfuran can be prepared from acetonylacetone by heating in the presence of phosphorous pentoxide (dehydration)



acetonyl aceton
keto form

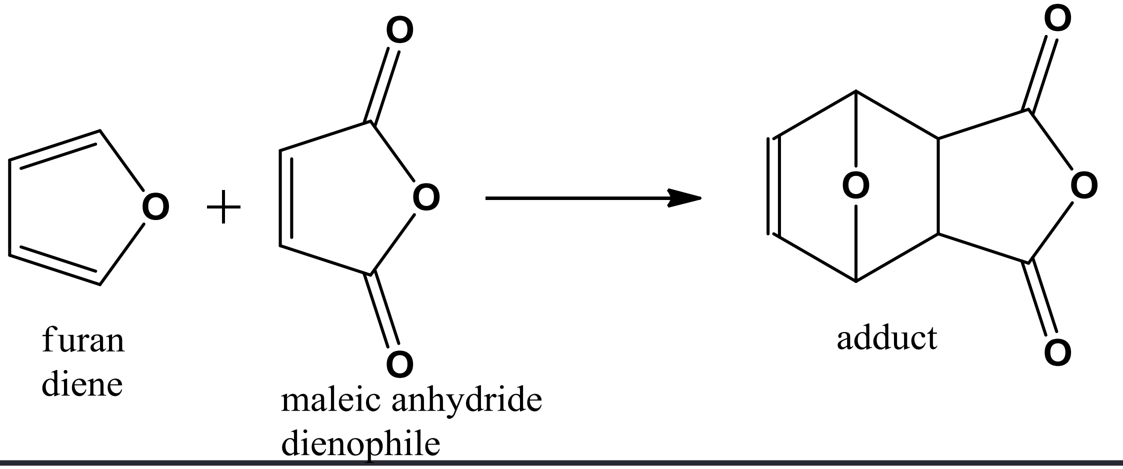
enol form

2,5dimethyl furan

Chemical Properties

First: Furan is a more active aromatic compound than benzene (the resonance energy is lower than that of benzene and is in the range of 23.7-26.54 kilocalories/mole). Due to this activity, furan gives reactions that indicate the presence of two double bonds in an conjugated position, the most important of which is :

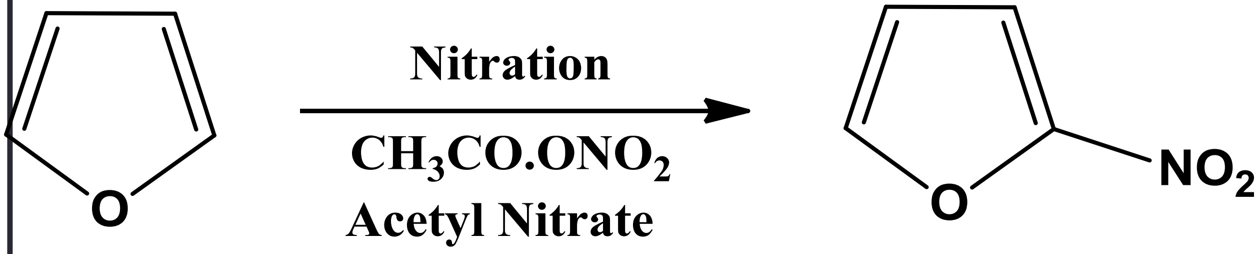
Deals – Alder Reaction This interaction can be represented as follows:



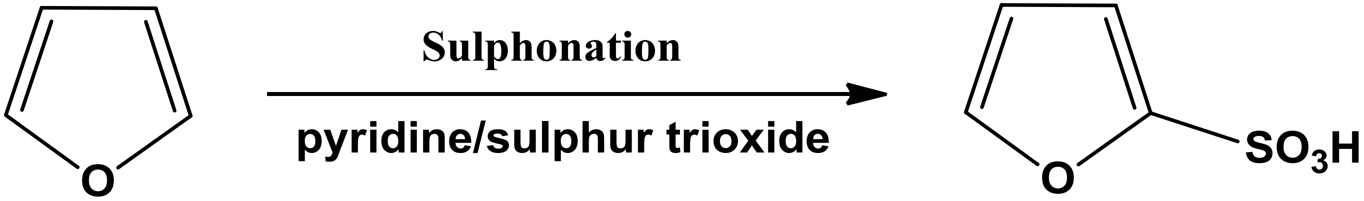
- **2- Substitution reaction**

Furan has aromatic properties similar to those found in benzene, and if the furan is more active, which forces us to reduce the reaction conditions for this electrophilic substitution. The most important of these interactions are:

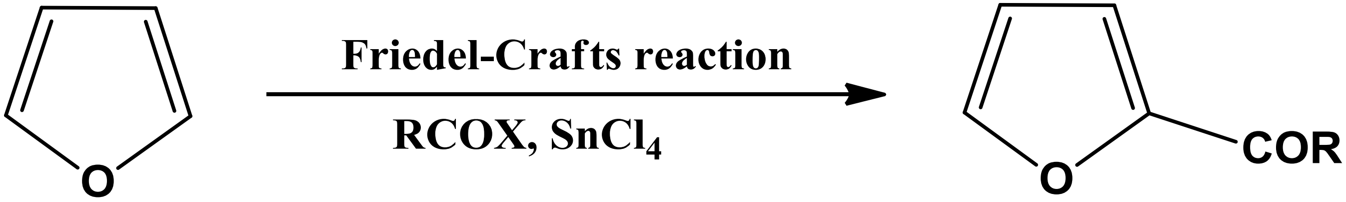
1- Nitration:



2- Sulfonation:

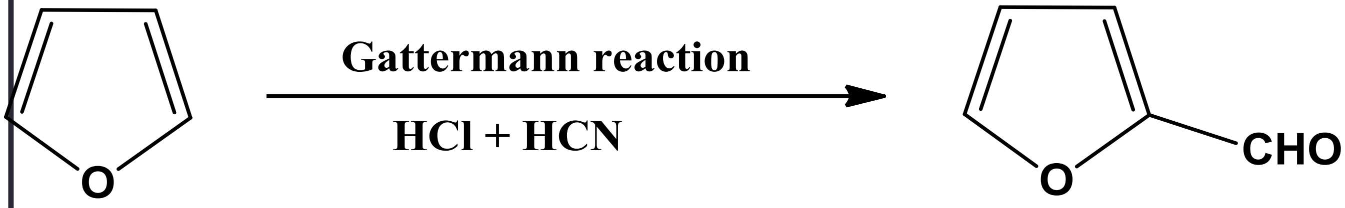


٣- فريدل – كرافت Acylation:

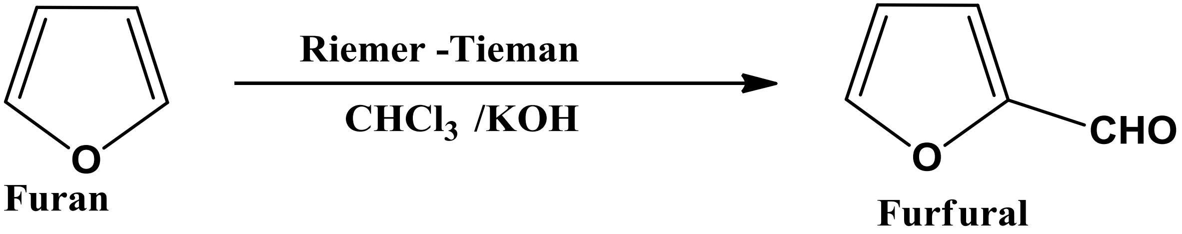


٤-تفاعل جاترمان

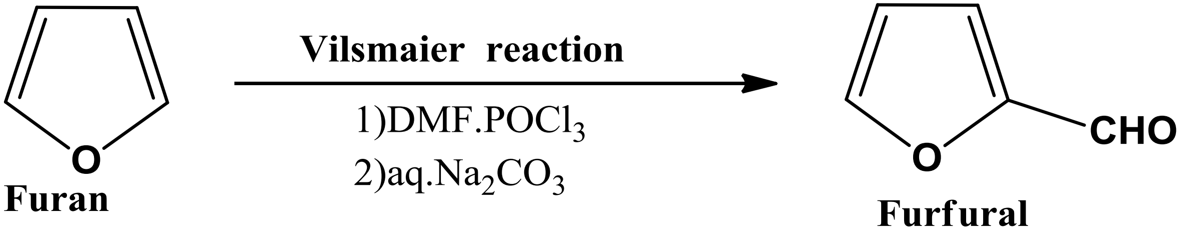
Formylation



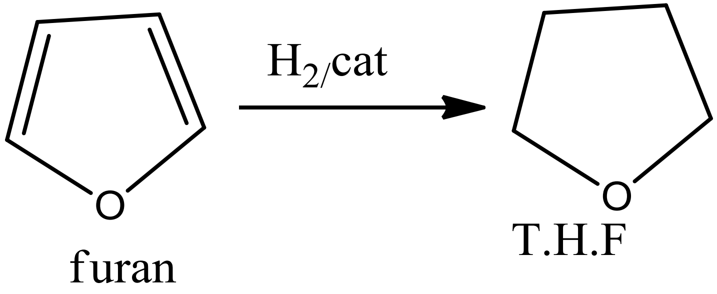
- ٥-تفاعل ريمر-تيمان



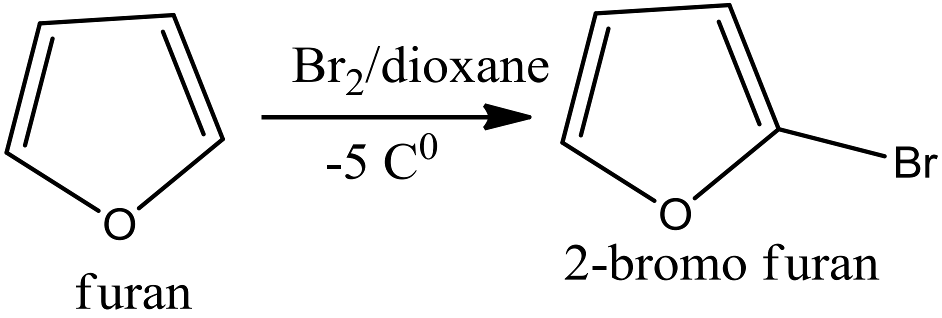
- ٦-تفاعل vilsmeier



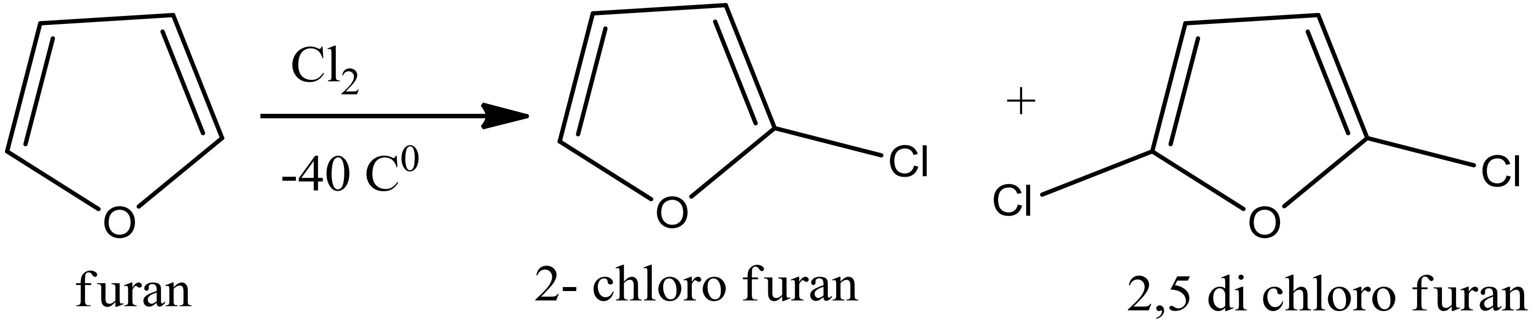
7-Reduction



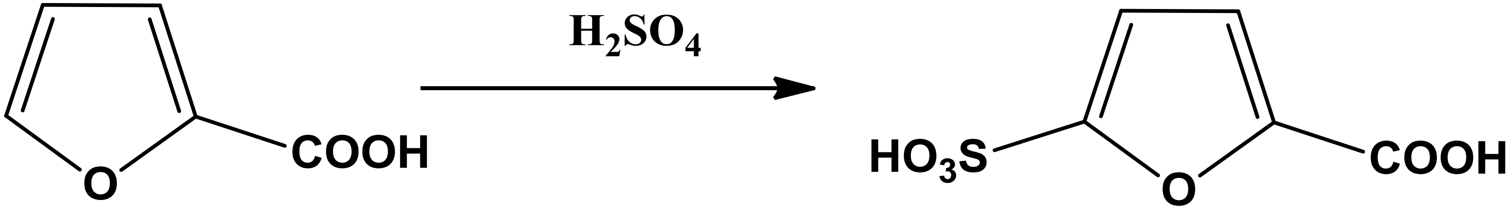
8-Halogenation (Bromination)



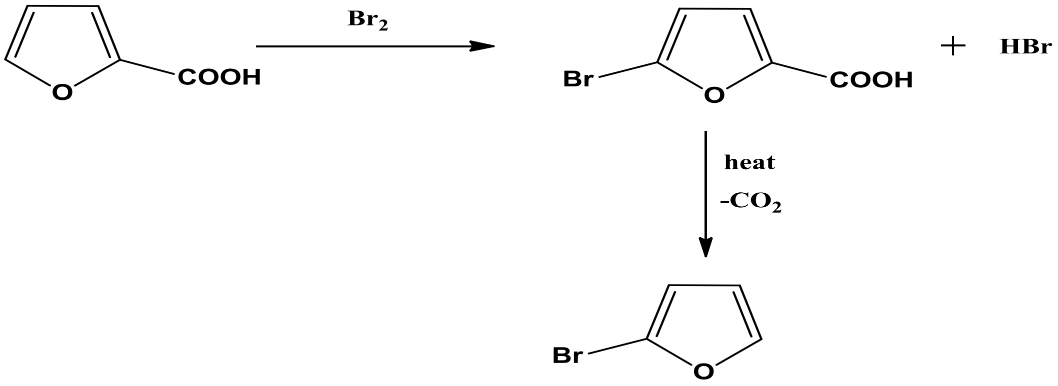
8-Halogenation (Chlorination)



- Some notes on previous substitution reactions: These reactions are mechanically similar to those of benzene Due to the activity of furan from benzene, the reaction conditions here are less severe than those of benzene. Furan can be sulfonated with sulfuric acid directly if there is an electron-withdrawing group in the furan molecule, such as a carboxyl group, as in Furoic Acid sulfonation.

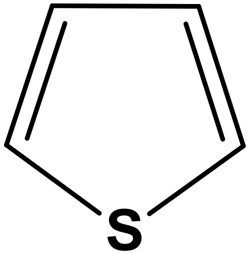


4. Furans cannot be halogenated directly, but an electron-withdrawing group is required in the molecule, as in the following example:



5. By examining the furan molecule using X-rays, the lengths of the bonds are determined, as well as the values of the angles between these bonds, knowing that the lengths are measured in angstroms, which is 8-10 centimeters and the angle is measured in degrees.

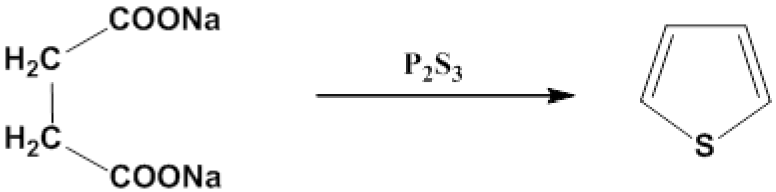
Thiophene الثيوفين



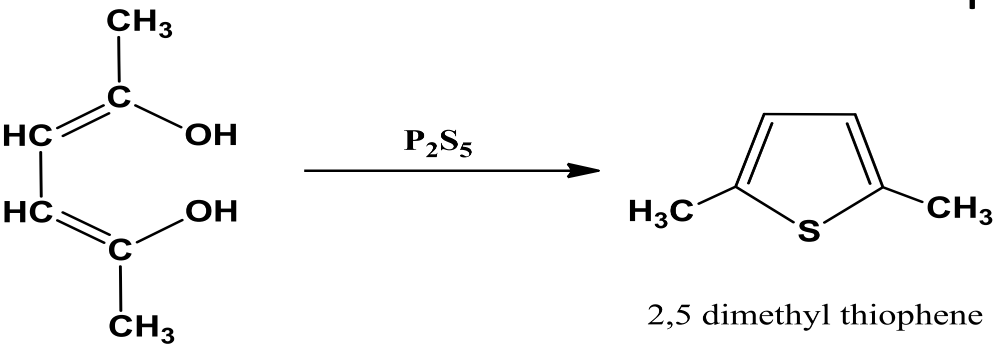
Thiophene is a colorless liquid that boils at 84°C

Preparation

Sodium succinate salt is distilled with phosphorous trisulfide.



From acetonyl acetone



2,5 dimethyl thiophene

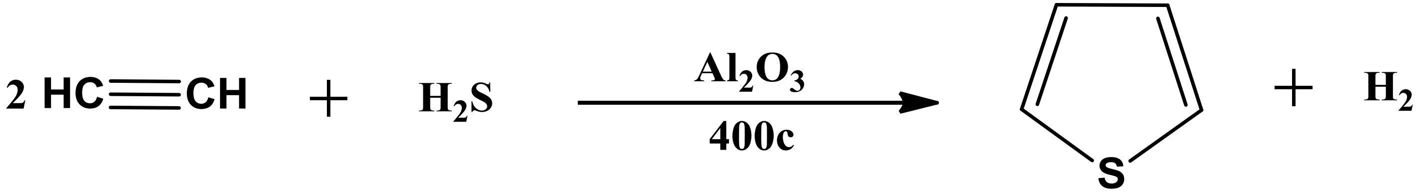
enol form of acetonylacetone

٢،٥ ثنائي ميثيل ثيوفين

اسيتونيل اسيتون(اينول)

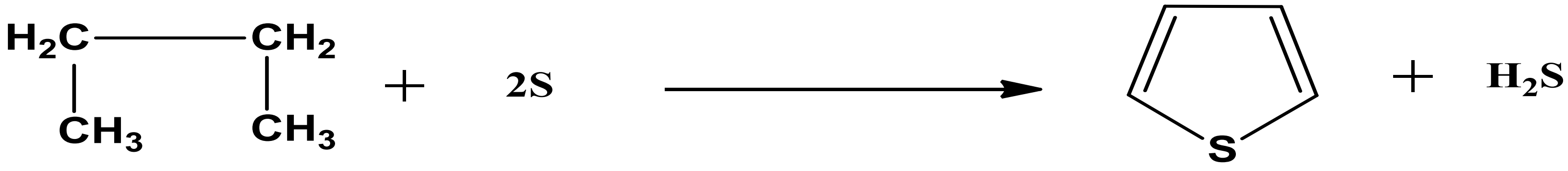
Preparation of thiophene

3- Heating a mixture of acetylene and hydrogen sulfide in the presence of alumina as a catalyst at a temperature of 400°C



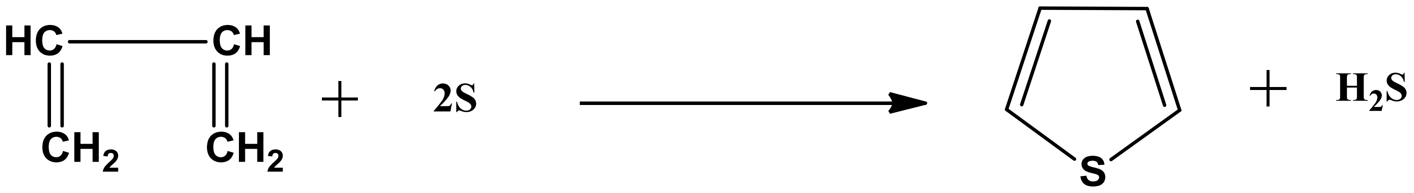
In industry

Heating a gas mixture of n- butane with elemental sulfur



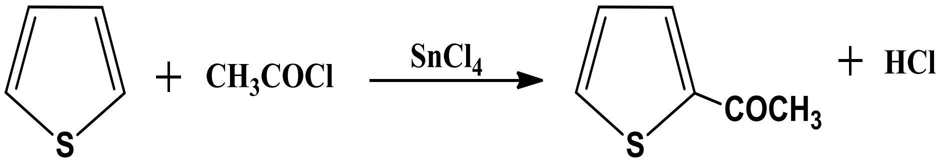
تحضير الثيوفين –التفاعلات
Preparation of thiophene-Reactions

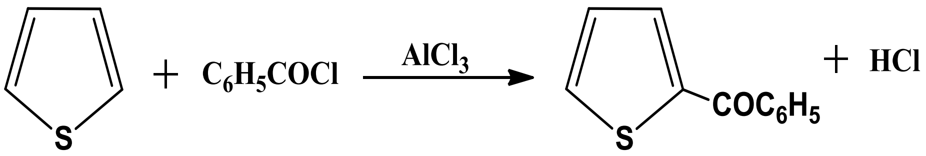
Heating butadiene with S تسخين البيوتادايين مع الكبريت.



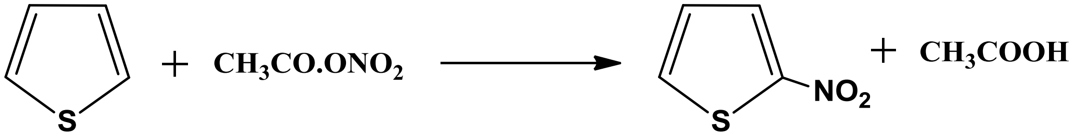
Reactions of thiophene:

Friedel – Crafts reaction :تفاعل فريدل - كرافتس





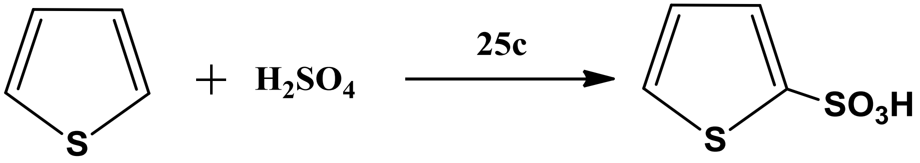
Nitration Reaction :تفاعل النيترة



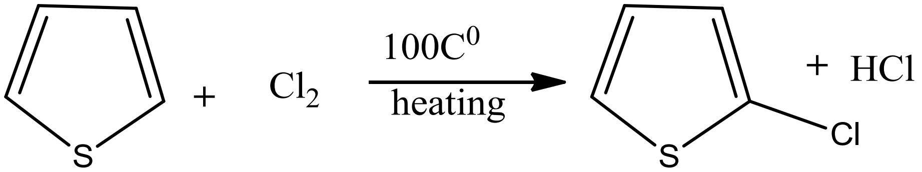
2-Nitrothiophene

Reactions of thiophene تفاعلات الثيوفين

Sulphonation reaction :تفاعل السلفنة



Halogenation :الهلجنة

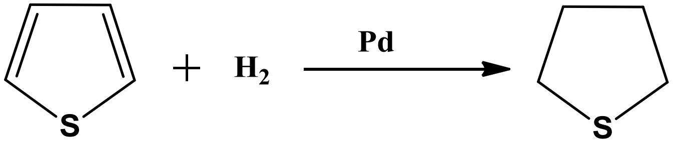


thiophene

2-Chloro thiophene

Hydrogenation :الهدرجة

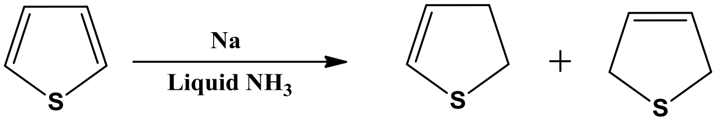
Full hydrogenation :هدرجة كاملة



thiophene

tetrahydrothiophene
thiolane

Partial hydrogenation :هدرجة جزئية



thiophene

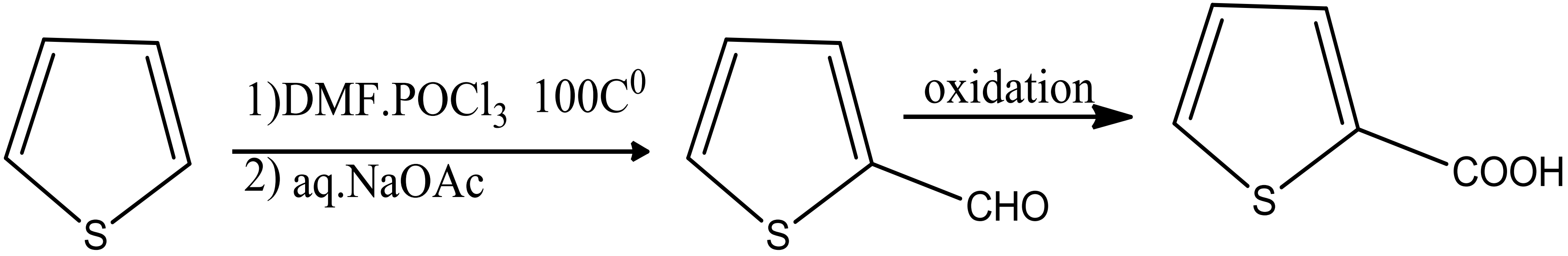
2,3dihydrothiophene

2,5dihydrothiophene

٢،٥-ثنائي هيدروثيوفين ٢،٣-هيدروثيوفين

Reactions of thiophene تفاعلات الثيوفين

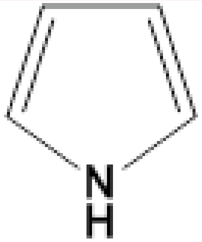
Formylation Vilsmeier –Hack reaction فورملة



thiophene

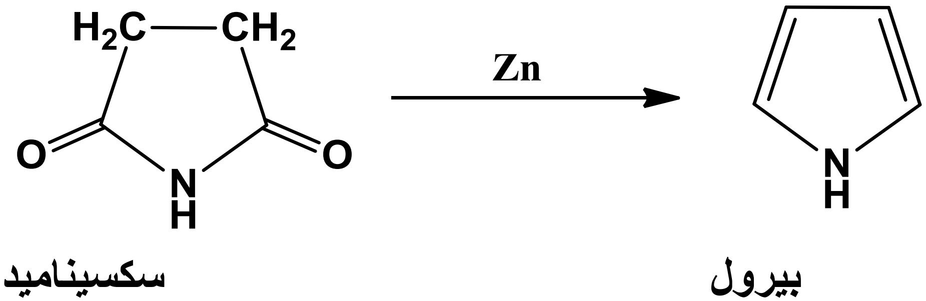
2- formyl thiophene

thiophene 2-carboxylic acid

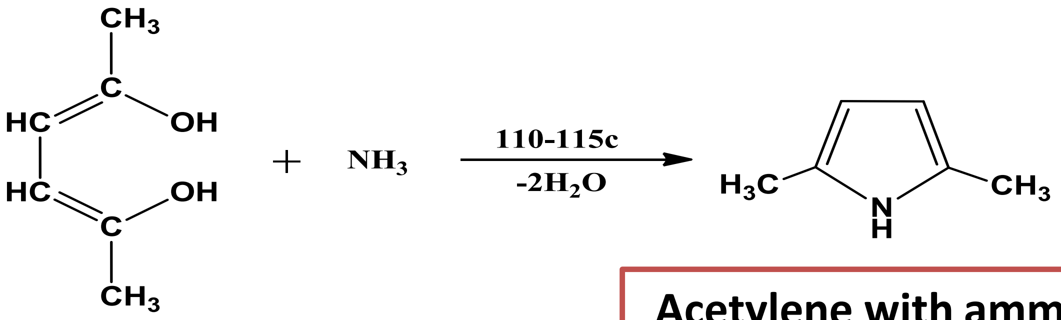


Pyrrole البيرول

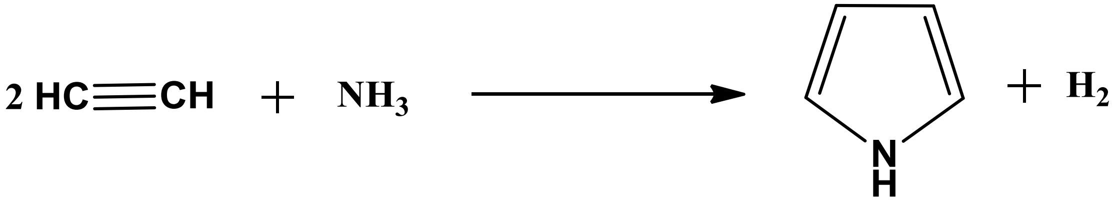
طرق تحضير البيرول preparation



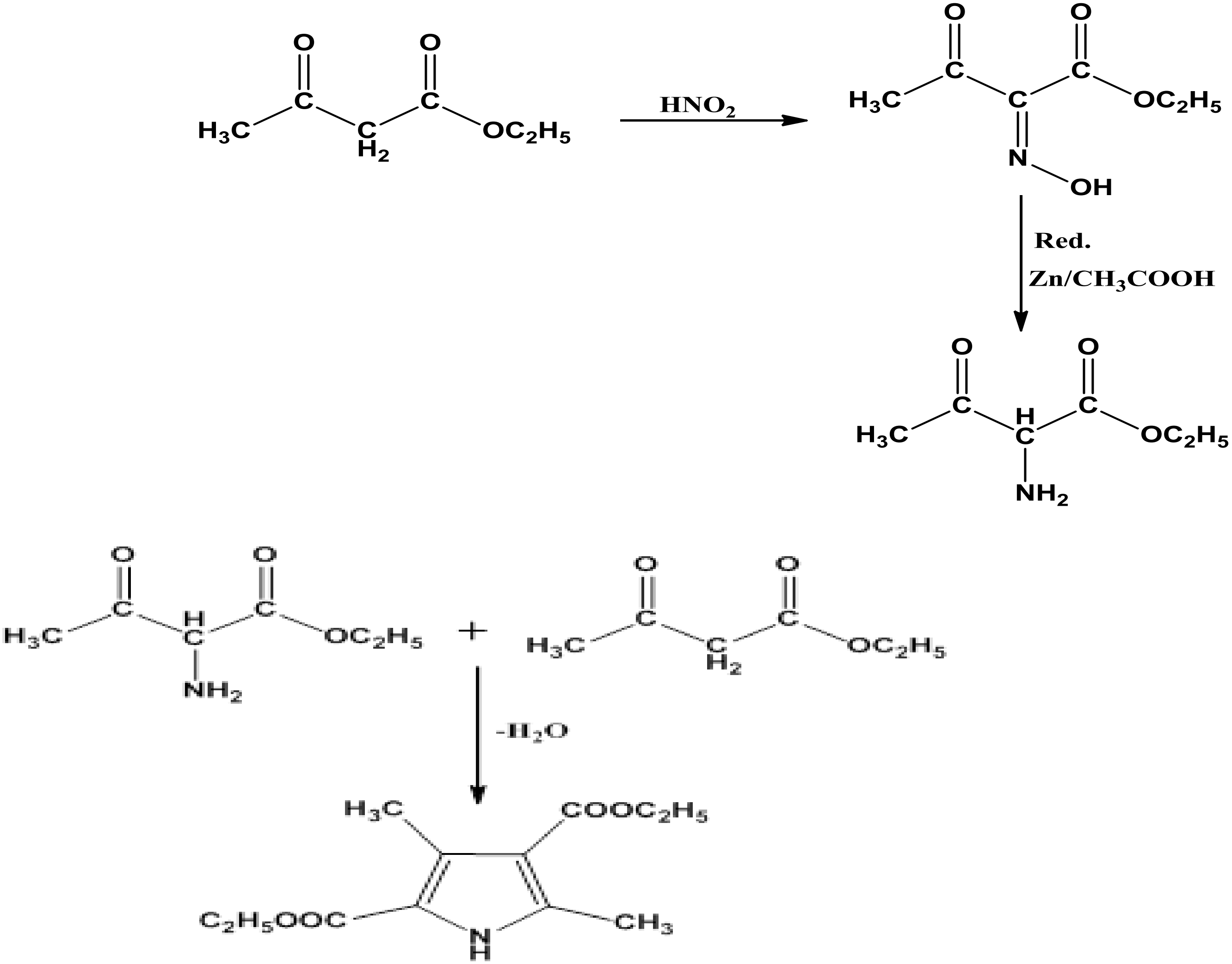
From acetonyl acetone (enol form) with ammonia



Acetylene with ammonia at high temperature

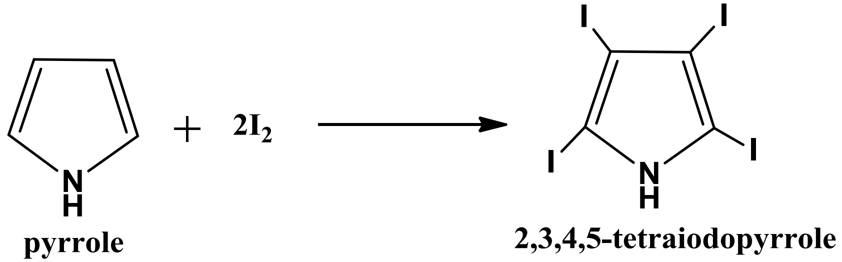


Pyrrole البيرول

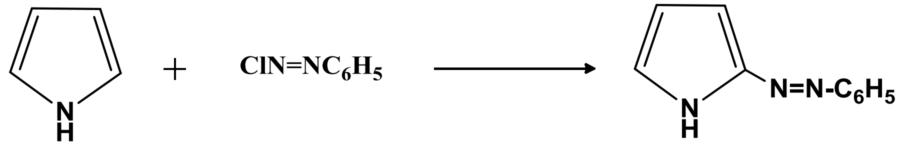


Pyrrole البيرول
Chemical reactions التفاعلات الكيميائية

Electrophilic substitution
Halogenation

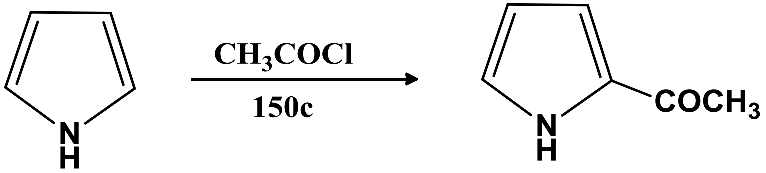


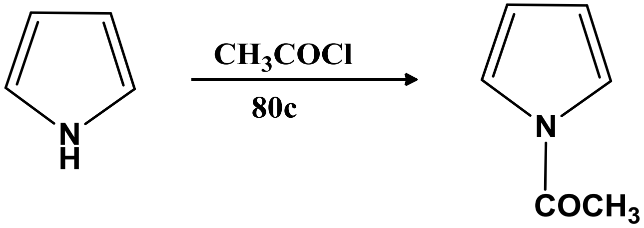
with diazonium salt



Alkylation and acylation

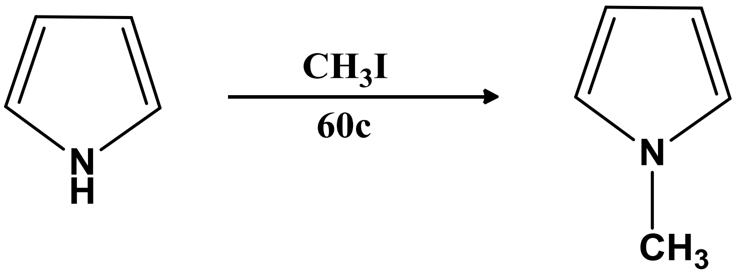
Acetylation at high temperature at position 2 and acetylation at low temperature at position1.

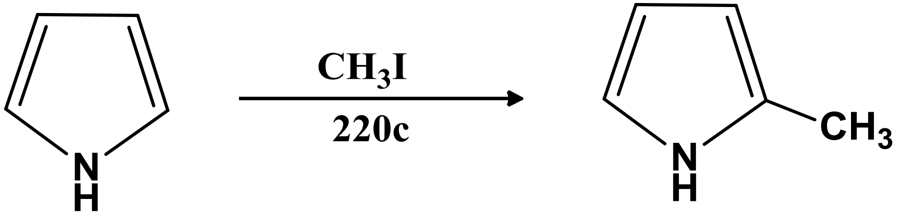




Acetylation at low temperature

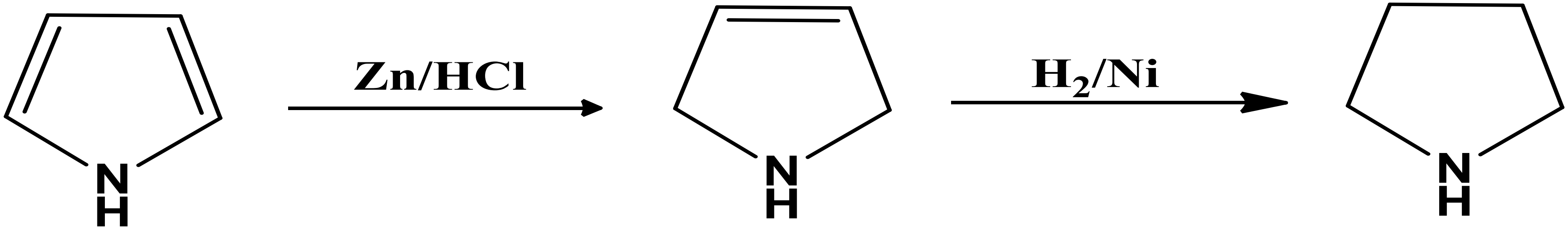
البيرول Pyrrole





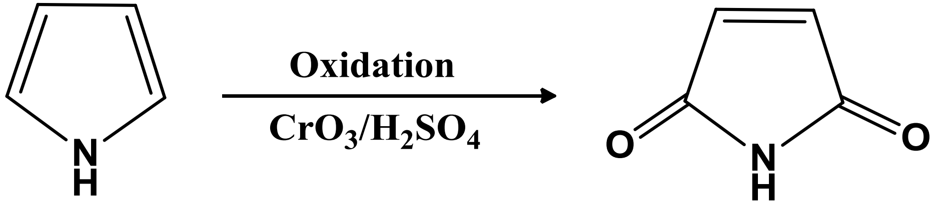
تفاعلات البيرول غير العطرية

الاختزال Reduction



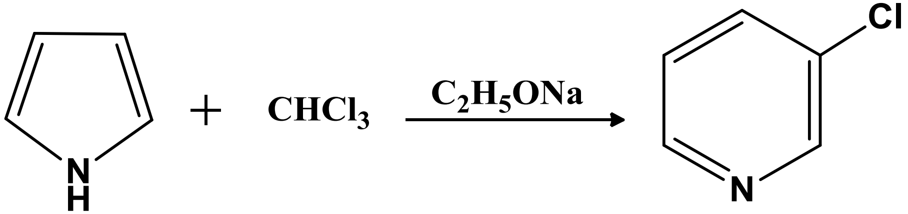
البيرول Pyrrole

الأكسدة Oxidation



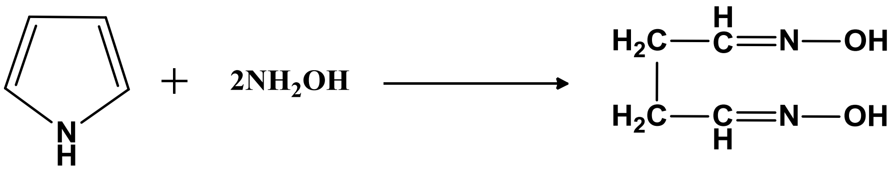
Maleic imide

Ring Expansion تفاعل اتساع الحلقة:



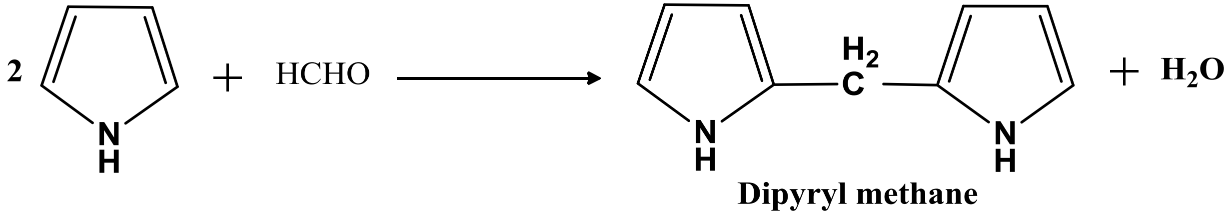
3-chloropyridine

With hydroxyl amine
التفاعل مع الهيدروكسيل أمين

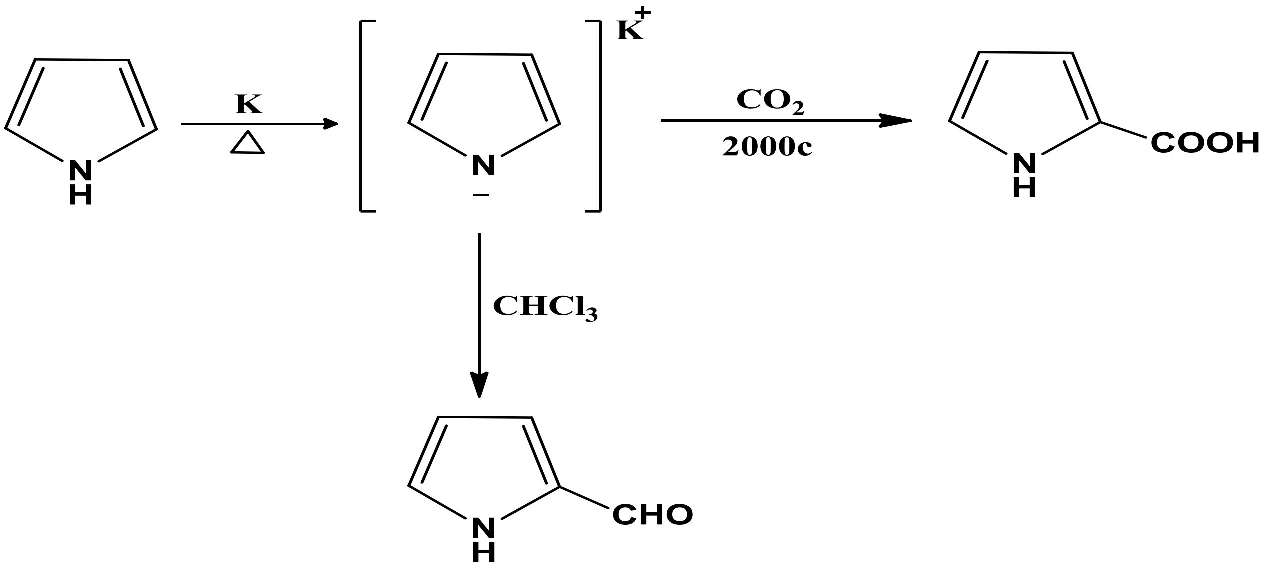


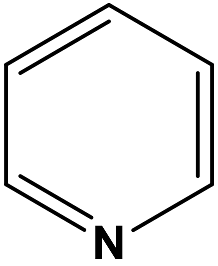
البيرول Pyrrole

with formaldehyde

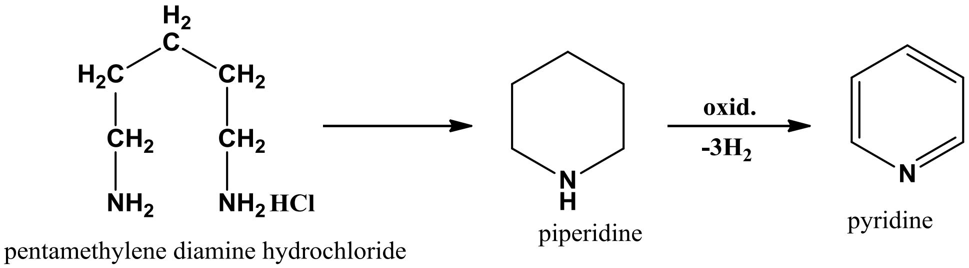


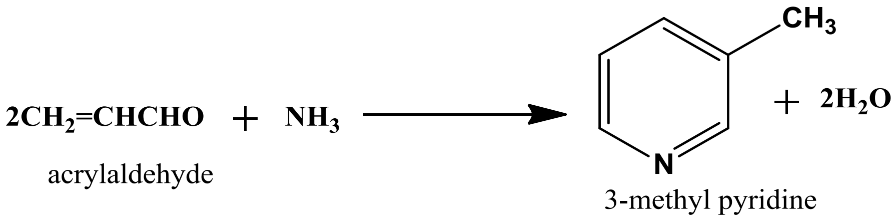
Pyrrole has a weak acidic property

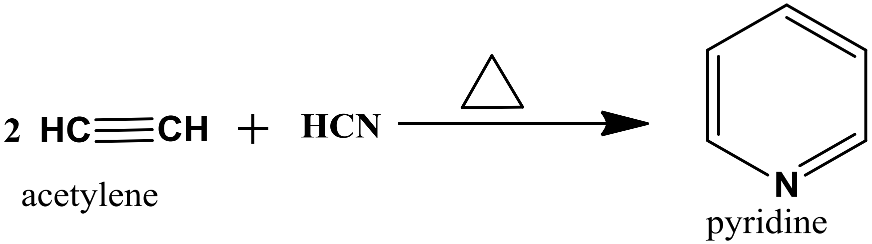




Pyridine البيريدين
Preparation طرق التحضير



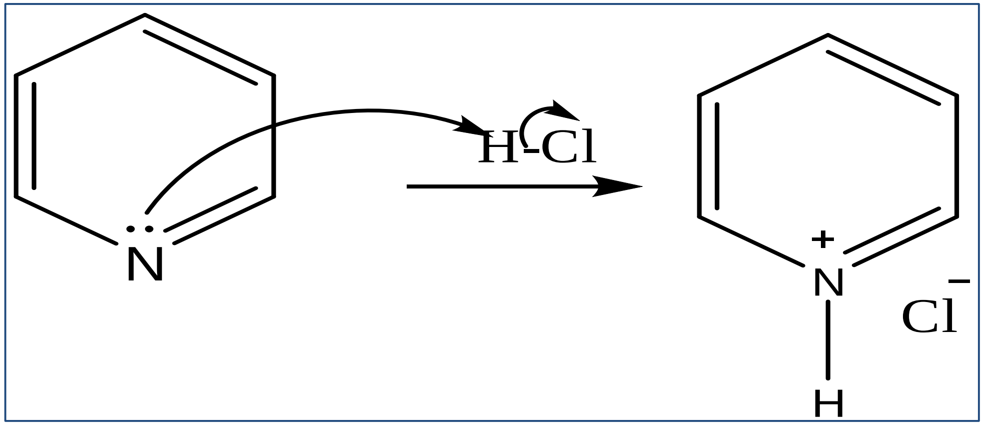




البيريدين Pyridine

Pyridine is a colorless liquid that turns brown when exposed to air. It boils at 115 °C. It dissolves in water as well as in organic solvents. It is a basic substance that resists oxidation and is used in industry as a catalyst and solvent. Compounds containing a pyridine nucleus are widely distributed in nature, for example vitamin B6, nicotinamide adenine dinucleotide phosphate. Pyridine compounds are of great biological importance. The pyridine nucleus is also involved in many medicinal drugs, alkaloids, and dyes. Pyridine is obtained in industry from the distillation of coal tar as well as an additional by-product in petroleum refining. These sources are sufficient to obtain pyridine for industrial purposes.

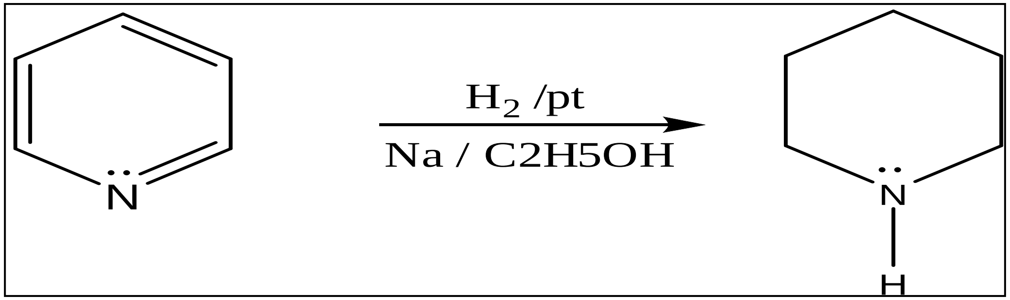
Chemical properties (with Hcl-reduction)

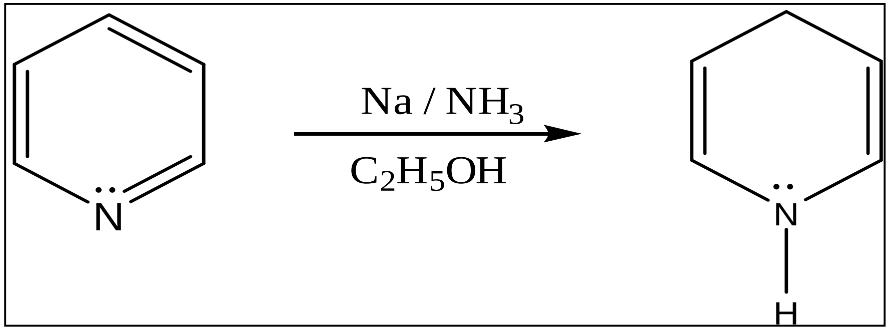


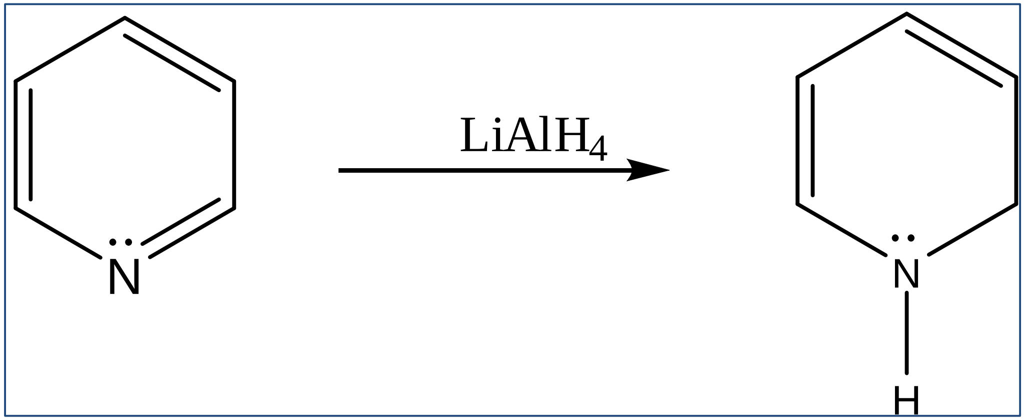
Chemical properties of pyridine • Pyridine is an aromatic compound with a high degree of stability, which is very similar to benzene.

• Basicity of pyridine: • Pyridine has basic properties, because the pair of free electrons on the nitrogen atom does not enter into the formation of its aromatic property. Therefore, pyridine is used as a solvent and base for some reactions in which acid is formed as a side product. Pyridine reacts with strong acids as a weak base to form water-soluble salts called pyridinium salts.

Reduction

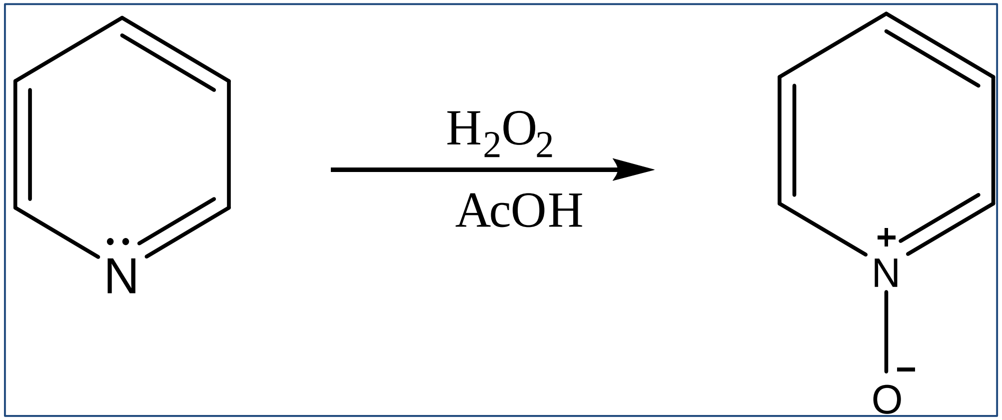




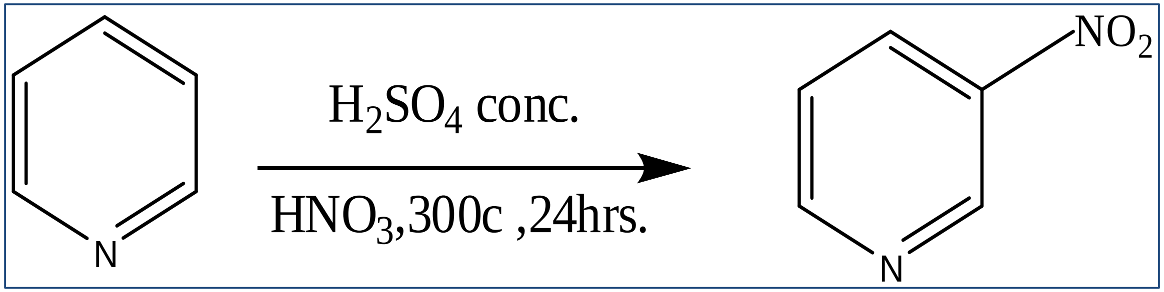


Oxidation

oxidation • Pyridine is oxidized by peroxy acids to 1-oxide or N-oxide, and this compound is considered an internal salt.

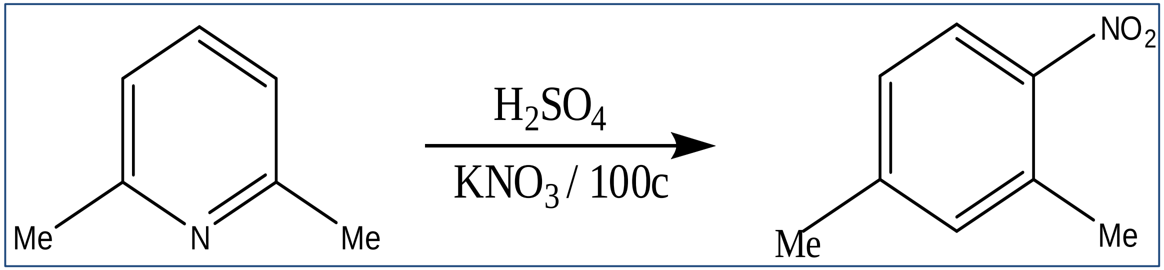


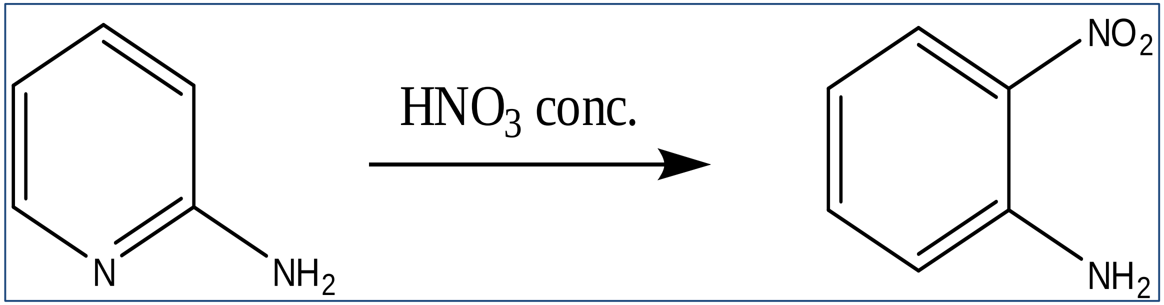
Nitration is done under vigorous conditions such as concentrated sulfuric acid and fuming nitric acid and heating to a high temperature of up to 300°C, where we get 3-nitropyridine.



Nitration

- The presence of electron-donating groups on the ring, such as alkyl groups, facilitates the nitration process.





References

- **1- I.L.FINAR Organic ChemistryVOL1 and VOL 2**

SOUTH VALLY UNIVERSITY

FACULTY OF SCIENCE
AT QENA

Stereochemistry

Stereochemistry of carbon compound

اعداد

د. امنية سيد زكي

كلية العلوم – قسم الكيمياء

العام الجامعي

٢٠٢٢-٢٠٢٣

بيانات الكتاب

الكلية :- كلية التربية – التعليم العام

الفرقة :- الثانية

تاريخ النشر :-

عدد الصفحات :-

المؤلف :-

المحتوي :-

Stereochemistry

Stereochemistry, study the relative spatial arrangement of atoms that form the structure of molecules . The study of stereochemistry focuses on stereoisomers, which by definition have the same molecular formula and sequence of bonded atoms (constitution), but differ in the three-dimensional orientations of their atoms in space.

Definition of isomers :-

Isomers are compound that have the same molecular formula but different in chemical structure .

(isomers can divided into two type)

stereoisomers isomer

- **1- optical isomers**
- **2- conformational**
- **3- Geometrical isomers**

constitutional isomer

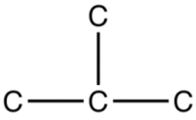
- **1- skeletal isomers**
- **2- positional isomers**
- **3-functional group**
- **4-tautomers isomers**

Constitutional isomer

1- Skeletal isomer:-

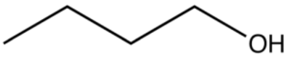
Skeletal isomers are constitutional isomers that have the same functional groups but differ from each other in the connectivity of the carbon skeleton.

carbon skeleton
of **1**

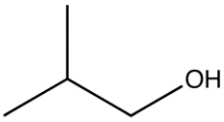


carbon skeleton
of **2**

Example (1):- **Butyl alcohol (1) and isobutyl alcohol (2) are constitutional isomers containing the same functional groups, namely the alcohol group.**



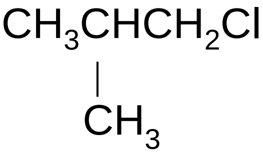
1



2

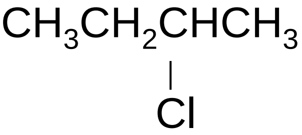
Example (2):- (1) $\mathrm{CH_3CH_2CH_2CH_2Cl}$

1-chlorbutane

(2) 

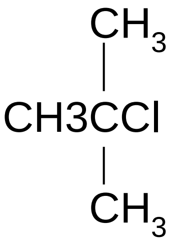
$\mathrm{CH_3\underset{\underset{\displaystyle CH_3}{|}}{CH}CH_2Cl}$

1-chloro-2-metylpropane

(3) 

$\mathrm{CH_3CH_2\underset{\underset{\displaystyle Cl}{|}}{CH}CH_3}$

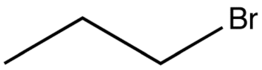
2-chlorobutane

(4) 

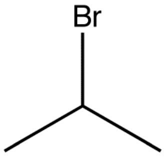
$\mathrm{CH3\overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}Cl}$

tertiary butyl chloride

- **Positional isomers :-**
- **Positional isomers** are constitutional **isomers** that have the same carbon skeleton and the same functional groups but differ from each other in the location of the functional groups on or in the carbon chain. eg. Propyl bromide (1) and isopropyl bromide (2)

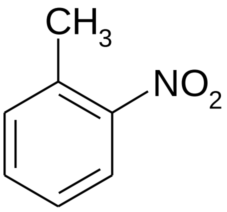


1



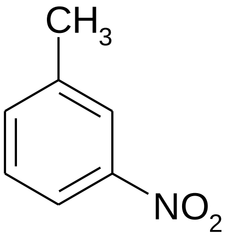
2

Example (2) :- also in aromatic compound

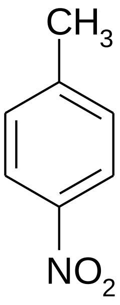


o-nitrotoluene

,



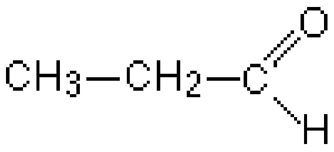
m-nitrotoluene



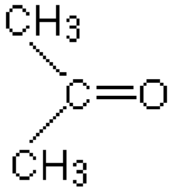
p-nitrotoluene

Functional group isomers :-

In this variety of structural isomerism, the isomers contain different functional groups - that is, they belong to different families of compounds (different homologous series). For example, a molecular formula C3H6O could be either propanal (an aldehyde) or propanone (a ketone).



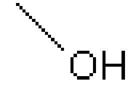
propanal



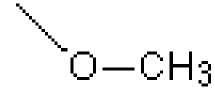
propanone

Example :-

- Another common example is illustrated by the molecular formula $C_3H_6O_2$. Amongst the several structural isomers of this are propanoic acid (a carboxylic acid) and methyl ethanoate (an ester).



propanoic acid

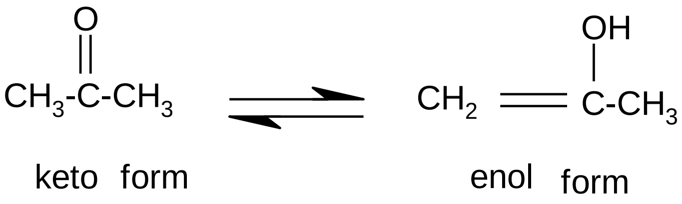


methyl ethanoate

- **Tautomerism**

  Tautomers are isomers of a compound which differ only in the position of the protons and electrons. The carbon skeleton of the compound is unchanged. A reaction which involves simple proton transfer in an intramolecular fashion is called a tautomerism. Keto-enol tautomerism is a very common process,

- Typically the 'keto' form of the compound is more stable, but in some instances the 'enol' form can be the more stable. **examples** :-



$$CH_3\text{-}\overset{\overset{\displaystyle O}{\|}}{C}\text{-}CH_3 \rightleftharpoons CH_2{=}\overset{\overset{\displaystyle OH}{|}}{C}\text{-}CH_3$$

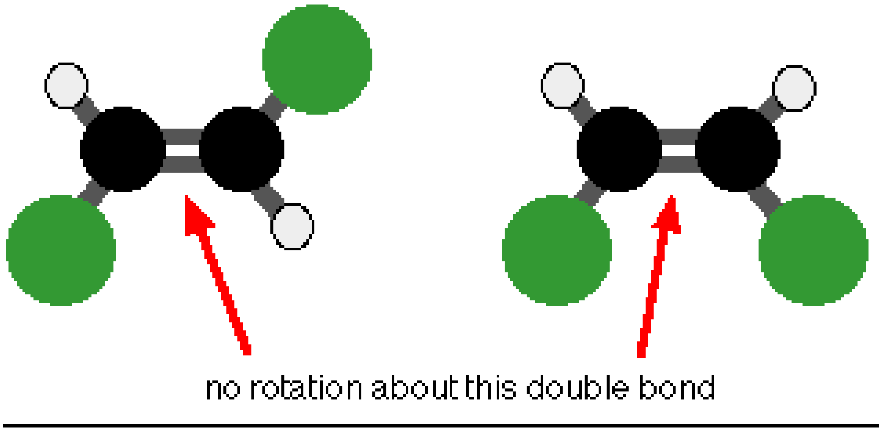
Geometrical isomers in carbon-carbon double bond

** Geometric isomers have **similar structural formulas but differ** in the arrangement of groups at a single atom, at double bonds, or in rings.

The carbon-carbon double bond won't rotate and so you would have to take the models to pieces in order to convert one structure into the other one. ... Drawing structural formulae for the last pair of models gives two possible isomers

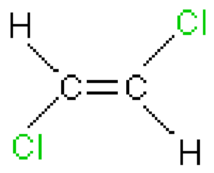
Geometric (cis / trans) isomerism:-

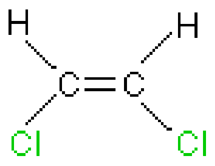
These isomers occur where you have restricted rotation somewhere in a molecule due to found carbon –carbon double bond .



the two chlorine atoms are locked on opposite sides of the double bond. This is known as the trans isomer. (trans : from latin meaning "across" - as in transatlantic).

In the other, the two chlorine atoms are locked on the same side of the double bond. This is know as the cis isomer. (cis : from latin meaning "on this side")

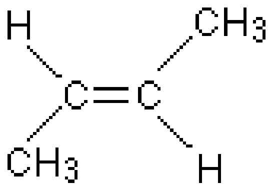


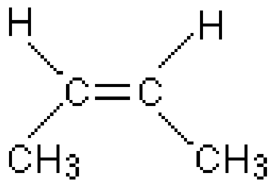


trans-1,2-dichloroethene *cis*-1,2-dichloroethene

Example (1):-

- but-2-ene. In one case, the CH_3 groups are on opposite sides of the double bond, and in the other case they are on the same side.

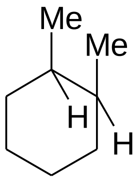




trans-but-2-ene *cis*-but-2-ene

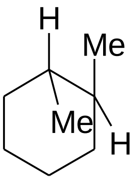
Example (2) :-

in cyclic compound .



(1)

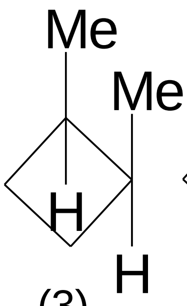
cis form



(2)

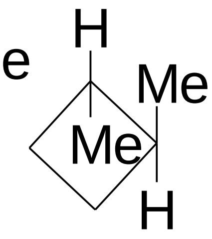
trans form

Example (3):-



(3)

cis form



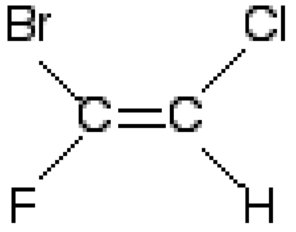
(4)

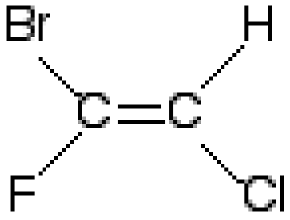
trans form

The symbols (E) and (Z)

The problem with the cis-trans system for naming geometric isomers

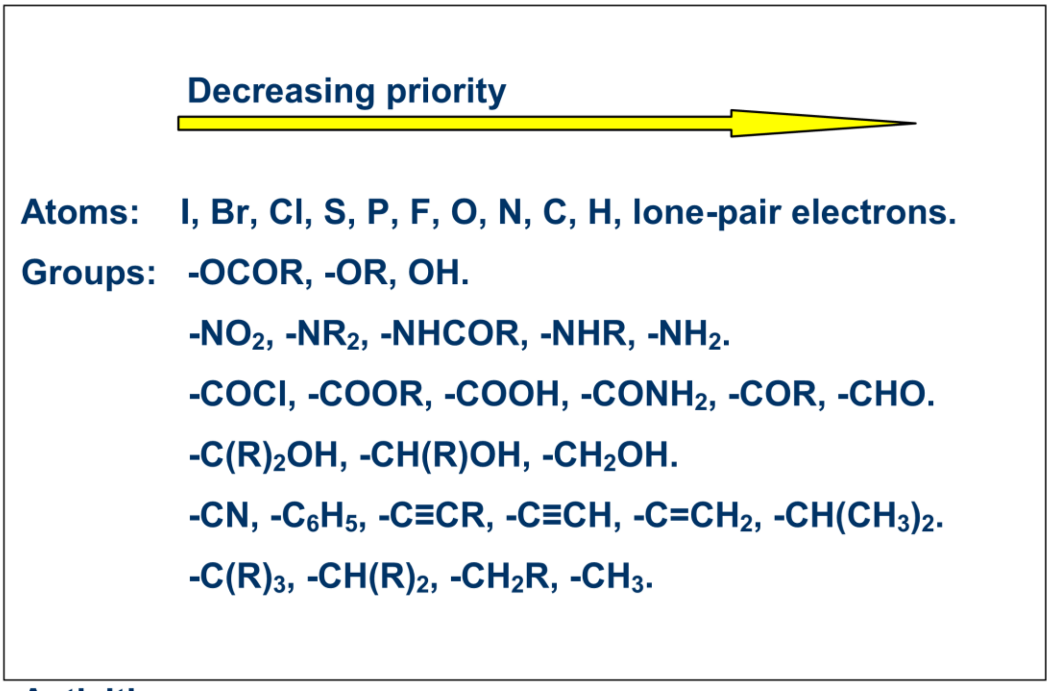
Consider a simple case of geometric isomerism, but There are problems as compounds get more complicated; Because everything attached to the carbon-carbon double bond is different.





How the E-Z system works

You look at what is attached to each end of the double bond in turn, and give the two groups a "priority" according to a set of rules.



Decreasing priority

Atoms: I, Br, Cl, S, P, F, O, N, C, H, lone-pair electrons.

Groups: -OCOR, -OR, OH.

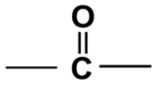
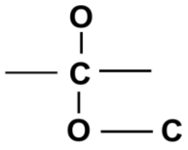
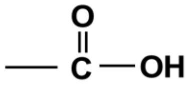
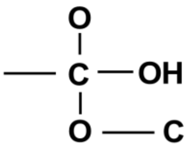
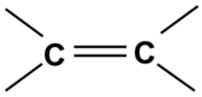
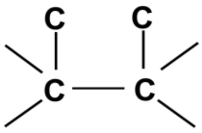
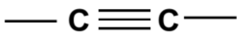
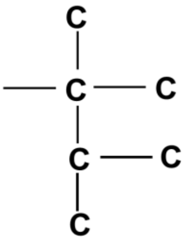
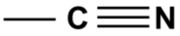
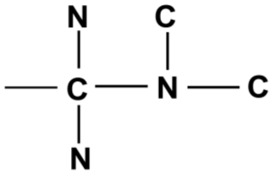
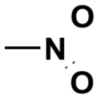
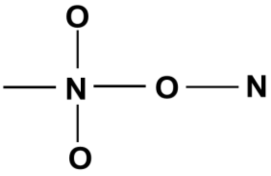
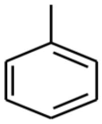
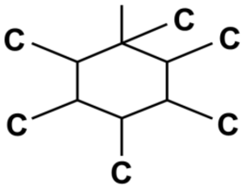
$-NO_2$, $-NR_2$, -NHCOR, -NHR, $-NH_2$.

-COCl, -COOR, -COOH, $-CONH_2$, -COR, -CHO.

$-C(R)_2OH$, -CH(R)OH, $-CH_2OH$.

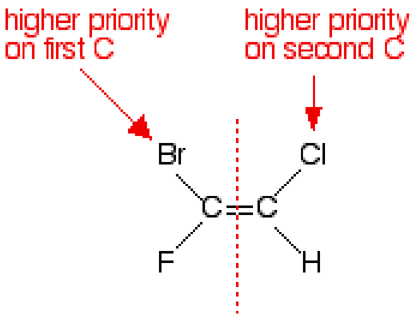
-CN, $-C_6H_5$, -C≡CR, -C≡CH, $-C{=}CH_2$, $-CH(CH_3)_2$.

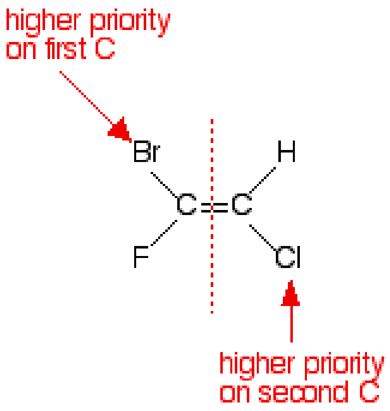
$-C(R)_3$, $-CH(R)_2$, $-CH_2R$, $-CH_3$.

group	Equivalent for priority
	
	
	
	
	
	
	

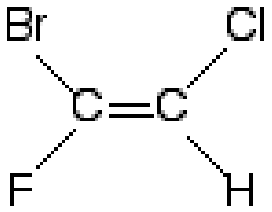
- In the example , at the left-hand end of the bond, it turns out that bromine has a higher priority than fluorine. And on the right-hand end, it turns out that chlorine has a higher priority than hydrogen.

- If the two groups with the higher priorities are on the same side of the double bond, that is described as the (Z)- isomer. So you would write it as (Z)-name of compound. The symbol Z comes from a German word (zusammen) which means together.

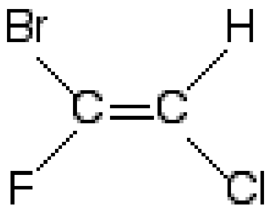




If the two groups with the higher priorities are on opposite sides of the double bond, then this is the (E)- isomer. E comes from the German (entgegen) which means opposite.

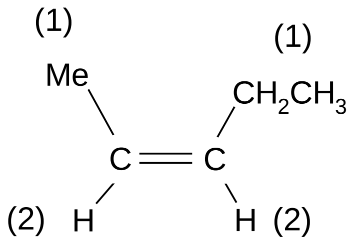


(Z)-rest_of_name

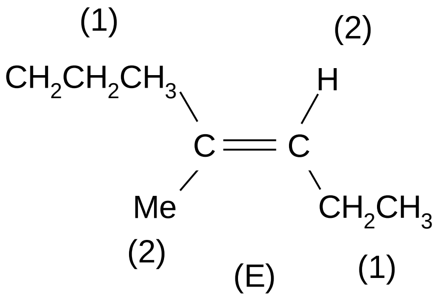


(E)-rest_of_name

Example (1):-



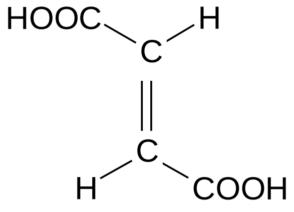
(Z)



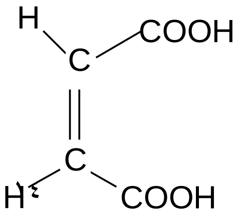
(E)

Geometric isomers in carboxylic acid

- There are some compounds that have the same molecular formula and exist in two isomeric form . Among these compounds are malic acid and fumaric acid, and their molecular formula is C4H4O4 One of them is in the form of cis and it is called malic acid and the other in the form is called trans and it is called fumaric acid.



fumaric acid



maleic acid

Syn and anti addition

What is Syn Addition?

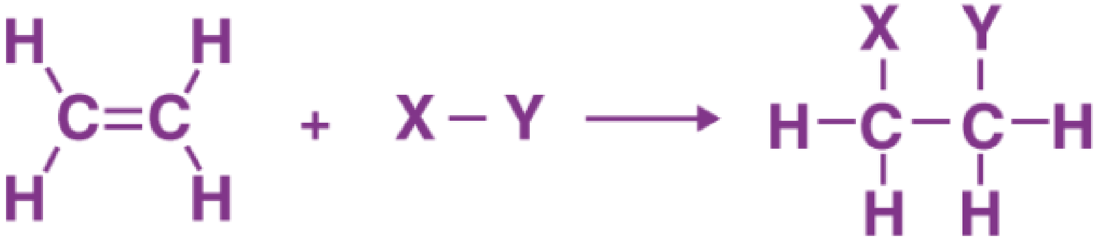
The addition of two substituents to the same side (or face) of a double or triple bond reduces the bond order but increases the number of substituents.

The addition of two substituents to the same side of an unsaturated molecule is known as syn addition. The addition of two substituents in opposite directions is known as anti-addition. This is the major distinction between syn addition and anti addition. These addition reactions change the bond order and the number of substituents in the reactant molecule.

Syn and anti Addition Reaction

A syn addition is an addition reaction of an alkene or alkyne in which the net reaction is the addition of two ligands to the multiple-bonded carbon atoms from the same face of the multiple bond , an anti addition is an addition reaction in which the net reaction is the addition of two ligands from the opposite faces of the multiple bond.

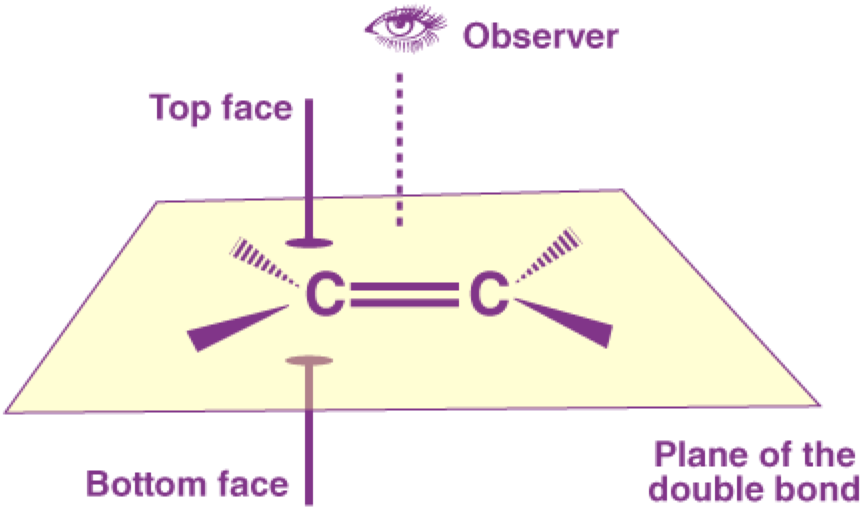
However, because a double or triple bond is frequently broken to generate the requisite single bonds, only chemical compounds with multiple bond characters can conduct an addition reaction. An addition reaction is essentially a reverse decomposition reaction, whereas a decomposition reaction is one in which one or more elements or compounds are compounded. Consider the following reaction (hydrochlorination) of propane (an alkene) as an example of an addition reaction.



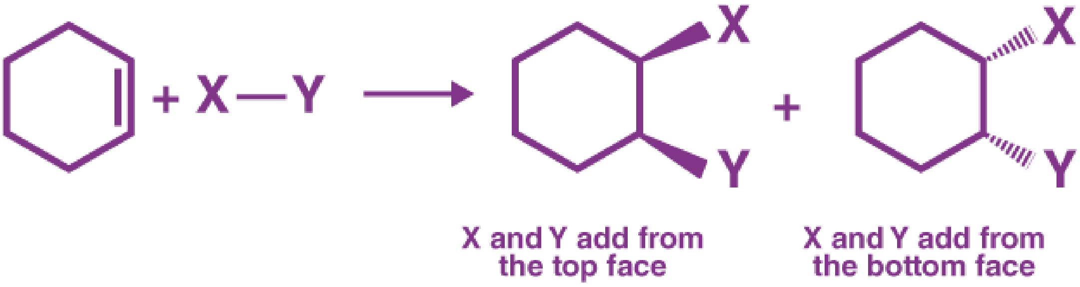
Addition Reaction

Stereochemistry of Alkene Addition Reactions

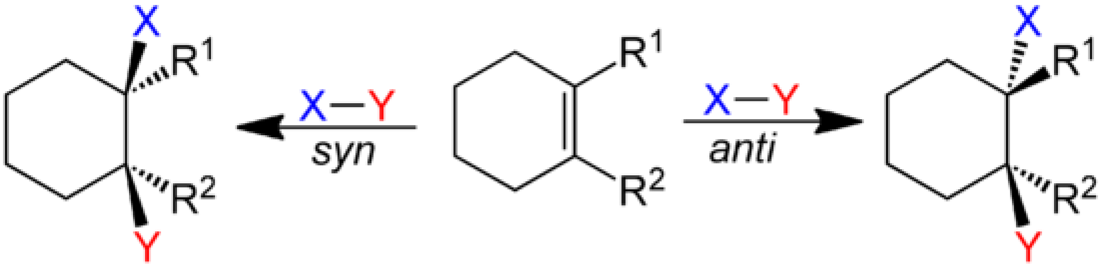
The stereochemistry of addition to a double bond is explained in terms of the plane in which the double bond and its four associated groups are located. This plane's sides are referred to as faces. The top face is the side of the plane closest to the observer, while the bottom face is the opposite side.

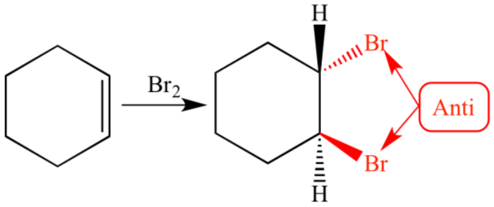


Two groups add to a double bond from the same face in a syn-addition:

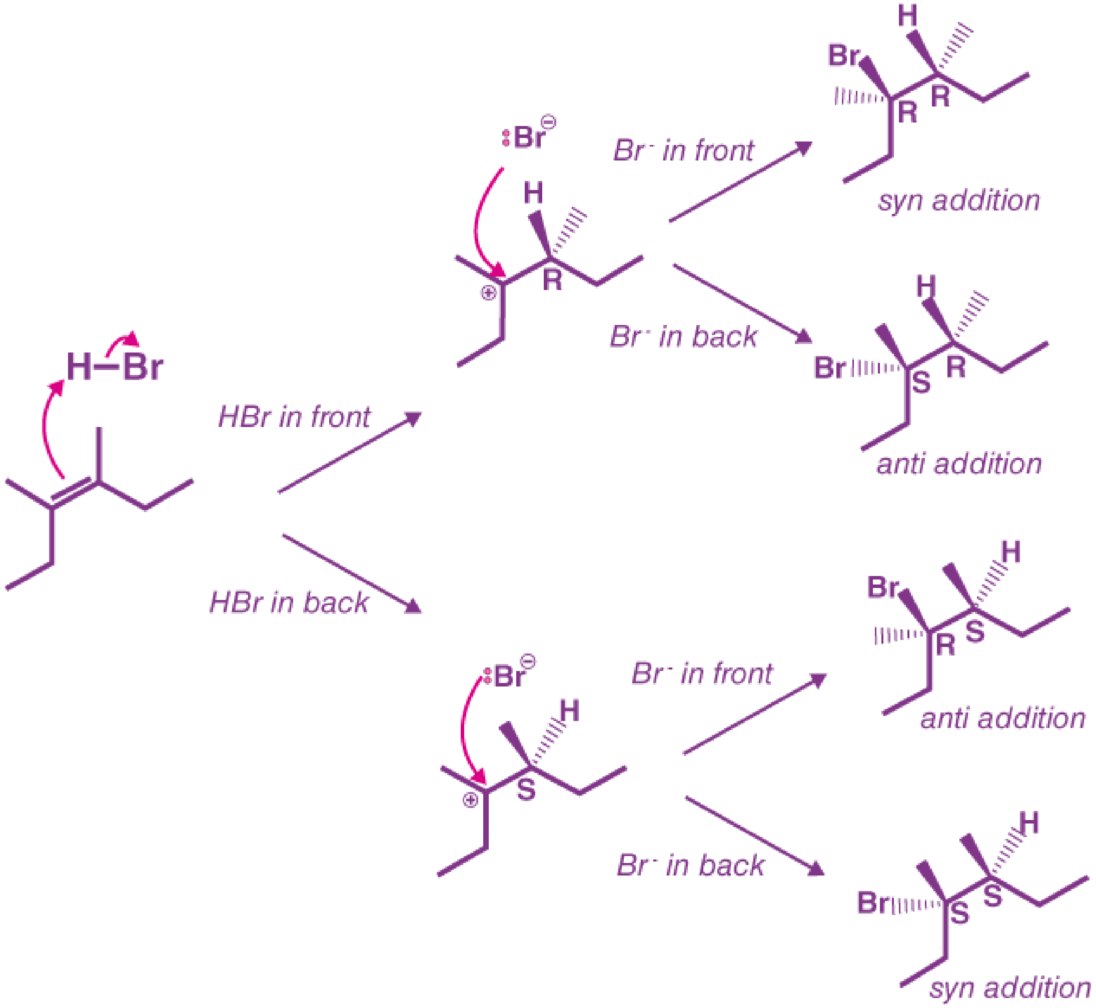


Electrophilic addition has the ability to create two additional chiral centres, depending on the structure of the initial alkene. The reaction between HBr and an alkene is not stereoselective; racemization occurs at both alkene carbons. Consider cis-3,4-dimethyl-3-hexene with HBr added to it. Because the acidic proton might be transferred to either side of the planar alkene carbon with equal chance during the initial proton abstraction stage, the centre could have either syn and anti addition.





Addition of Br_2 to an alkene is an anti addition because the two new carbon-bromine bonds are formed on opposite faces of the alkene.



Difference between Syn and Anti Addition

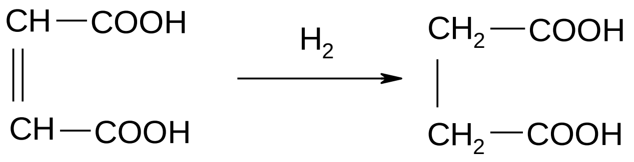
The difference between syn and anti addition is tabulated below.

Syn Addition	**Anti Addition**
The addition of two substituents to the same side (or face) of a double or triple bond reduces the bond order but increases the number of substituents. The substrate is usually an alkene or alkyne.	**Anti addition is the polar opposite of syn addition. Anti addition involves adding two substituents to opposite sides (or faces) of a double or triple bond, resulting in a drop in bond order and an increase in the number of substituents. Bromination (any halogenation) of alkenes is a classic example of this.**

The addition of substituents to the same side of a double or triple bond is known as syn addition.	**The addition of substituents to the opposite sides of a double or triple bond is known as anti addition.**
Ex: Oxidation of alkenes to diols in the presence of Os04	**Ex: Halogenation of alkenes**

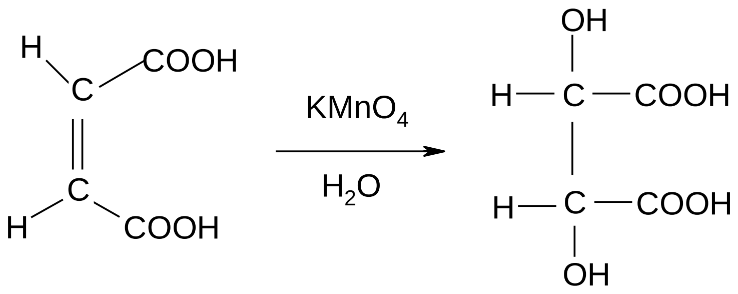
Characteristics of these compounds by experimental :-

1- Reduction :-



succinic acid

2- Oxidation :-

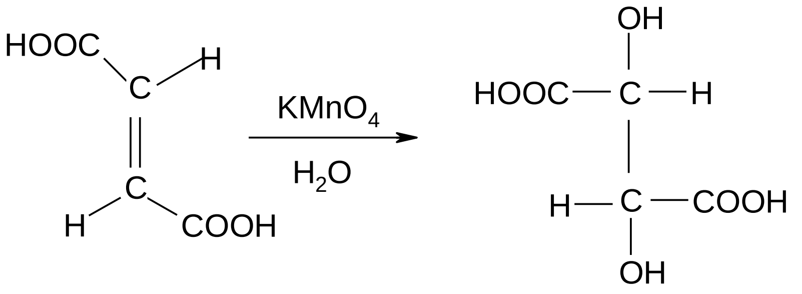


maleic acid

meso tartaric acid

Oxidation of maleic acid form meso tartaric acid (acid have no optical activity) due to present of plane of symmetry divided the molecule into two identical part .

*** (which will explain by details in optical isomers)

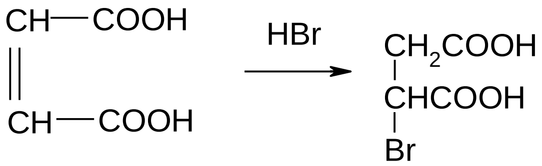


fumaric acid

racimic tartaric acid

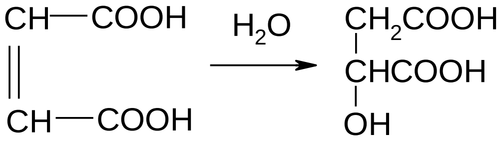
While oxidation of fumaric acid form racemic tartaric acid which have optical activity .

3- Reaction with HBr :-



bromo succinic acid

4- Reaction with water **:-**

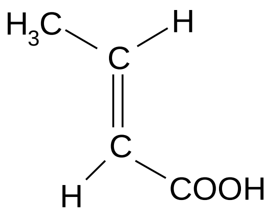


malic acid

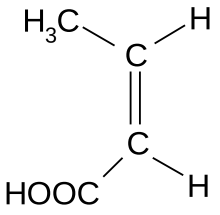
Carboxylic acids containing a double bond: -

- If the shape of acids that are similar in molecular formula but different in geometrical form, it is possible to distinguish them by names specific to each geometric shape (i.e. without placing any syllable in front of the name of the acid), for example: - malic and fumaric acid

- If the syllable (ISO) is placed in front of the name of **aliphatic acid,** it has an advantage in terms of stability, as the syllable (ISO) indicates the less stable form.

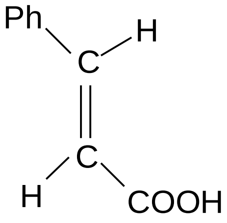


cotonic acid
(trans)
most stable

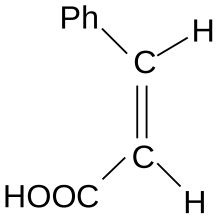


isocrotonic acid
(cis)
less stable

. If the syllable (allo) is placed in front of the name of the acid in **aromatic acids**, it has an advantage in terms of stability and indicates the less stable form .



cinnamic acid
(trans)
most stable



allo cinnamic acid
(cis)
less stable

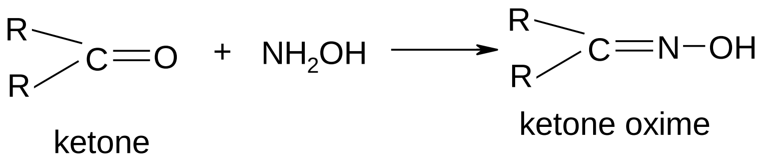
Geometric isomers in oxime

- An oxime is a chemical compound belonging to the imines, with the general formula RR'C=NOH, where R is an organic side-chain and R' may be hydrogen, forming an aldoxime, or another organic group, forming a ketoxime.

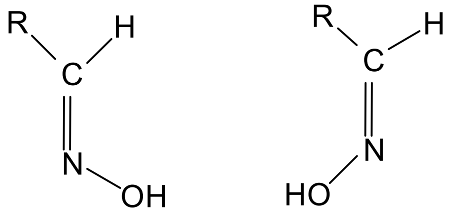
$$R{-}CHO \quad + \quad NH_2OH \longrightarrow R{-}CH{=}NOH$$

aldehyde

aldehyde oxime

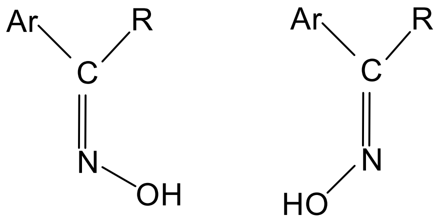


Stereochemistry of oxime


anti

syn

adehyde oxime


anti

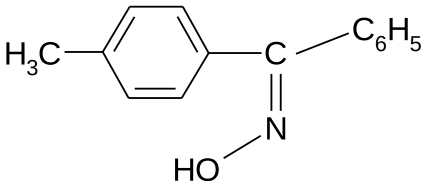
syn

ketone oxime

For aldehyde oxime, if the OH is found in the same direction as the big group, the compound is called (Syn), but if they are oppositely found, the compound is called (Anti).

While the ketone oxime can named by the two way

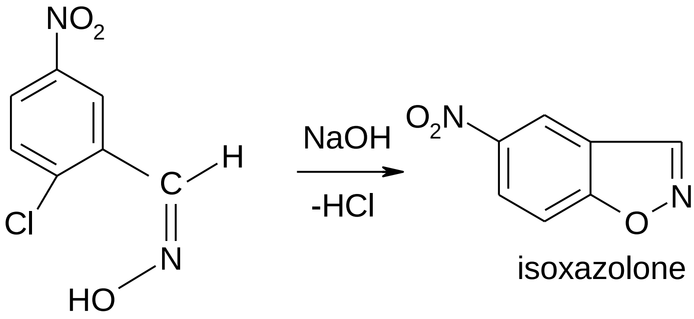
Example:-



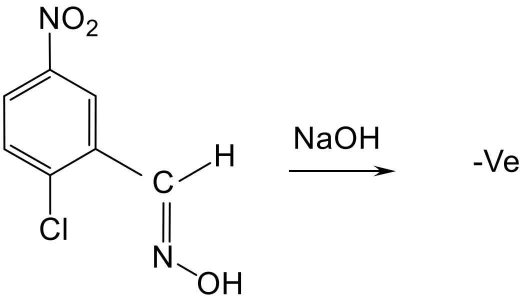
Syn p-tolyl phenyl ketoxime

Anti phenyl p-tolyl ketoxime

syn oxime more active in reaction than anti and the following reaction show that.

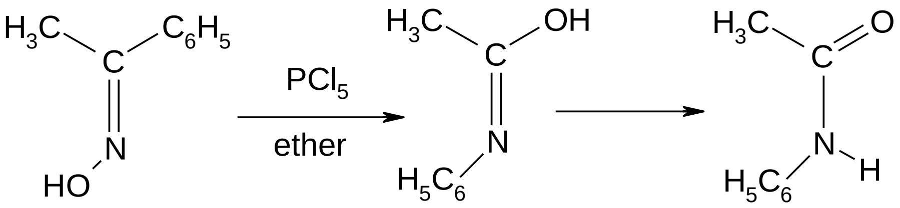


While the anti form for the same compound don't give the reaction



Beckmann rearrangement

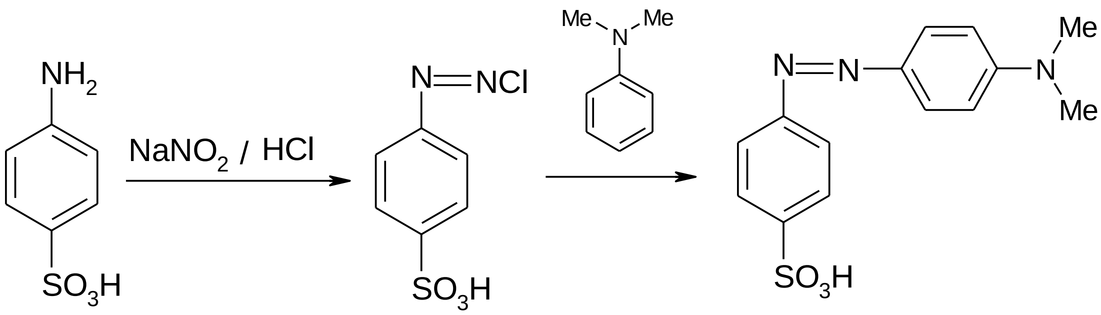
is a rearrangement of an oxime functional group to substituted amides. By treatment the oxime with phosphoresce phosphorus pentachloride PCl_5 in ether .



The most common reaction mechanism of the Beckmann rearrangement consists generally of an alkyl migration anti-periplanar to the expulsion of a leaving group to form a nitrilium ion. This is followed by solvolysis to an imidate and then tautomerization to the amide.

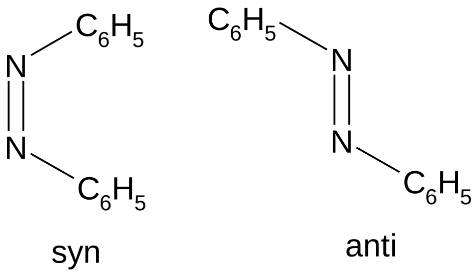
Geometrical isomerism in azo compound :-

Azo compounds are organic dyes prepared from the reaction of aromatic amines with hydrochloride and sodium nitrite salt and then combined with phenol or any compound containing an active methylene group.



Example (1):-

Azo benzol found in two form (syn) and (anti)

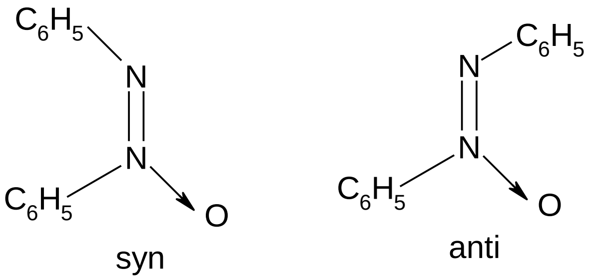


Geometrical isomerism in azoxy compound

Azoxy compounds are a group of chemical compounds sharing a common functional group with the general structure $RN=N^{+}(O^{-})R$ They are considered N-oxides of azo compounds. Azoxy compounds are 1,3-dipoles.

Example (2) :-

Azoxy benzol found also in two form syn and anti

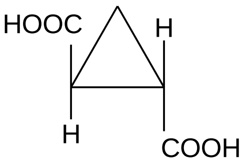


Geomtrical isomer in cyclic compound

The cyclic compounds that begin with cyclo-propane (cyclo-propane) are in a state of geometric symmetry, and it is possible that these geometric images in these compounds also have optical activity.

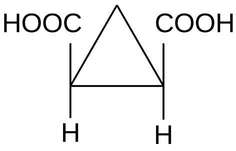
Example (1):-

The simplest cyclic compounds cyclopropane from which we take a derivative such as cyclopropane-1,2-dicarboxylic acid (compounds 1,2) There are two forms, one is called (cis) and the other is (Trans).



(2)

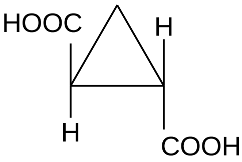
trans



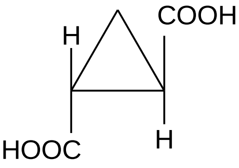
(1)

cis

Cis (also called meso) is optically inactive. (Trans) is optically active and there are two forms of it (3, 4), which rotate the left (L) and right (D).



(4)

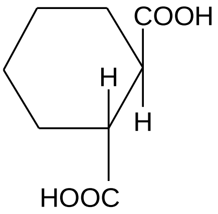


(3)

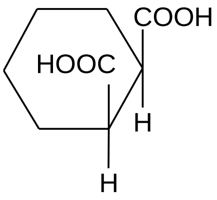
Example (2) Cyclohexane If two carboxylate groups enter it to become a dicarboxylic acid.

The two carboxyl groups on two neighboring atoms, in this case we get the two forms (1 and 2).

1,2-hexahydrophthalic acid (cis and trans)

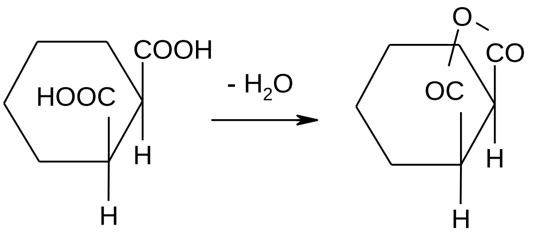


(2)
trans



(1)
cis

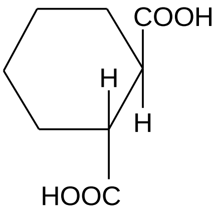
Compound (1) is called (cis) and it optically inactive and gives the anhydride easily.



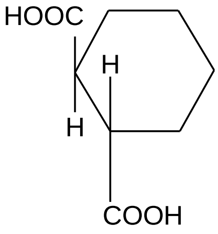
(1)
cis

anhydride

Compound (2) is called(trans), and it is optically active and has two forms (D, L)



(4)



(3)

D	**L**

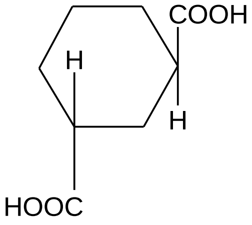
2- The two carboxyl groups on the two carbon atoms (1, 3).

The compound is called hexahydroisophthalic acid and there are two forms of it (3, 4).

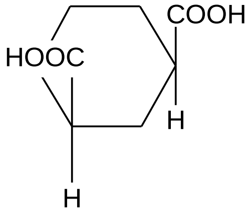
Compound (3) is called (cis) and it is optically inactive,

compound (4) is called (trans) and it is optically active

Compound (3) give anhydride rapidly, in contrast to (4) which give with difficulty.



(4)
trans

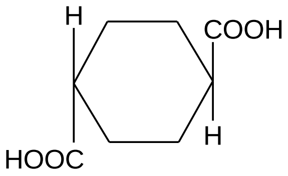


(3)
cis

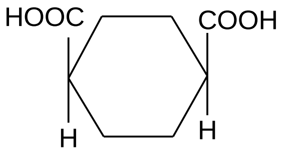
3-The two carboxyl groups on the two carbon atoms (1, 4).

The compound is called hexahydro-terphthalic acid and there are two forms of it (5, 6). Compound (5) is called (cis) and it is optically in active Compound (6) is called (trans) and it is also optically in active.

Compound (5) gives anhydride quickly but (6) does not give anhydride at all.



(6)
trans

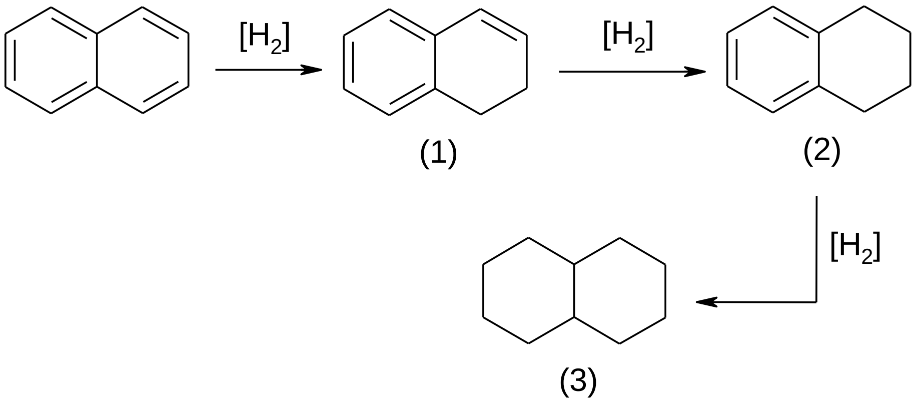


(5)
cis

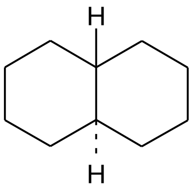
Geometrical isomer in bicyclic compound

Naphthalene

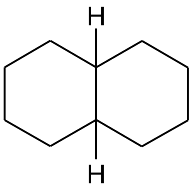
Which convert to Decalene by repeat hydration (addition of hydrogen).



Compound (3) is called decalene, and it has geometrical isomerism as it is found in two forms (CIS) and (Trans). We note that hydrogen in both compounds is responsible for the emergence of this activity .



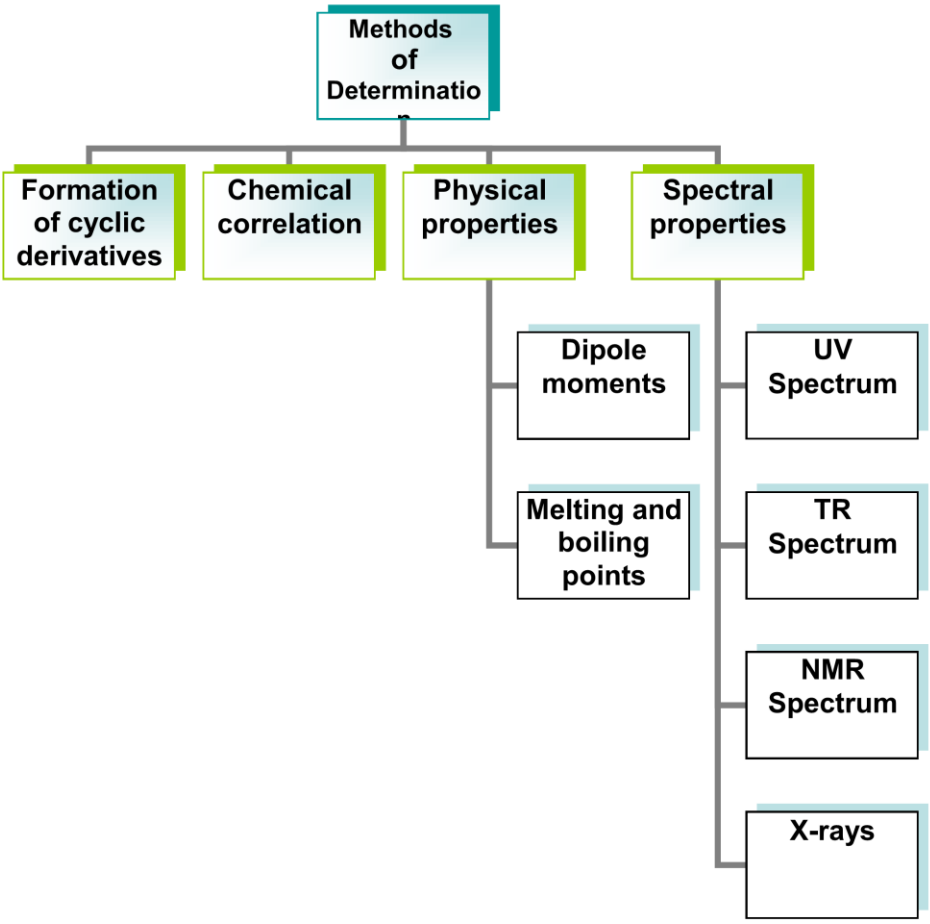
trans



cis

Determination of the configuration of geometrical isomers

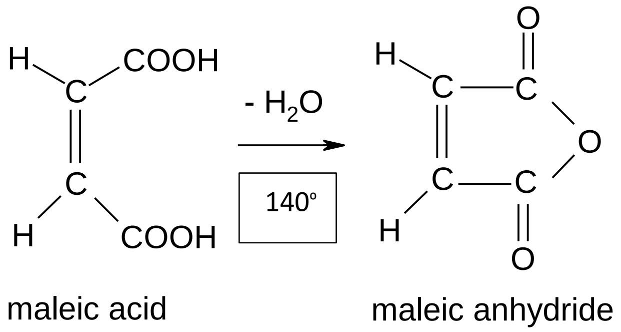
There are many method are used for the Determination of the configuration of geometrical isomers.



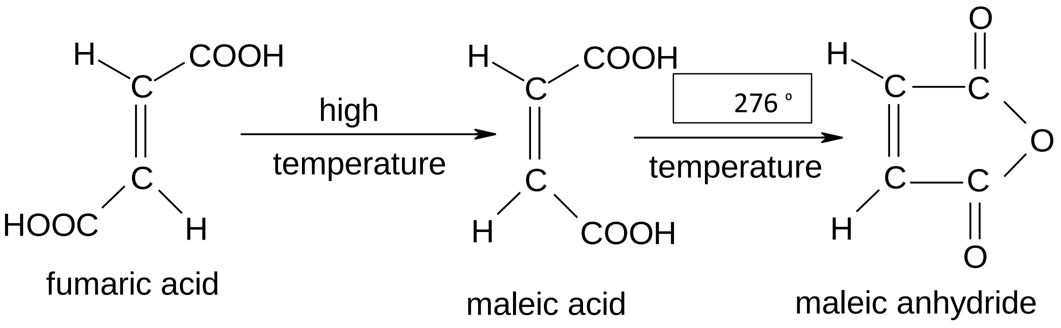
1- formation of cyclic derivatives :-

this behavior can illustrated in maleic and fumaric acid

the melting point of maleic acid = 130° and easily form maleic anhydride we heating to 140° , while fumaric acid don't give any thing at the same temperature.



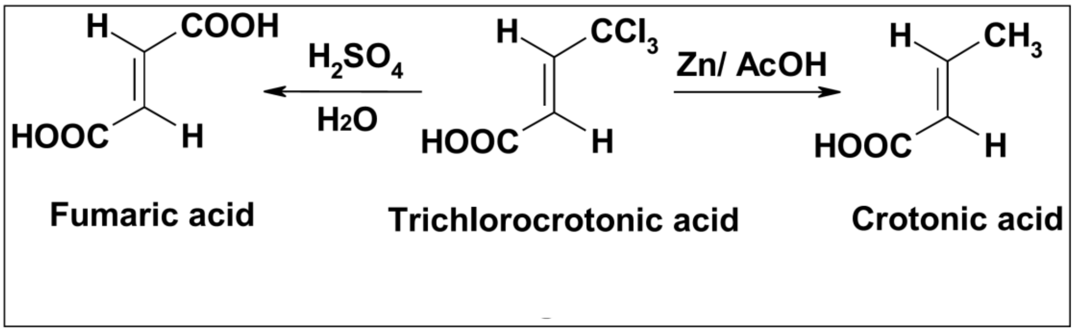
the melting point of fumaric acid = 270° and hardly form maleic anhydride we heating to 276° , so we can concluded that the two carboxylic group must be in the same direction in malic acid ,and in opposite direction in fumaric acid .



2- chemical correlation :-

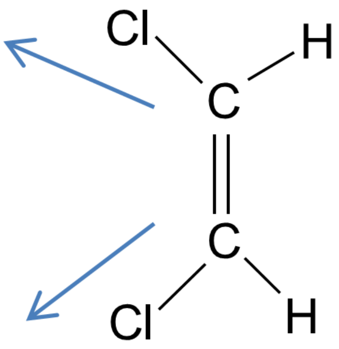
This method depends on conversion of unknown configurationally isomer into known isomer.

An example of chemical correlation is the transformation of trichlorocrotonic acid (m.p=114) into fumaric acid by hydrolysis in acid water with H_2SO_4 , and by reduction into crotonic acid (m.p=72).

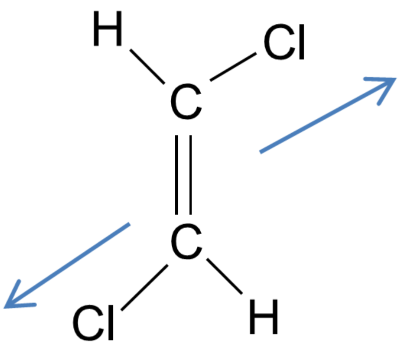


3- physical properties :-

a- dipole moments:- occur when there is a separation of charge. They can occur between two ions in an ionic bond or between atoms in a covalent bond; **dipole moments** arise from differences in electronegativity.



1.9 D

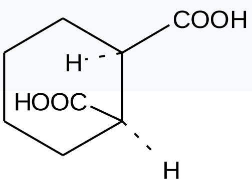


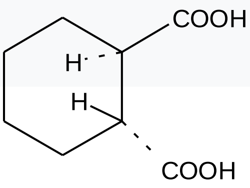
ZERO D

b- <u>**optical activity**</u>

optical activity is **the ability of a chiral molecule to rotate the plane of plane-polairsed light**, measured using a polarimeter. ... When light passes through a sample that can rotate plane polarised light.

The geometrically symmetrical compounds (with the shape of cis) are not optically active , while the compounds (with the shape of **trans**) are optically active because they are not asymmetric (not identical).





c- melting and boiling points

- Melting point in cis form less than trans (in acid) form
- Boiling point in cis form more than trans form (in acid)

Stereomutation

Is a conversion of cis to trans-isomer or the reverse process

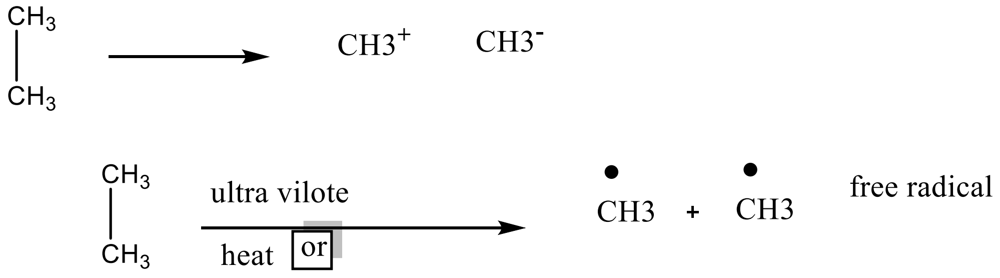
The transformation of (cis) into (trans) is easy under the appropriate conditions such as exposure of the compounds (cis) to halogens or nitroso acid ((HNO_2) or by heating.

As for the transformation of (trans) into (cis), it is difficult.

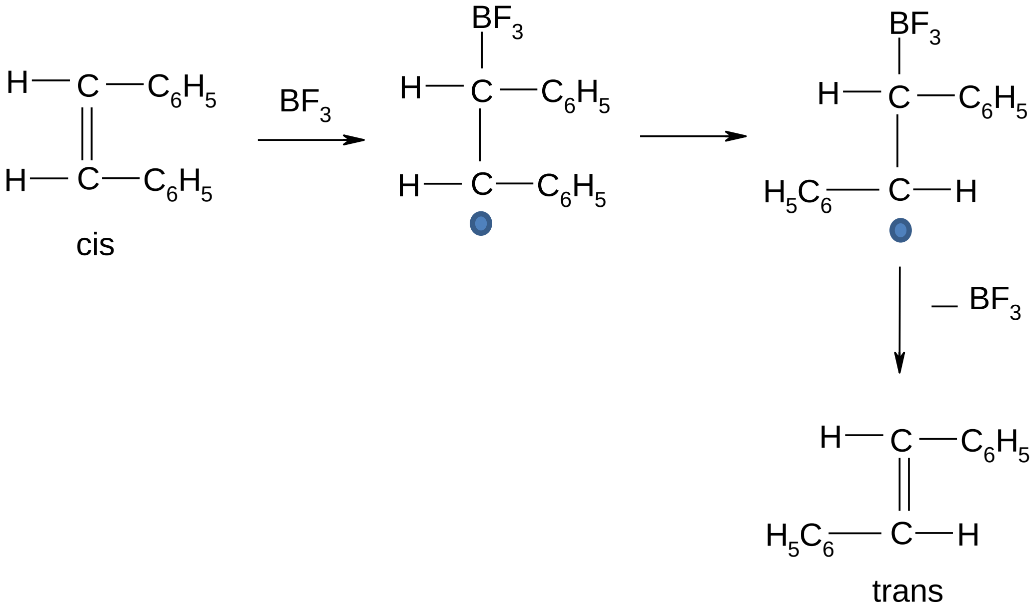
Free radical

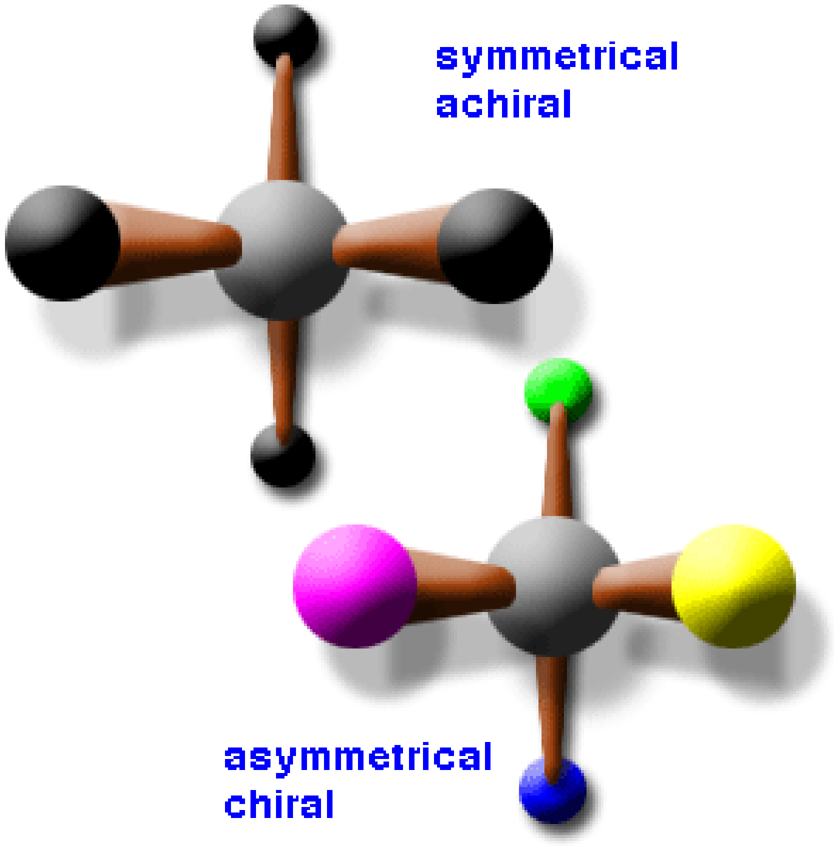
It was developed to explain the transformation of the compounds (Cis) into (trans). It states that the compound (Cis) is transformed into (trans) by forming free radicals using cofactors such as (BF3).

Initiation step :-



transformation step :-





Optical isomerism

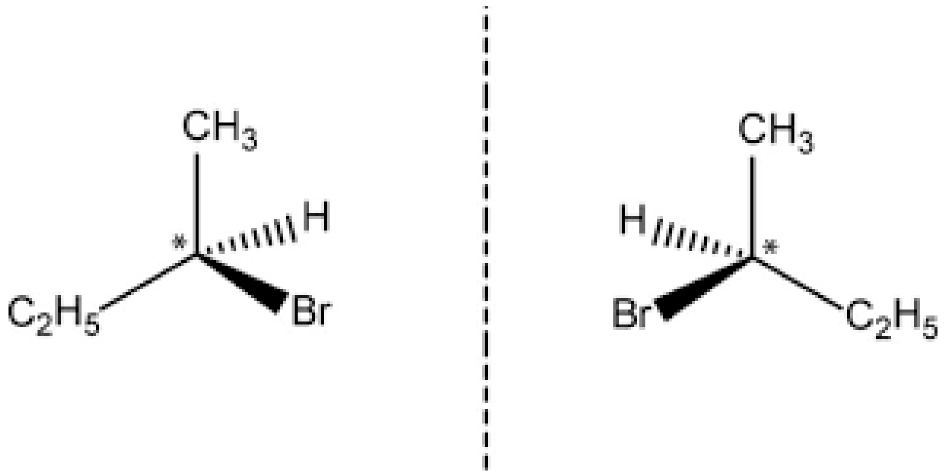
Optical isomerism is a case where the isomers display identical characteristics in terms of molecular weight as well as chemical and physical properties. However, they differ in their effect on the rotation of polarized light.

Optical isomerism occurs mainly in substances that have the same molecular and structural formula, but they cannot be superimposed on each other.

In simple words, we can say that they are mirror images of each other. Alternatively, it can also be found in *substances that have an asymmetric carbon atom.*

asymmetric carbon atom (chiral carbon) :-

- The molecule that cannot be superimposed on its mirror image is chiral
- **Chiral carbon atoms :-**
- Carbon atom are connected to four different group called chiral carbon
- Such molecule is chiral and exist as pair of enantiomers

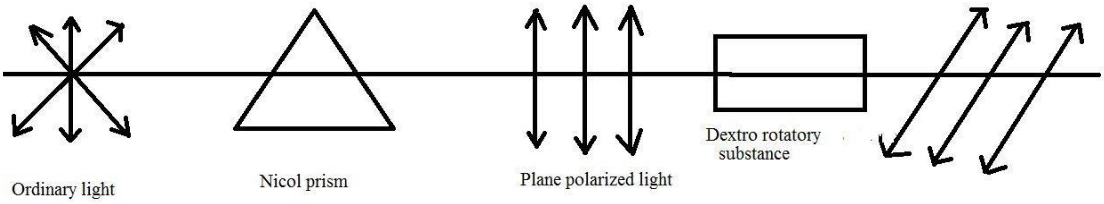


Optical activity

An optical activity substance is one that rotate the plane of polarized light ,if the rotation of plane to right the substance is dextrorotatory , while ,if the rotation of plane to left the substance is levorotatory

The direction of rotation and its degree can be determined by polarimeter.

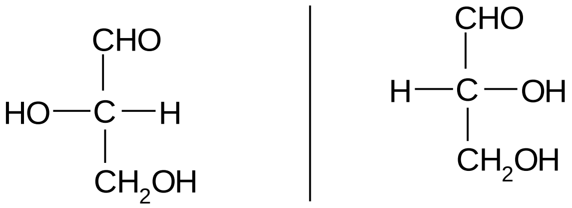
polarimeter is a scientific instrument used to measure the angle of rotation caused by passing polarized light through an optically active substance



The observed angle of rotation in the case of an optically active subustant depend in :-

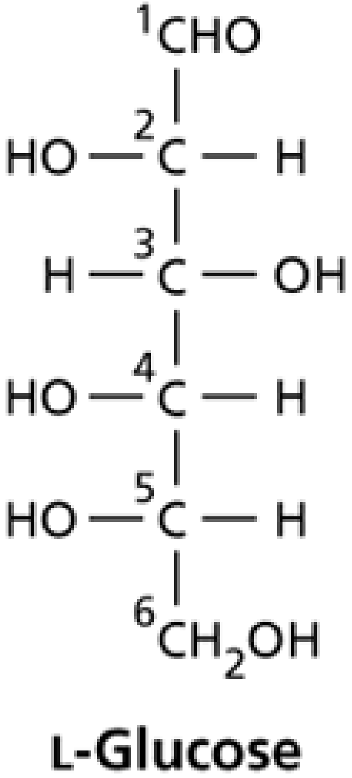
1- Concentration of the substance in the solution
2- Length of the tube
3- Wave length of polarized light
4- Temperature
5- Nature of solvent used

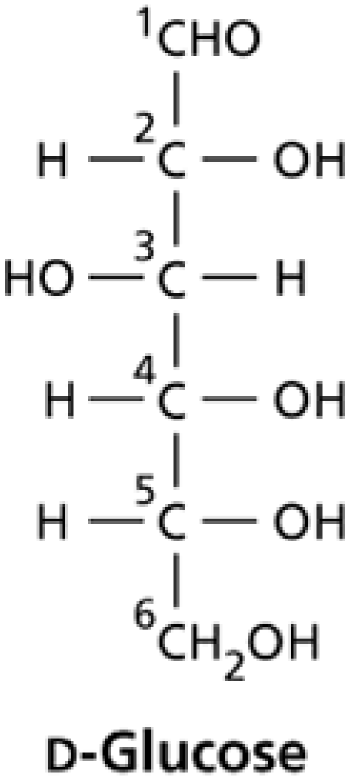
Example :-



L (-) gylceraldehyde D (+) gylceraldehyde

- If the OH- group right it become (D)
- If the OH- group left it become (L)
- If the compound have more than one chiral carbon we take the last one .



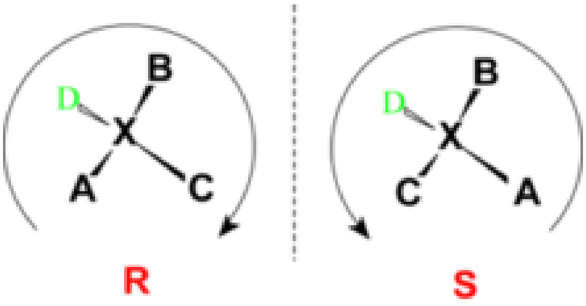


The chiral carbon atoms are (C2-C3-C4-C5) because they are attached to dissimilar atoms or groups, while C1-C6 are non-chiral because they are attached to similar atoms.

As for the nomenclature, the last chiral carbon atom is looked at, which is C5. If the OH is to the right, the name becomes D-glucose, but if it is vice versa, it is called L-glycose.

no. of optical Isomer in Glycose $= 2^n = 2^4 = 16$

Rectus (R) and sinister (S)

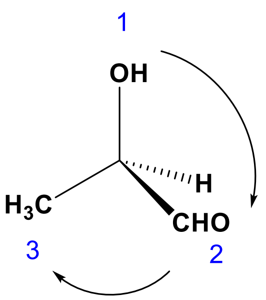


The "right hand" and "left hand" nomenclature is used to name the enantiomers of a chiral compound. The stereo centers are labeled as R or S.

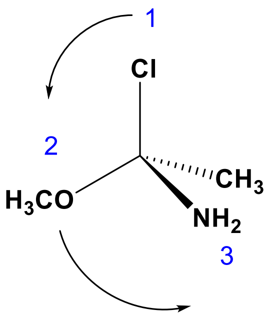
Consider the first picture: a curved arrow is drawn from the highest priority to the lowest priority . If the arrow points in a counterclockwise direction configuration at stereo center is considered *S* ("Sinister" → Latin= "left").

If, the arrow points clockwise then the stereo center is labeled *R* ("Rectus" → Latin= "right").

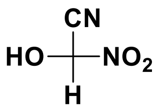
Example :-



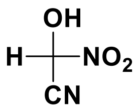
R



S



L



R

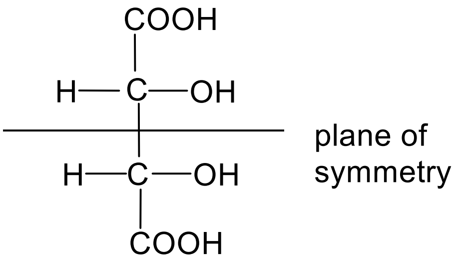
Element of symmetry

symmetry elements. A symmetry element is a line, a plane or a point in or through an object, about which a rotation or reflection leaves the object in an orientation indistinguishable from the original.

The compound have symmetry element become optically inactive .

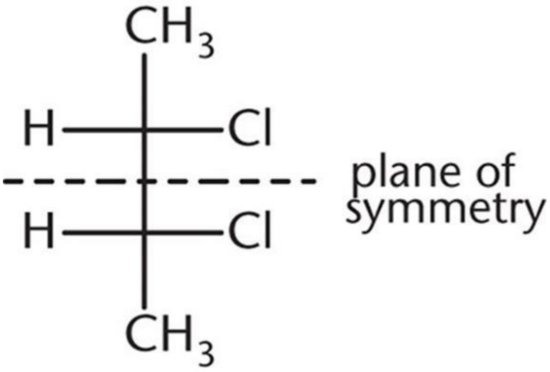
1- **plane of symmetry** :- which dividing the molecule into two identical part and become optically inactive.

Example (1):-



meso tartaric acid

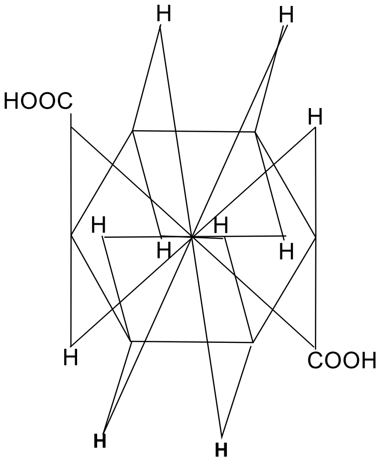
Example (2):-



2- center of symmetry :- is any point in space such that any group on the molecule can be reflected back through that point an equal distance but opposite direction and an equivalent group are found.

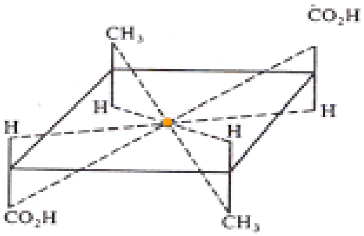
Example (1):-

Hexahydro-terphthalic acid



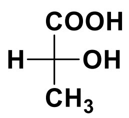
Example (2):-

Trans-2,4-dimethylcyclobutane-1,3-dicarboxylic acid

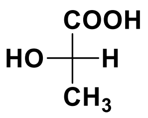


Enantiomer:-

In enantiomer (also named optical isomer) the two stereoisomers that are mirror images of each other that are non-superposable (not identical), much as one's left and right hands are mirror images of each other that cannot appear identical simply by reorientation.



D- lactic acid



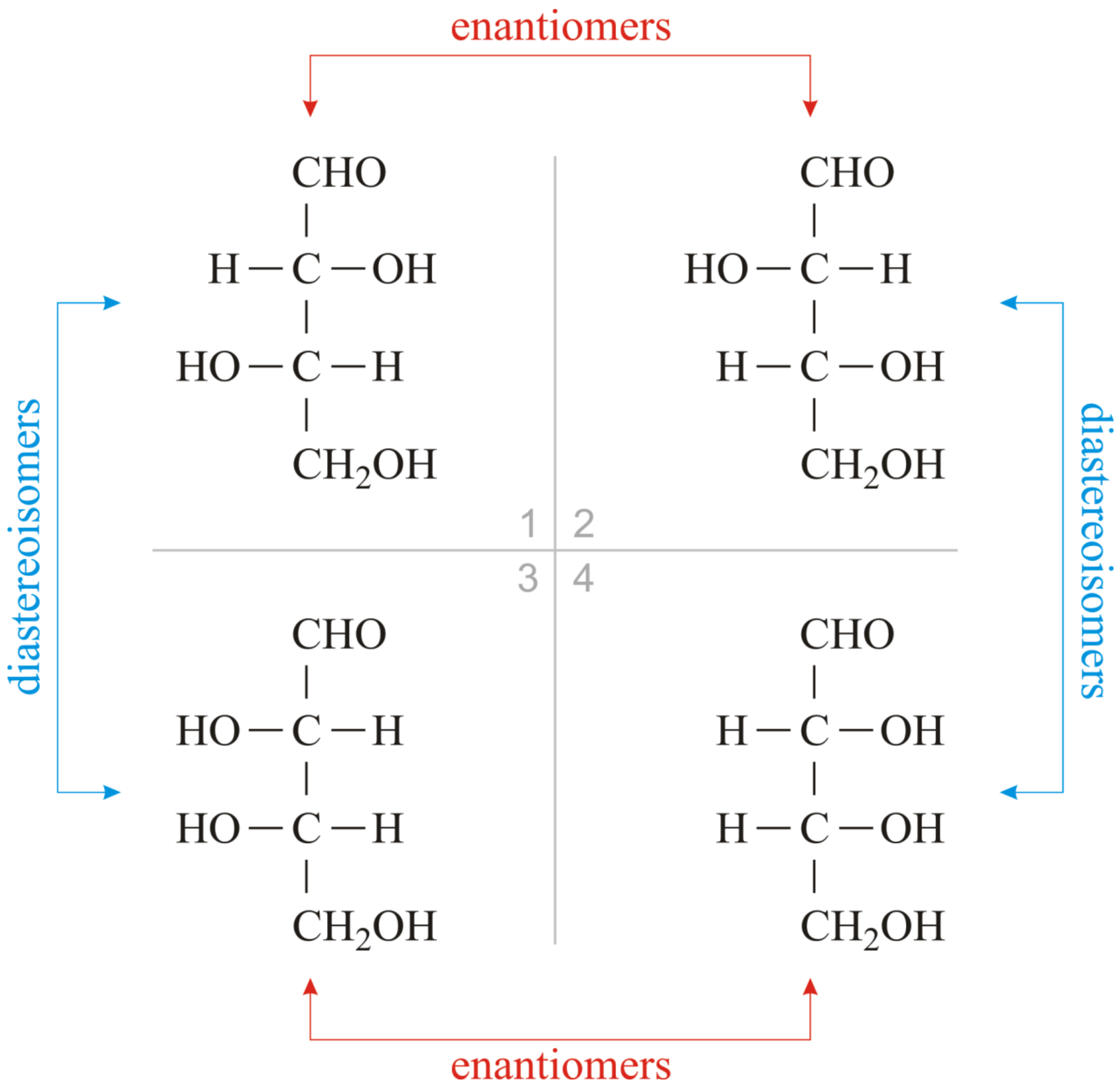
L-lactic acid

Diastereoisomers

Diastereoisomers are defined as non-mirror image non-identical stereoisomers. They occur when two or more stereoisomers of a compound have different configurations at one or more (but not all) of the equivalent (stereocenters) and are not mirror images of each other.

** in the structure below, **1** and **2** are enantiomers and so are **3** and **4** while **1** and **3** are diastereoisomers, as are **2** and **4**.

**Unlike enantiomers, diastereoisomers need not have closely similar physical and chemical properties.

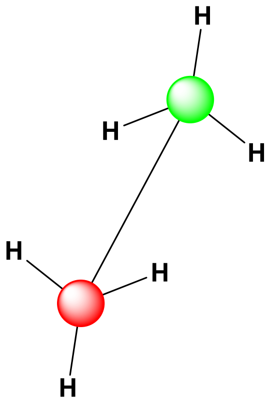

enantiomers
diastereoisomers
diastereoisomers
1
2
3
4
CHO
H—C—OH
HO—C—H
CH2OH
CHO
HO—C—H
H—C—OH
CH2OH
CHO
HO—C—H
HO—C—H
CH2OH
CHO
H—C—OH
H—C—OH
CH2OH
enantiomers

conformational isomers

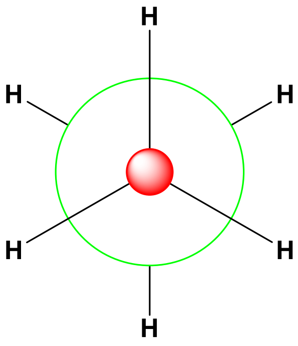
They are stereoisomers that describe the phenomenon of molecules that have the same structural formula but have a different chemical conformation due to the rotation of the atoms around the single sigma bond. As a result of this rotation the compound exists in more than one form, these forms are called isomers of the (formal) shape.

Conformational of Ethan CH3CH3

Some forms of the ethane molecule were expressed by the method (the projection of the scientist Sowers and the Newman world) as a result of free rotation around the carbon-carbon single bond.



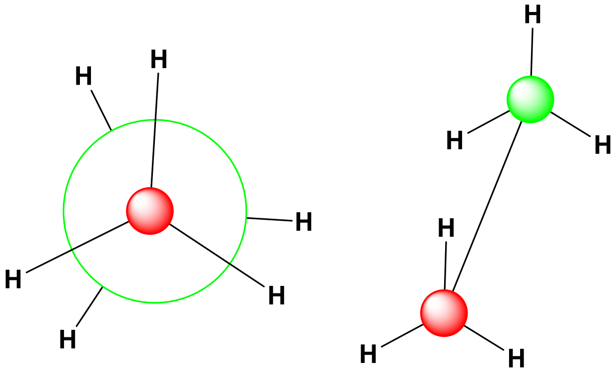
Sawhorse projection



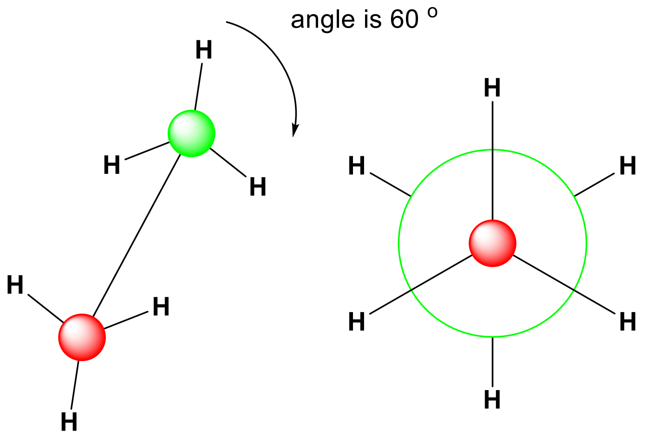
Newman projection

Ethane have 6 form (3 eclipsed form and 3 staggered form)

(eclipsed form)



(staggered form)



We note that the staggered form is the most stable form, as the angle between groups or atoms is 60 degrees, but in the eclipsed form, the angle is zero.

The conformation of cyclohexane:

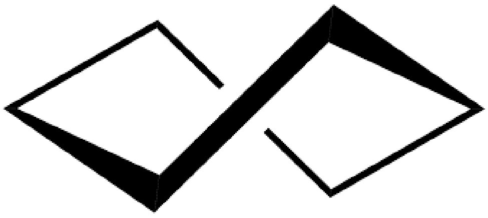
All cyclohexane bonds are single, and therefore there are four free forms:

1- Chair form

Chair conformation is a term used for the most stable chemical conformation of hexagonal carbon rings such as cyclohexane. When atoms are bonded together, the electrons tend to scatter as far from each other as possible.

Due to the natural need for the sp³ hybrid orbital (i.e carbon-hydrogen bonds) in the tetravalent carbon atoms to reach 109.5°, cyclohexane is not a planar molecule. Cyclohexane exists in chair and twisted form, the chair form being the most stable form, and stress in this form makes the angle C-C-C 111.5°.

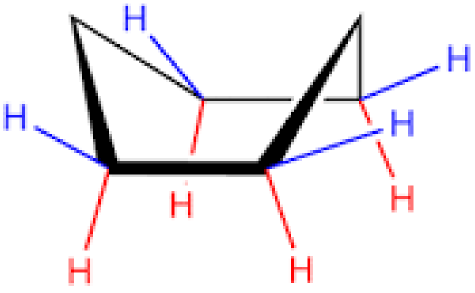
2- Twisted boat form :-



Cyclohexane is also present in conformers in the form of a twisted boat. The twisted boat is the only one that can be isolated like the chair form, because it represents a low energy, although its energy is higher than the seat structure (chair), due to the presence of torsion stress that is not present in the chair form.

3- Boat form

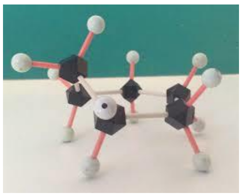
The boat structure and the chair form represent a transitional state between the twisted boat structure and the chair structure, respectively, and they cannot be separated.



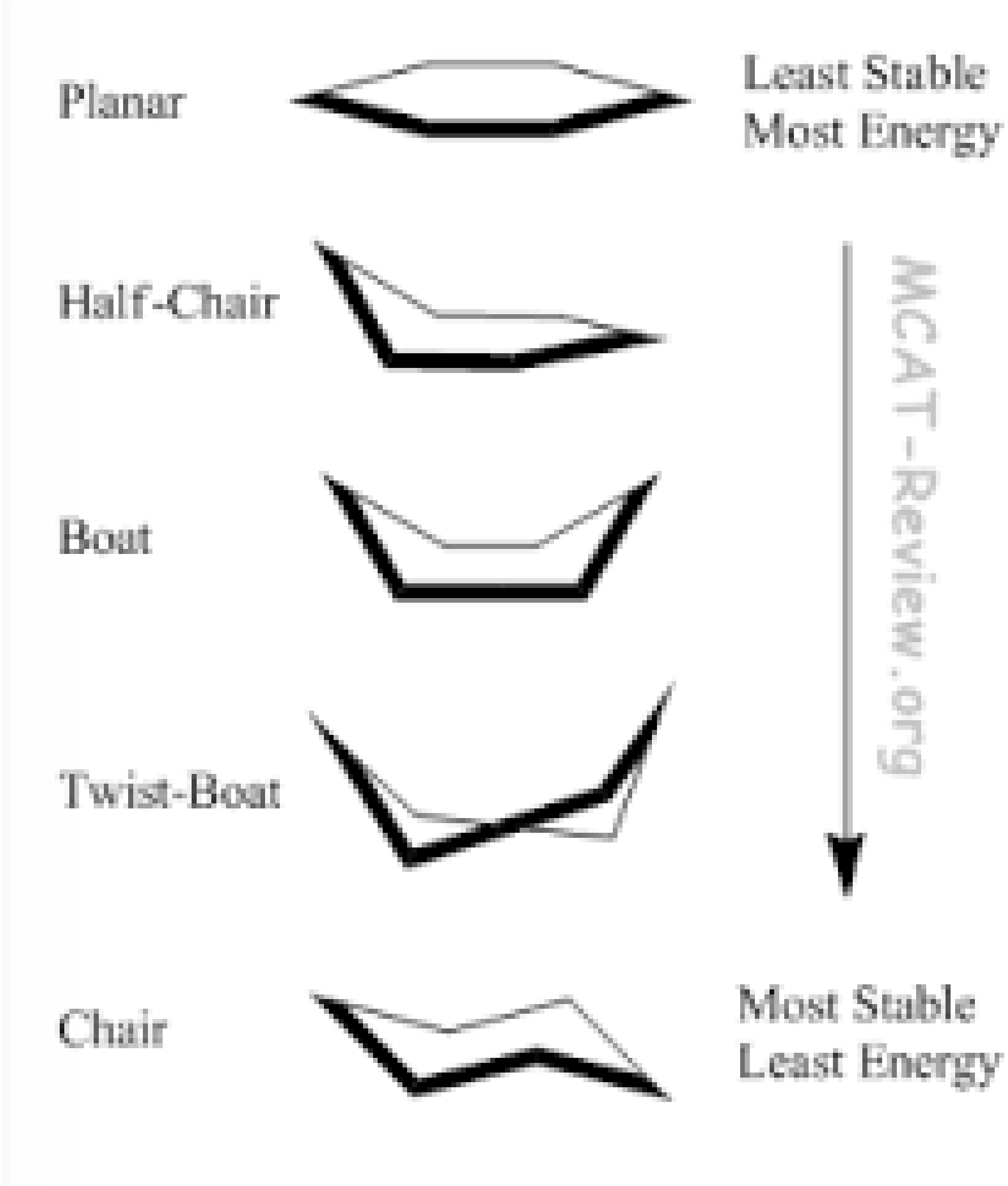
3

4- Haif chair form

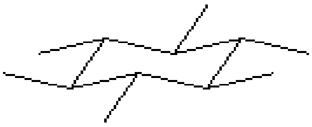
It is the highest form of energy



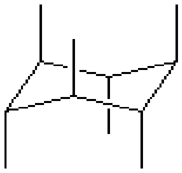
Energy level of four form



As for the distribution of groups, it is equatorial and axial as in the pictures .



equatorial bonds



axial bonds

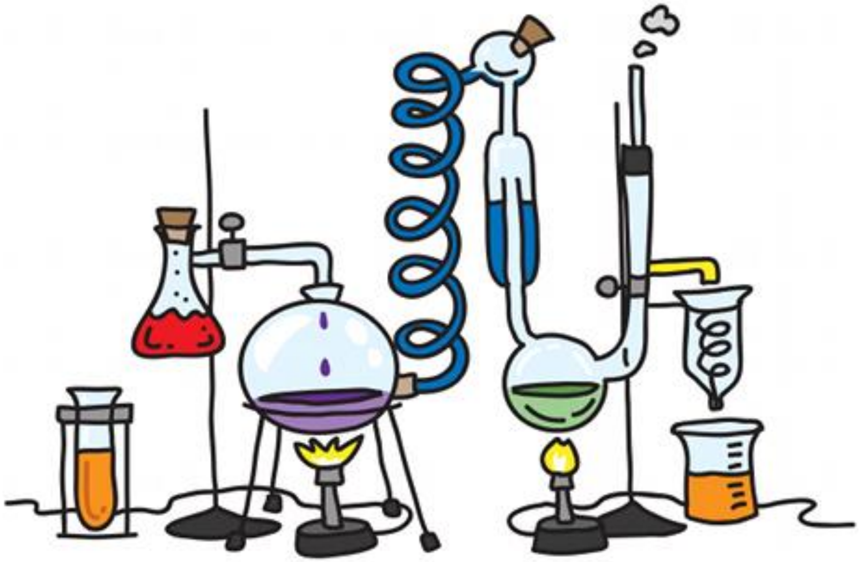
Reference :-

1- Stereochemistry of organic compound

المراجع :-

١- كتاب الكيمياء العضوية الفراغية
٢- كتاب اسس الكيمياء العضوية

Purification of Organic Compounds



Prepared by

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Chemistry Department – Faculty of Science

العام الجامعي

2022-2021

بيانات الكتاب

الكلية: التربية

الفرقة: الثانية

الشعبة: العلوم البيولوجية والجيولوجية - لغة إنجليزية

عدد الصفحات: 110

Contents:

- **Introduction**
- **Basic organic chemistry lab equipment**
- **Methods of purification of organic compounds**
  - **Purification of solid compounds**
    - Crystallization
    - Sublimation
  - **Purification of Liquid compounds**
    - **Distillation**
      - Simple Distillation
      - Fractional Distillation
      - Vacuum Distillation
      - Steam Distillation
    - **Differential Extraction**
    - **Chromatography**
      - **Thin Layer Chromatography (TLC)**
      - **Column Chromatography (CC)**

Introduction:

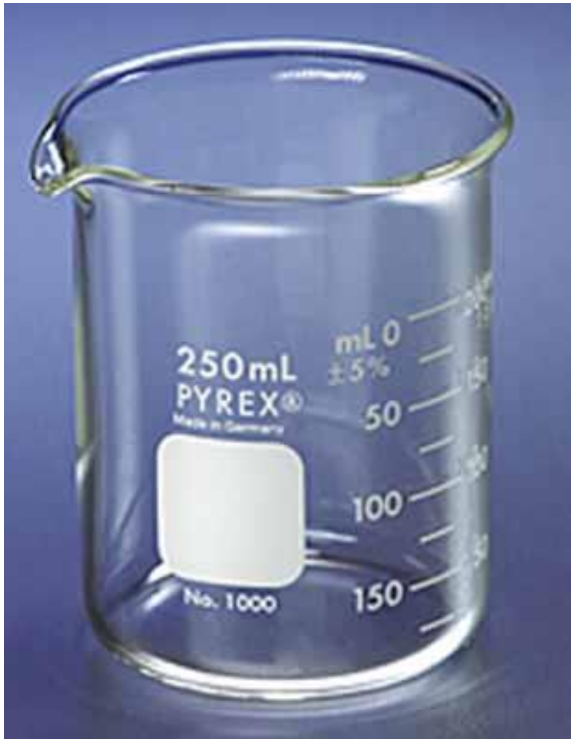
This course will focus on purification of organic compounds. Firstly, the main organic lab equipment will be presented, and then, the methods used in purification of solid organic compounds (Crystallization and Sublimation) and purifications of liquid organic compounds (Distillation, extraction, and chromatography) will be explained in some details.

Organic Compounds

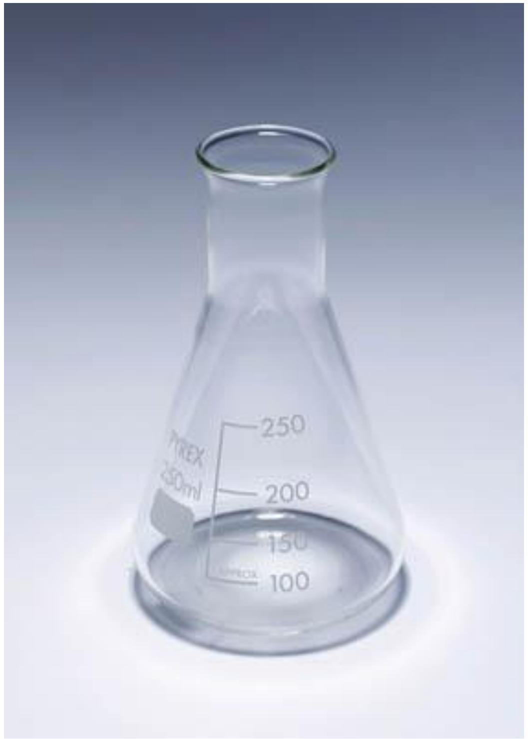
- Once the organic compounds extracted from a natural sources or synthesized in the laboratory, it's essential to purify it.

For Characterization (Full analysis)

Basic Organic Chemistry Lab Equipment



Beaker



Conical Flask

Measuring Cylinder

Basic Organic Chemistry Lab Equipment

Round bottom flask Single nick

Round bottom flask 2 nicks

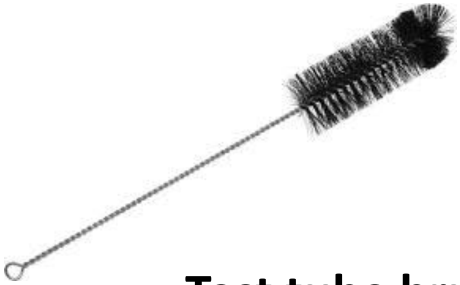
Some Distillation apparatus

Basic Organic Chemistry Lab Equipment

Test tube

Test tube rake

Test tube holder



Test tube brush

bunsen burner

Basic Organic Chemistry Lab Equipment

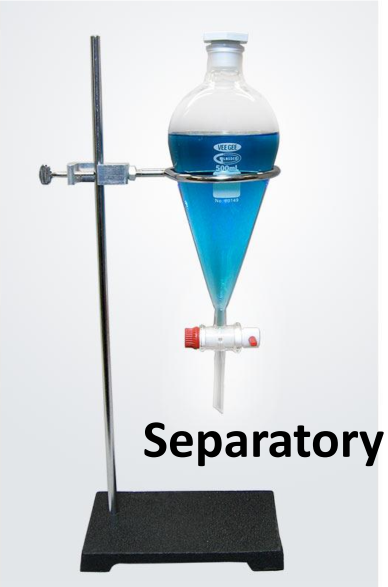
Condenser

Pipette

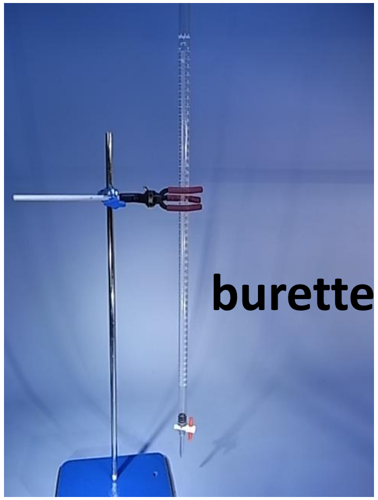
Micro pipette

Basic Organic Chemistry Lab Equipment

Ring stand



Separatory funnel



burette

Spatulas and scoopula

Basic Organic Chemistry Lab Equipment

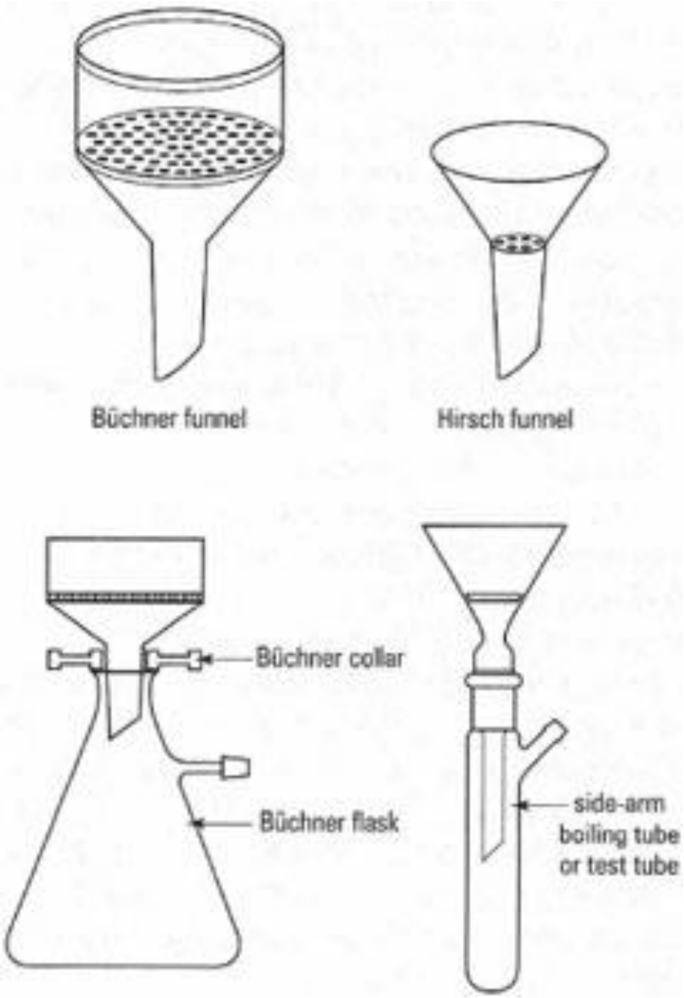
Filter funnel

Filter paper

Buchner filter funnel

Hersch filter funnel

Basic Organic Chemistry Lab Equipment



Buchner System for filtration

Basic Organic Chemistry Lab Equipment

Heat/stir plate

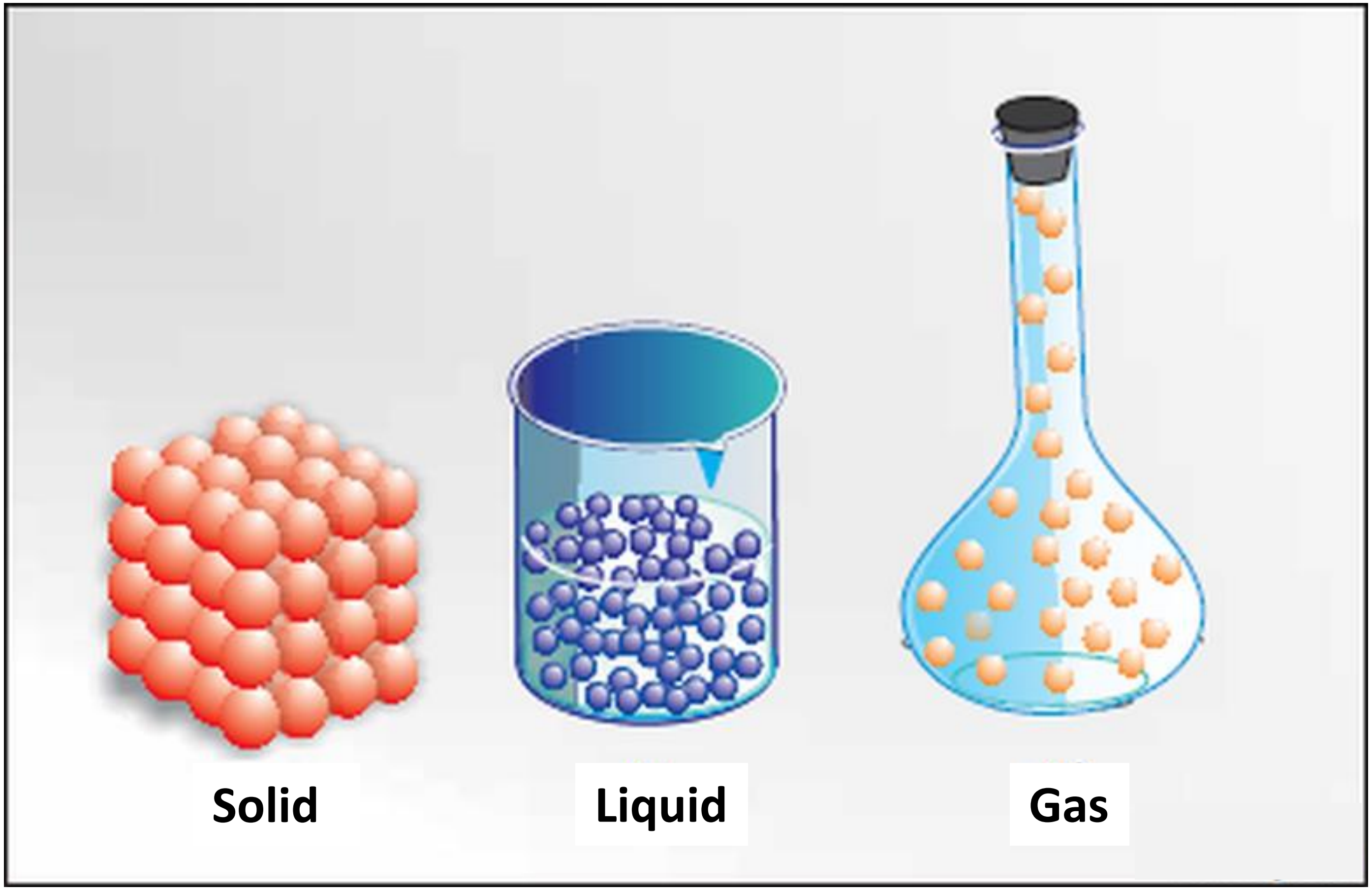
Heating mantle

Lab Oven

Melting point apparatus

Digital balance (Scale)

Organic Compounds



Methods of Purification of Organic Compounds

- Various methods used for the purification of organic compounds are based on the **nature of the compound** and **the impurities** present in it.

Purification of Solid

1- Crystallization

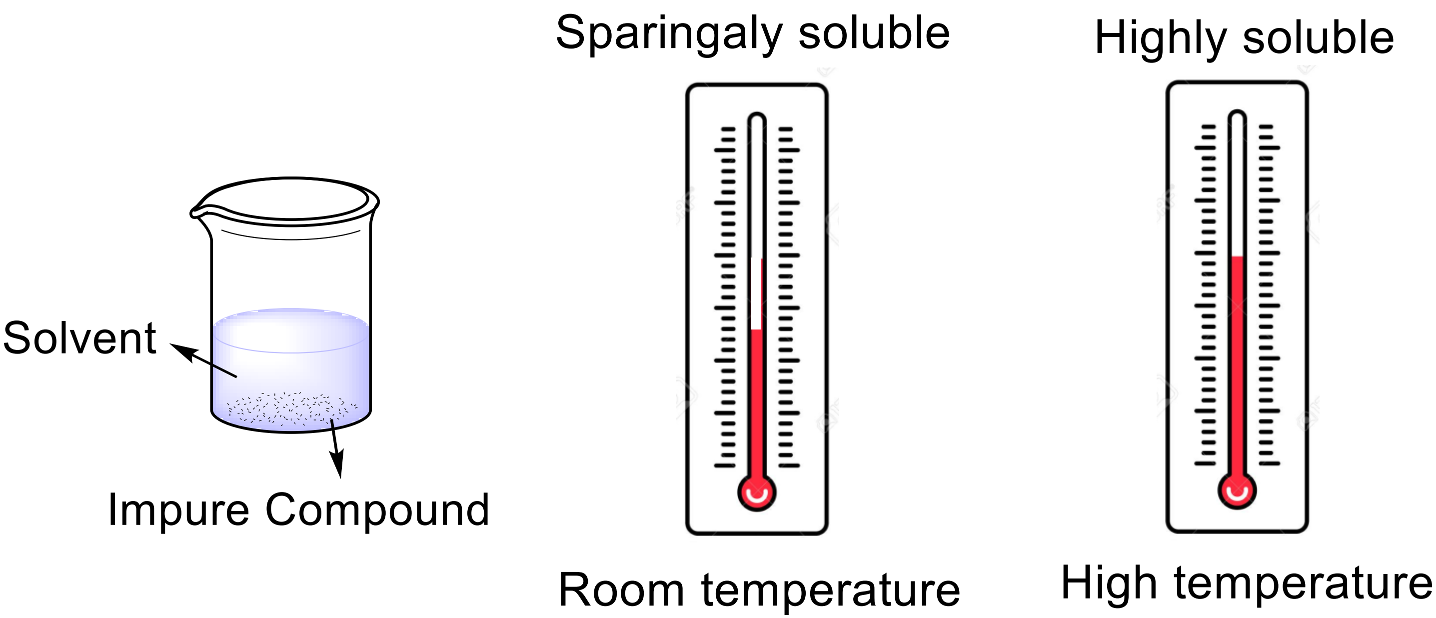
2- Sublimation

Crystallization

- Crystallization is the solidification of atoms or molecules into a highly structured form called a crystal.
- Crystallization can also refer to the solid-liquid separation and purification technique in which mass transfer occurs from the liquid solution to a pure solid crystalline phase.

Crystallization

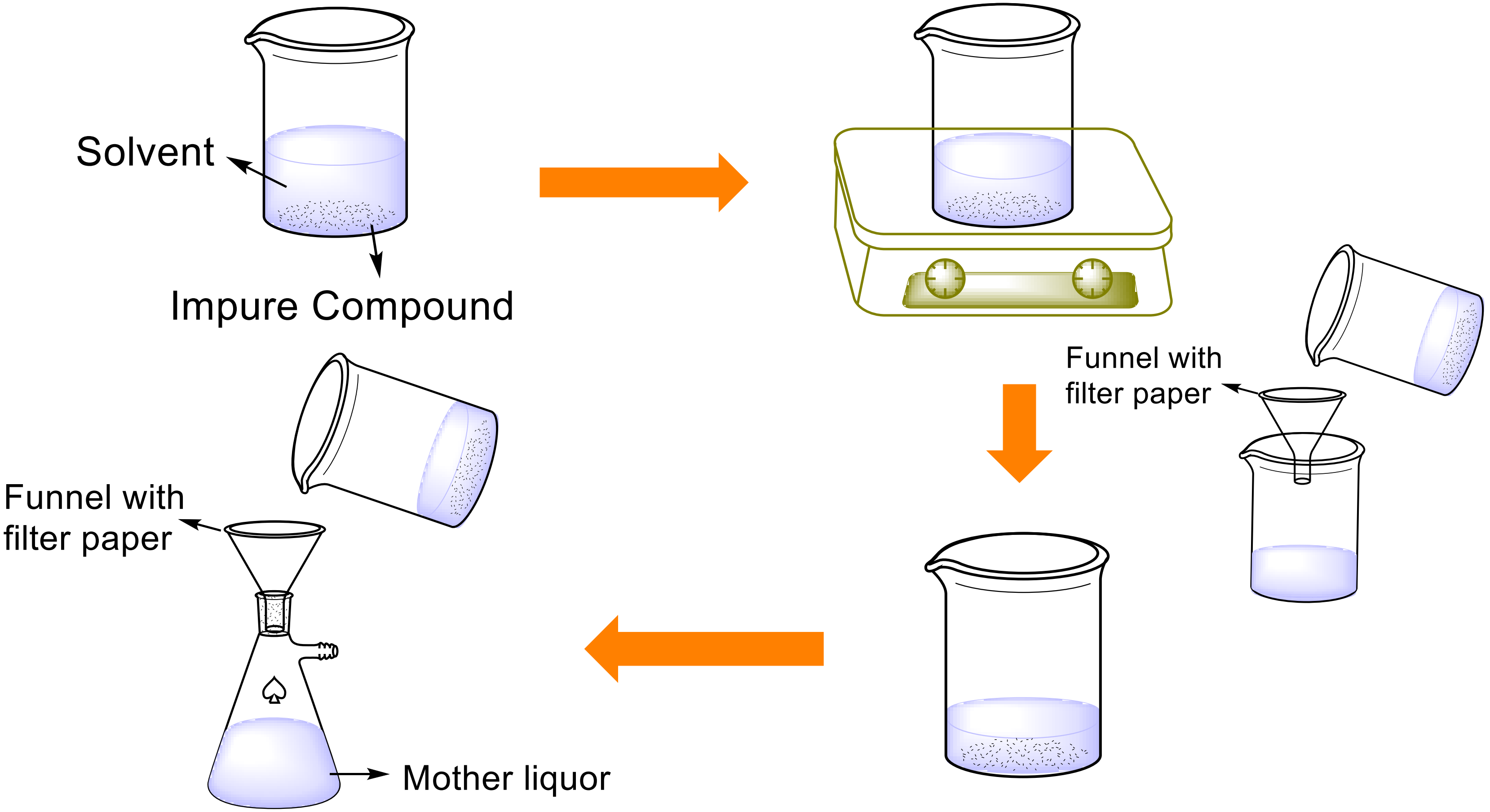
❖ **The impure compound is dissolved in a solvent in which it is sparingly soluble at room temperature but more soluble at higher temperature.**



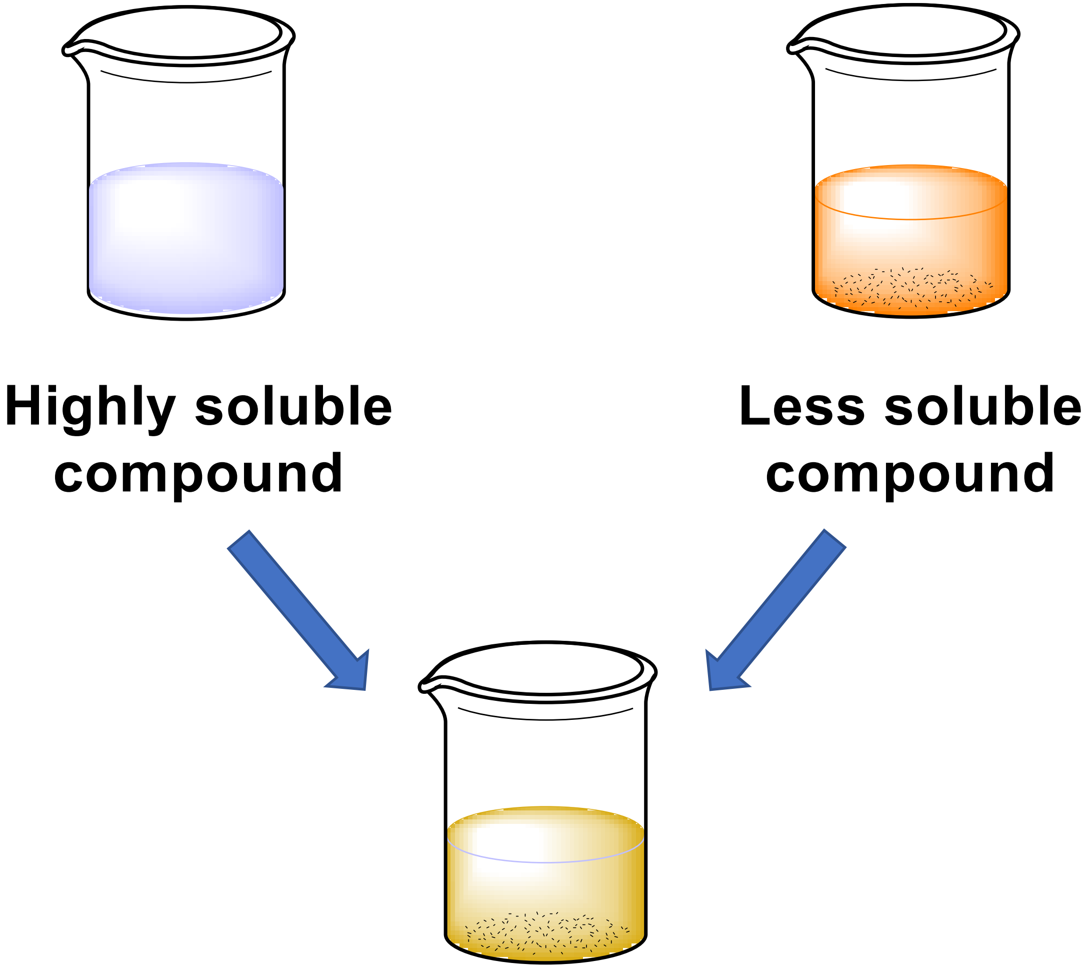
Crystallization

- The solution is concentrated to get a nearly saturated solution.
- On cooling the solution, pure compound crystallises out and is removed by filtration
- The filtrate (mother liquor) contains impurities and small quantity of the compound.
- Impurities, which impart colour to the solution are removed by adsorbing over activated charcoal

Crystallization



Crystallization



Highly soluble compound

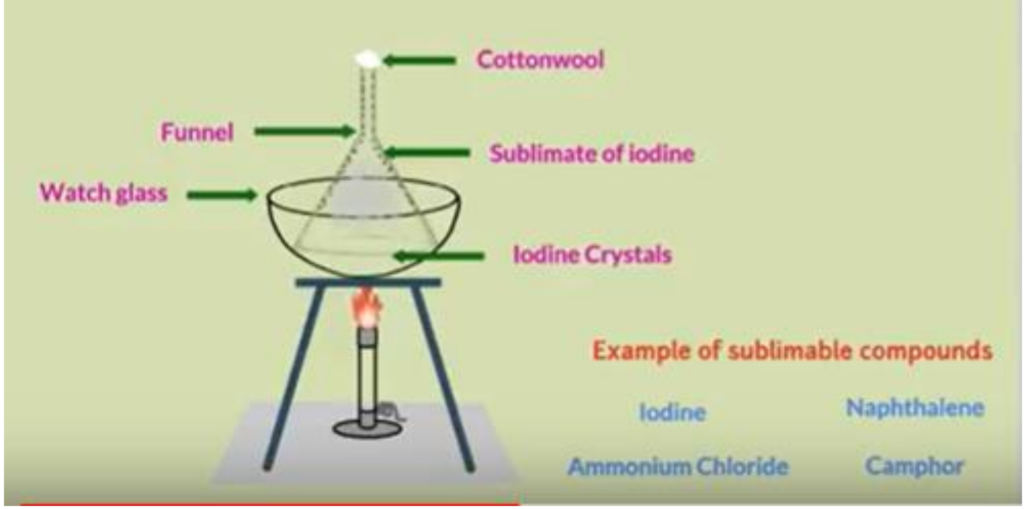
Less soluble compound

Crystalization solvent

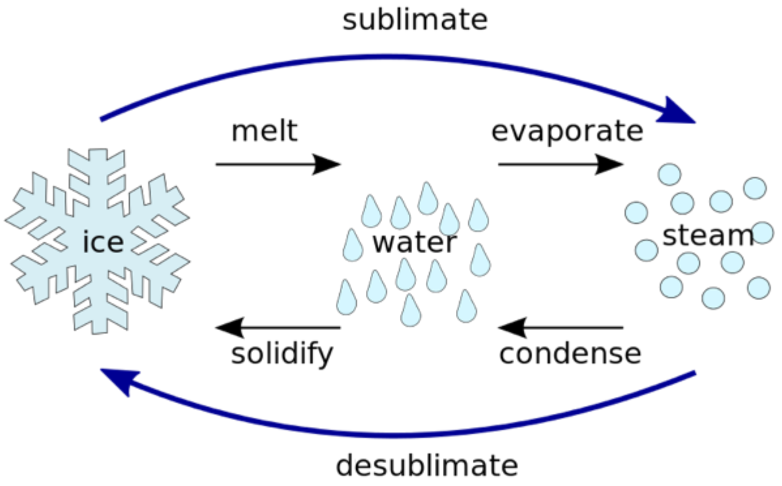
Sublimation

- Solid substance change to vapour stat without passing through liquid state on heating.

- Separate sublimable compounds from non-sublimable impurities.



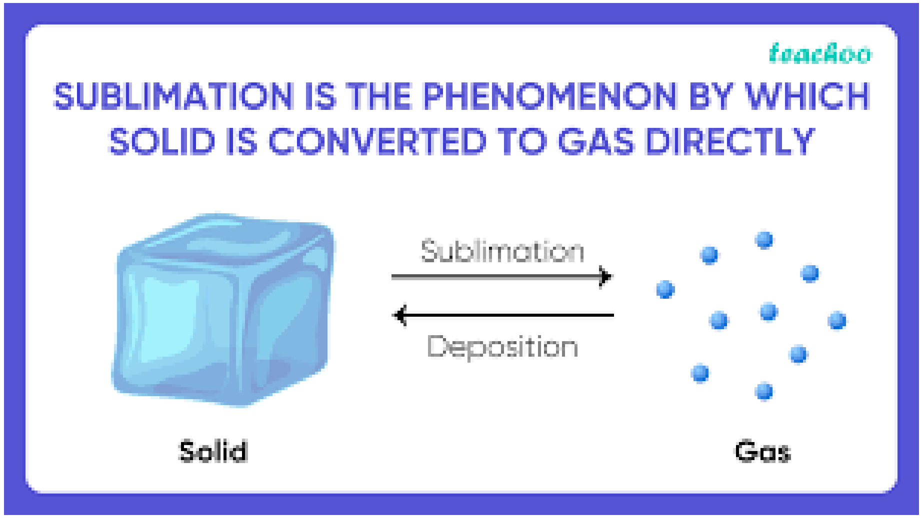
Sublimation



Sublimation is the transition of a substance directly from the solid to the gas state, without passing through the liquid state. Sublimation is an endothermic process that occurs at temperatures and pressures below a substance's triple point in its phase diagram, which corresponds to the lowest pressure at which the substance can exist as a liquid.

The reverse process of sublimation is deposition or desublimation, in which a substance passes directly from a gas to a solid phase. Sublimation has also been used as a generic term to describe a solid-to-gas transition (sublimation) followed by a gas-to-solid transition (deposition).

Sublimation



SUBLIMATION IS THE PHENOMENON BY WHICH SOLID IS CONVERTED TO GAS DIRECTLY

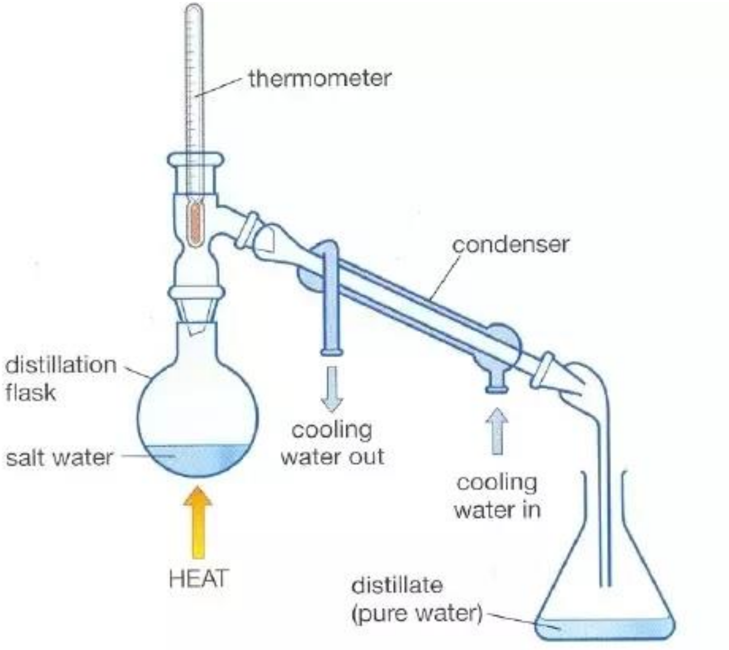
Sublimation is a technique used by chemists to purify compounds. A solid is typically placed in a sublimation apparatus and heated under vacuum. Under this reduced pressure, the solid volatilizes and condenses as a purified compound on a cooled surface (cold finger), leaving a non-volatile residue of impurities behind. Once heating ceases and the vacuum is removed, the purified compound may be collected from the cooling surface

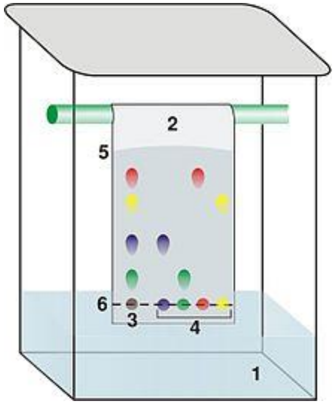
Purification of Liquids

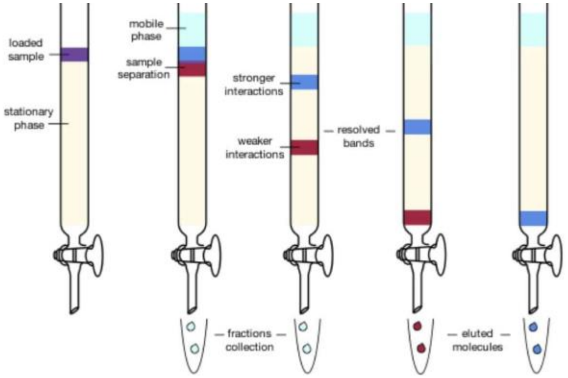
1- Distillation

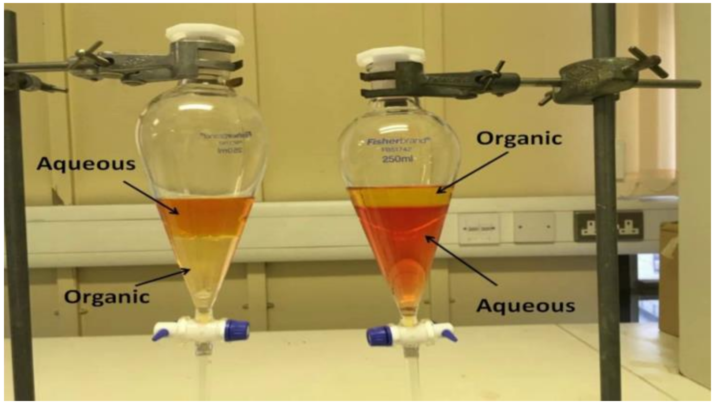
2- Differential Extraction

3- Chromatography





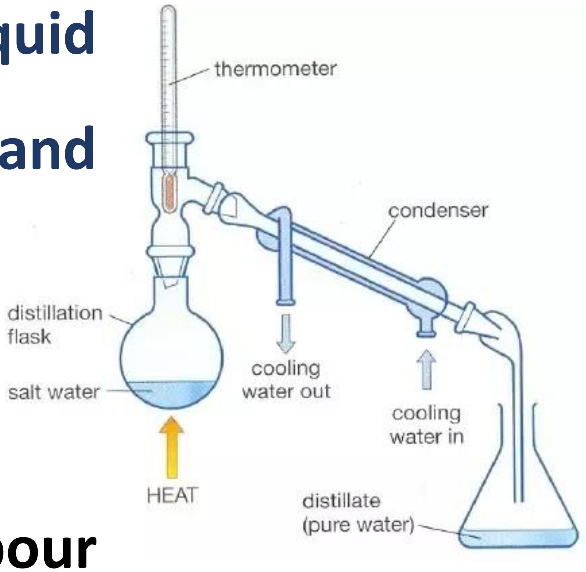




Distillation

Distillation

Is the process of separating the components or substances from a liquid mixture by using selective boiling and condensation

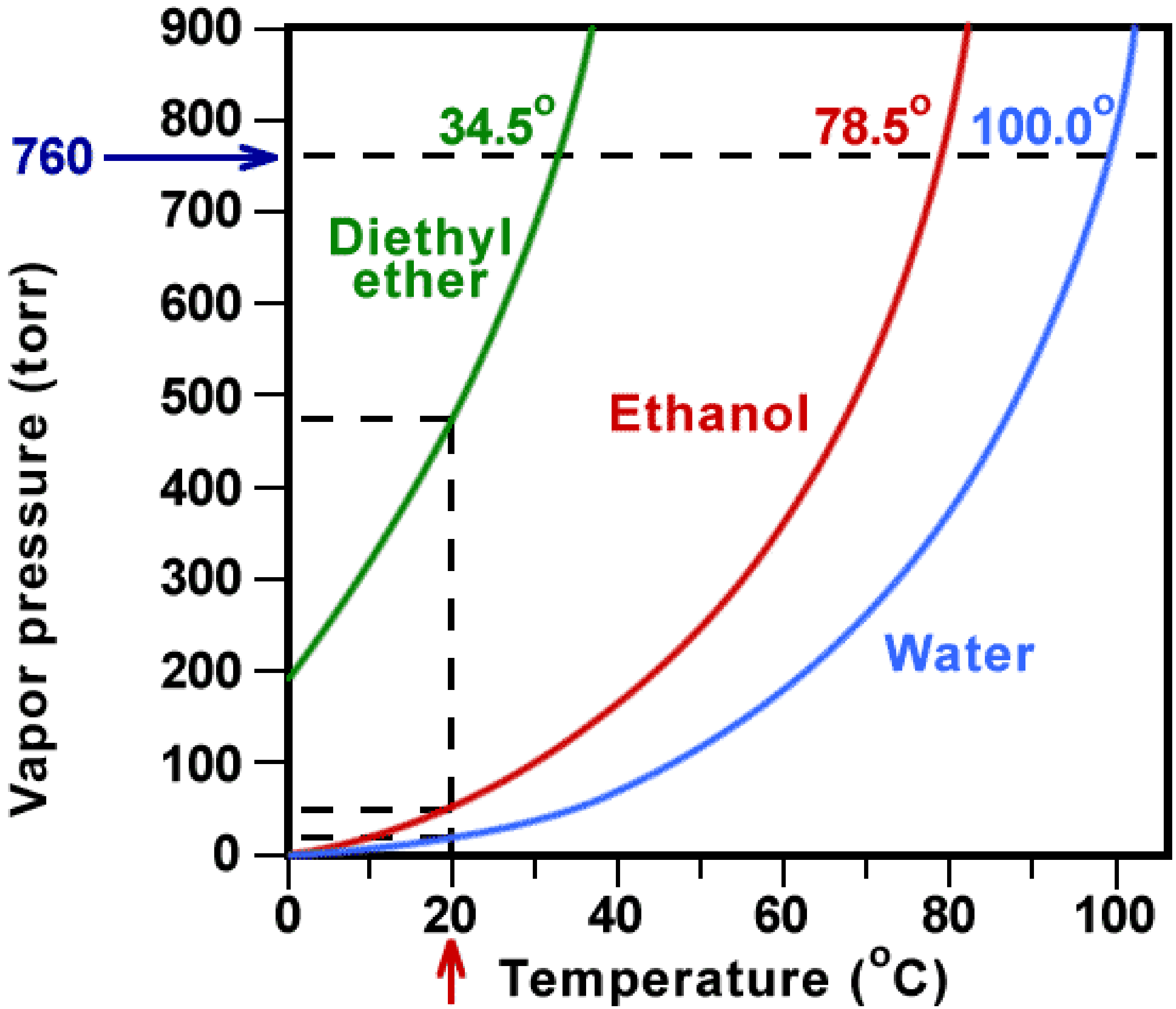


- Distillation processes based on the **vapour pressure** (**P_{vap}**) of the mixture, which is dependant on **fraction mole** of each component

Distillation

Distillation may result in essentially **complete separation** (nearly pure components), or it may be a **partial separation** that increases the concentration of selected components in the mixture.

Relation between vapour pressure and temperature



Distillation

The Basic

- By increasing the temperature of the liquid mixture, the vapours that form will increase the pressure.

- When the vapour pressure equals the atmospheric pressure, the liquid will start boiling

- Evaporation of the liquids depending on the **Dalton’s and Raoult’s laws**

There are 4 types of Distillation

Simple Distillation

Fractional Distillation

Vacuum Distillation

Steam Distillation

Simple Distillation

Simple distillation is a procedure by which two liquids with different boiling points can be separated.

- **Simple distillation** can be used effectively to separate liquids that have at least (25 – 50) degrees difference in their boiling points

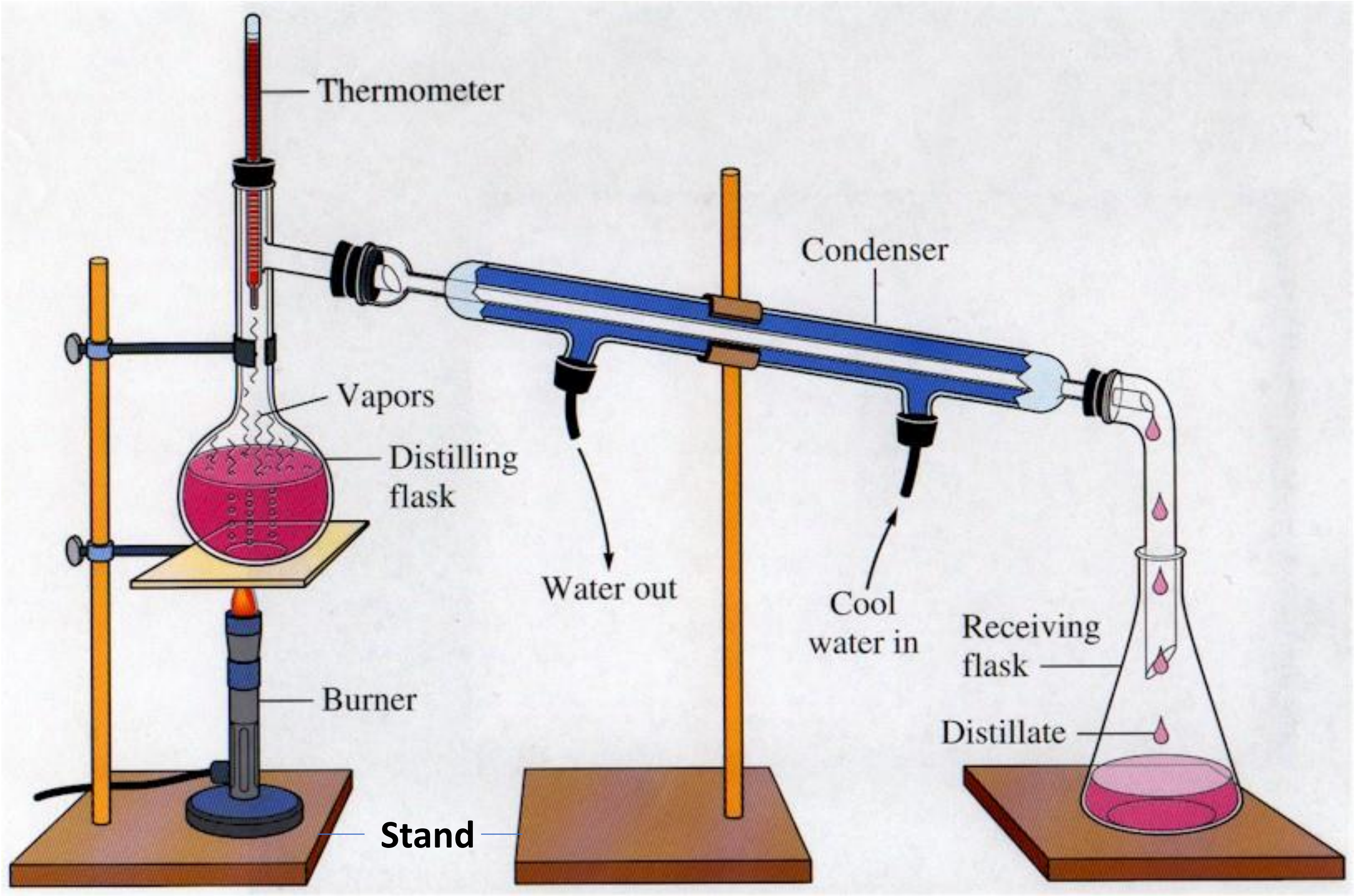
Simple Distillation

Also, It can be used to purify the liquid from solid impurities

Ex: **Water Distillation**

Separating salt water to create pure water and salt.

Simple distillation apparatus



How can you connect the simple distillation apparatus?

Raoult and Dalton's Laws

Raoult's Law

$$P_{vap} = (\chi_{liq})\, P^{o}_{vap}$$

Mole fraction

Dalton's Law

$$P_{total} = P_{vap(a)} + P_{vap(b)}$$

Ideal Gas Law

Ideal Gas Law

$$PV = nRT$$

$$\frac{P_{(a)}}{P_{(total)}} = \frac{n_{(a)}}{n_{(total)}} = \chi_{(a)}$$

$$\frac{P_{(a)}}{P_{(total)}} = \chi_{(a)}$$

Boiling a Binary Mixture

● = Toluene

$P^{o}_{vap} = 300$ torr

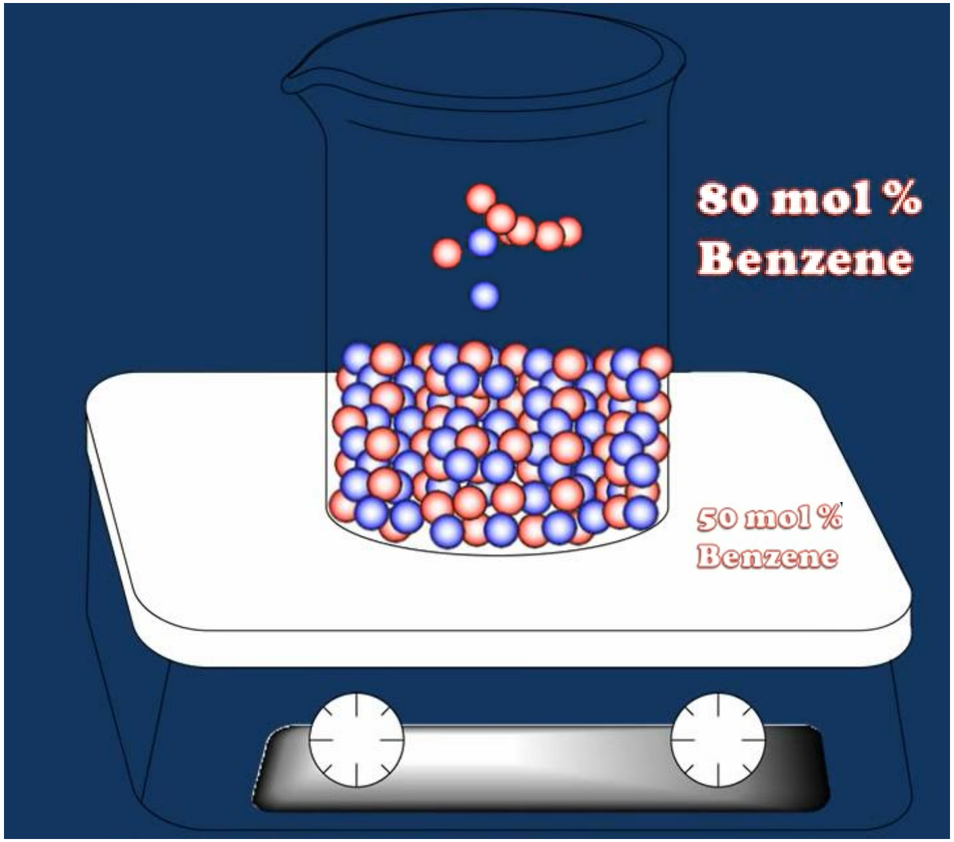
$P_{vap} = (\chi_{liq})\, P^{o}_{vap}$
$P_{vap} = (0.5) * 300$ torr
$P_{vap} = 150$ torr

● = Benzene

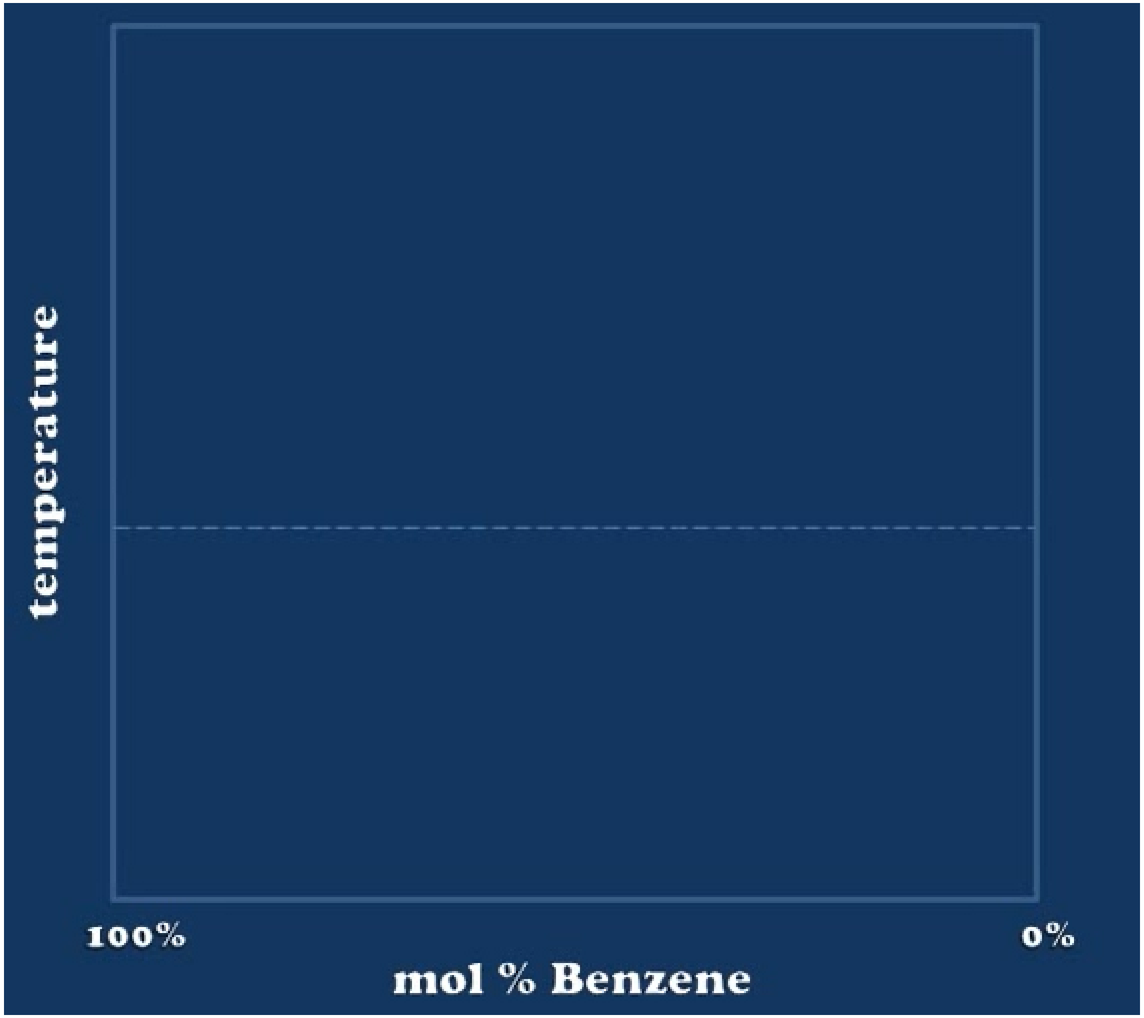
$P^{o}_{vap} = 1200$ torr

$P_{vap} = (\chi_{liq})\, P^{o}_{vap}$
$P_{vap} = (0.5) * 1200$ torr
$P_{vap} = 600$ torr

$(\chi_{vap}) = P_{vap} / P_{total}$
$(\chi_{vap}) = 600 \text{ torr}/750\text{torr}$
$(\chi_{vap}) = 0.80 = 80$ mol%



The Liquid-Vapor Composition Plot



The Liquid-Vapor Composition Plot

🔵 = **Toluene**

$P^{o}_{vap} = 300\ \text{torr}$

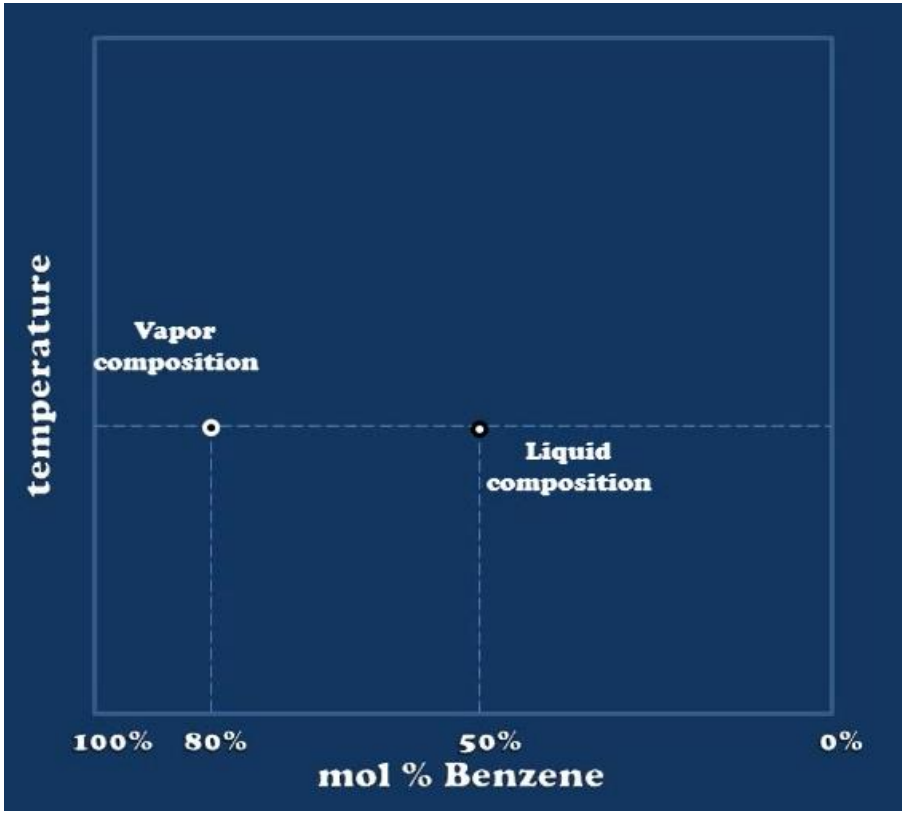
$P_{vap} = (\chi_{liq})\, P^{o}_{vap}$
$P_{vap} = (0.5) * 300\ \text{torr}$
$P_{vap} = 150\ \text{torr}$

🔴 = **Benzene**

$P^{o}_{vap} = 1200\ \text{torr}$

$P_{vap} = (\chi_{liq})\, P^{o}_{vap}$
$P_{vap} = (0.5) * 1200\ \text{torr}$
$P_{vap} = 600\ \text{torr}$

$(\chi_{vap}) = P_{vap} / P_{total}$
$(\chi_{vap}) = 600\ \text{torr} / 750\text{torr}$
$(\chi_{vap}) = 0.80 = 80\ \text{mol\%}$



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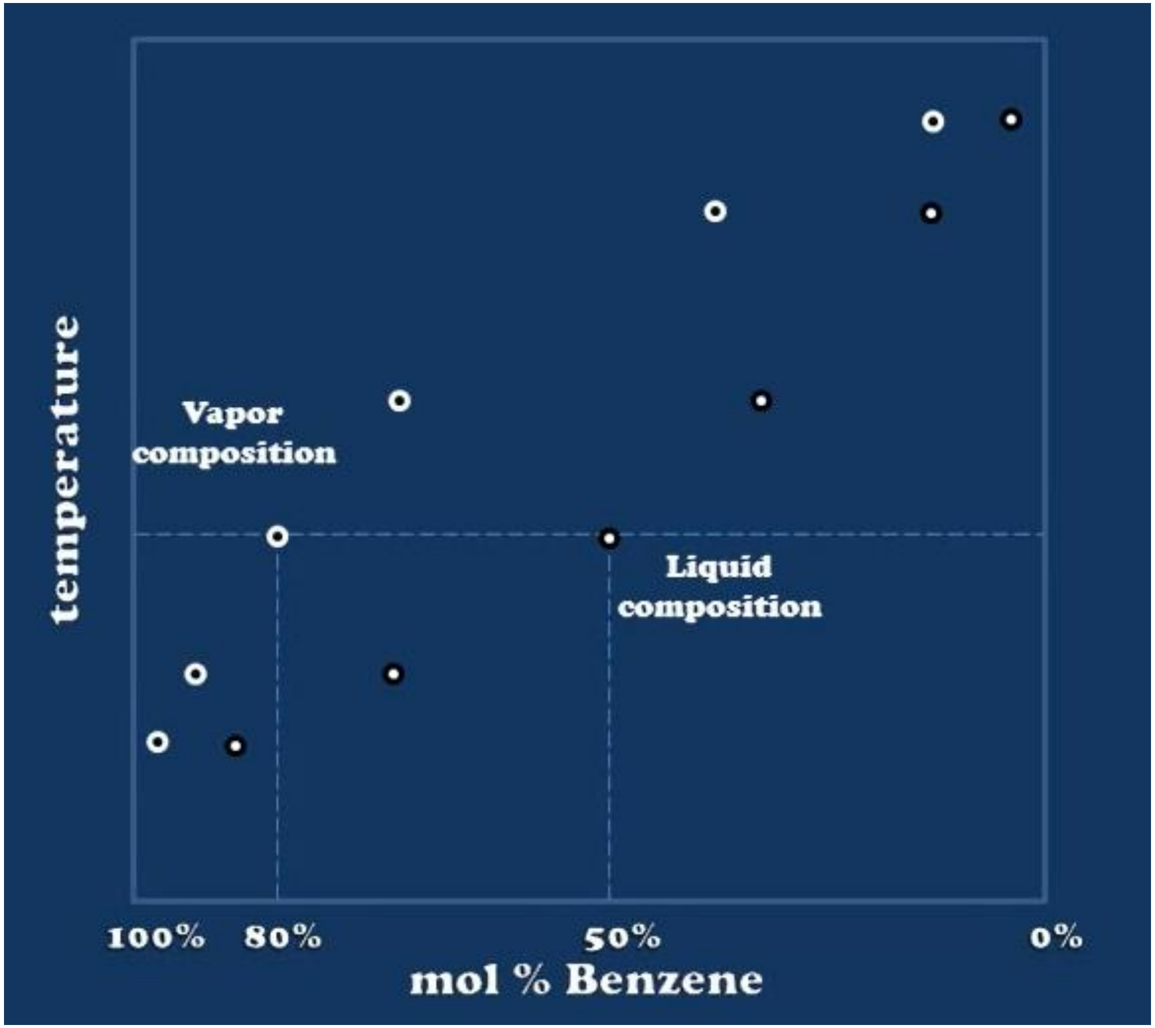
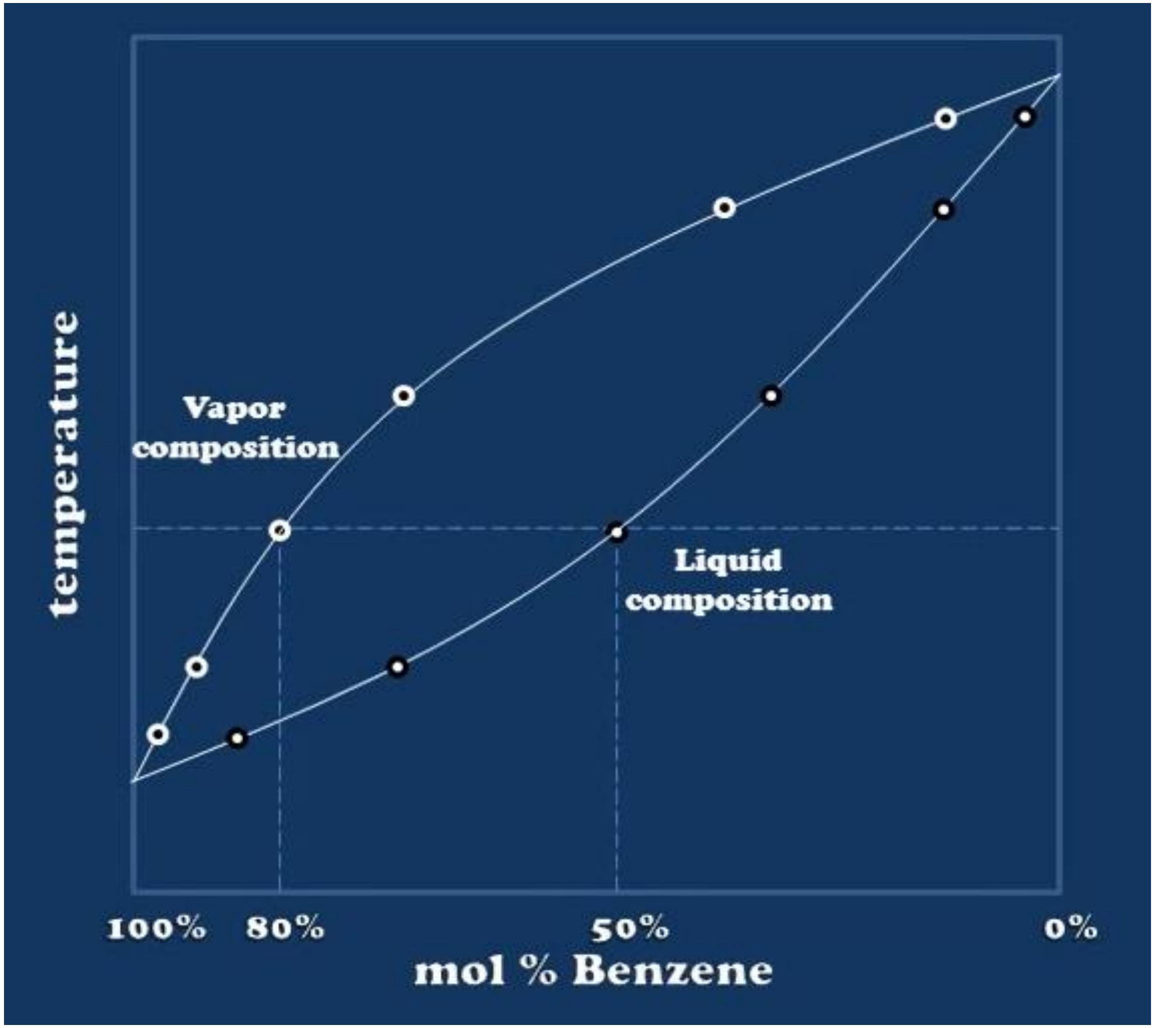
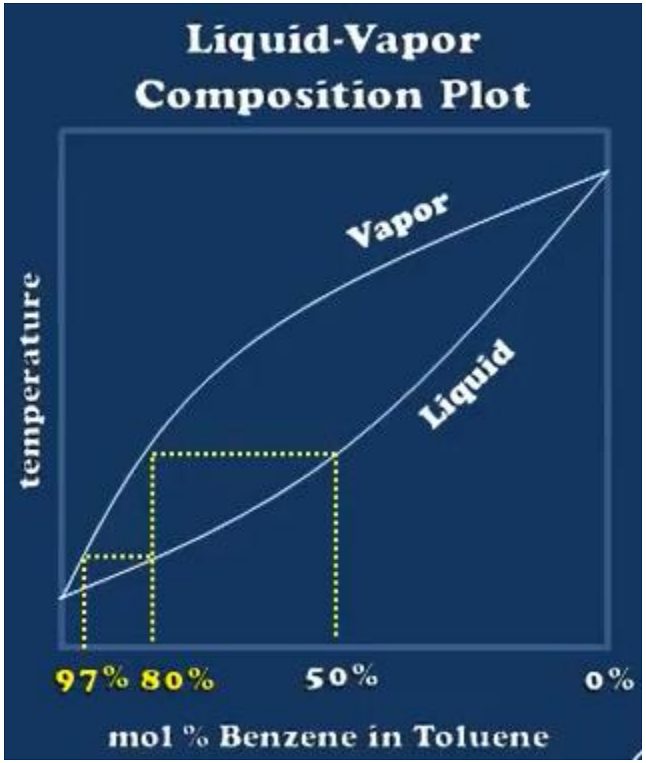
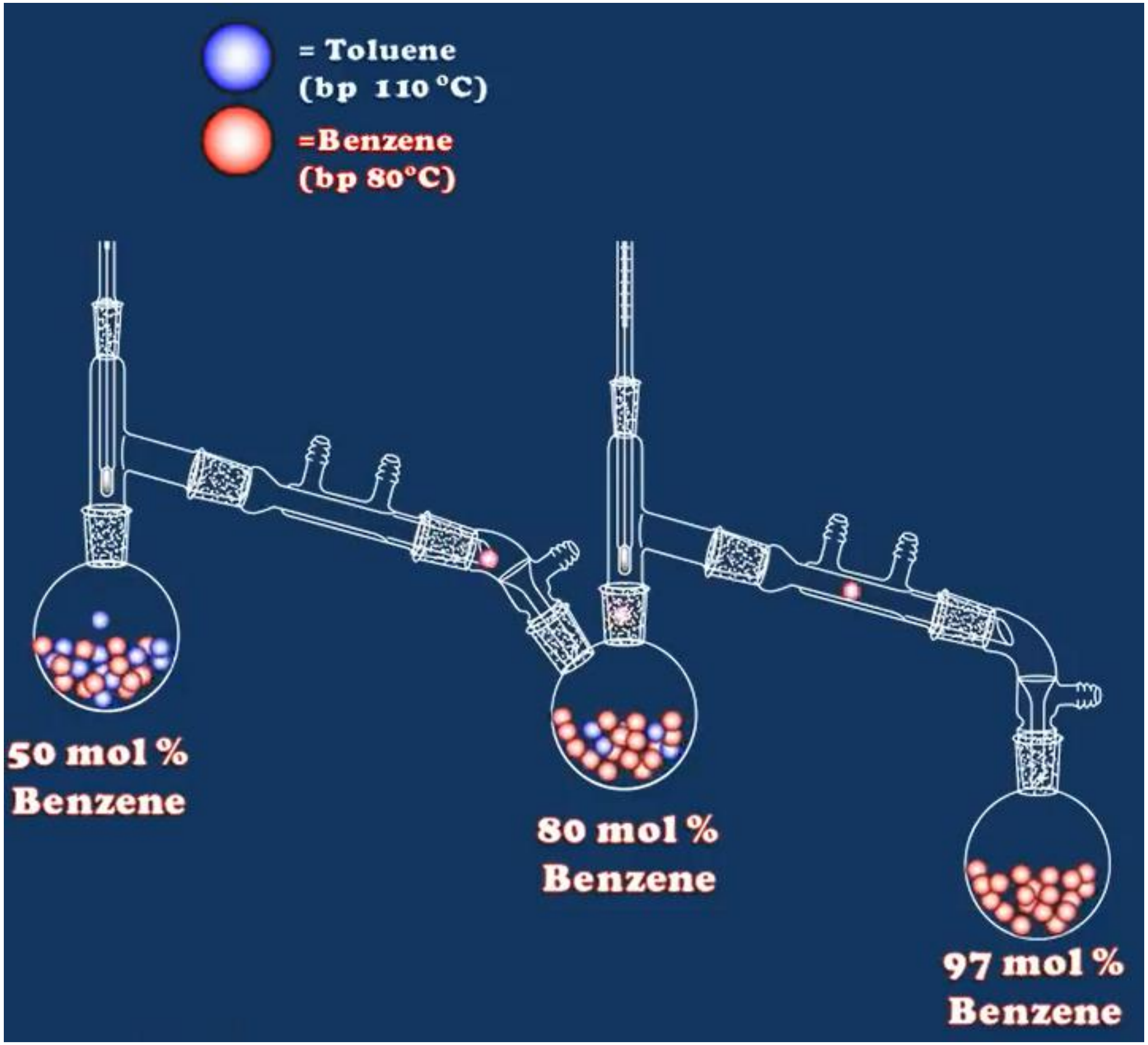


The Liquid-Vapor Composition Plot



Is it possible to have pure liquid from simple distillation?!





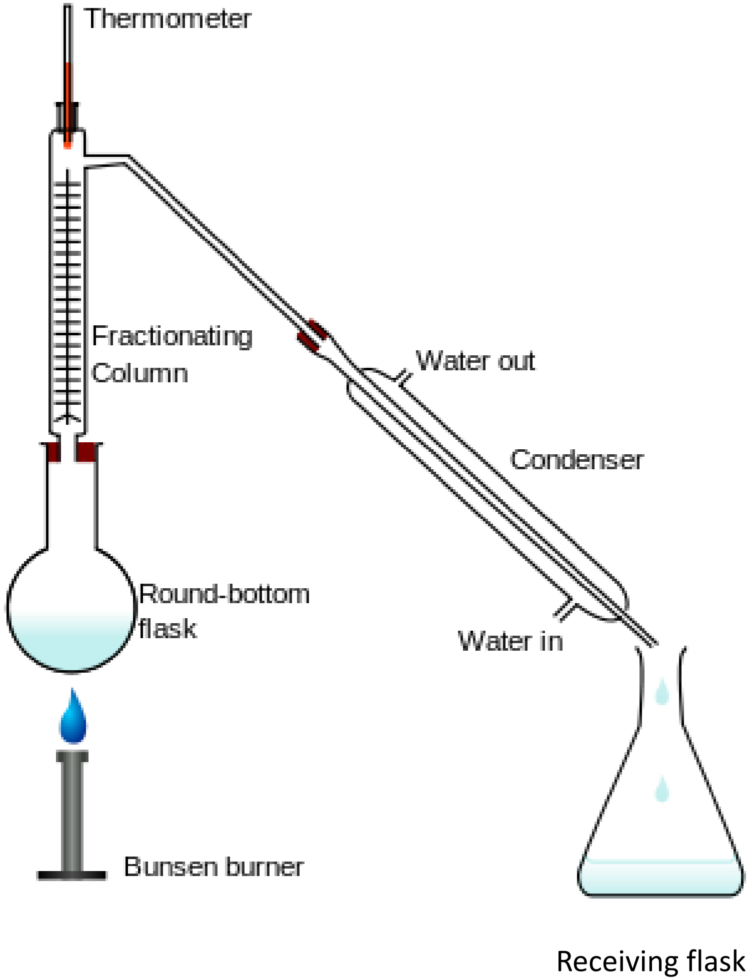
Fractional Distillation

Fractional Distillation

- Is the separation of a mixture into its component parts, or fractions.
- Chemical compounds are separated by heating them to a temperature at which one or more fractions of the mixture will vaporize.
- Generally the component parts have boiling points that differ by less than 25 °C (77 °F) from each other under a pressure of one atmosphere.

Fractional distillation apparatus

Fractional distillation is the most common form of separation technology used in petroleum refineries, petrochemical and chemical plants, natural gas processing and cryogenic air separation plants



Vacuum Distillation

Vacuum Distillation

Distillation of a liquid under reduced pressure, enabling it to boil at a lower temperature than normal

Vacuum Distillation

"low-temperature distillation"

- This technique is used when the boiling point of the desired compound is **difficult to achieve**, will cause the compound to **decompose**.
- For compounds with a normal bp above 200 ^{o}C
- To save energy in heating

Sources of Vacuum

Aspirator

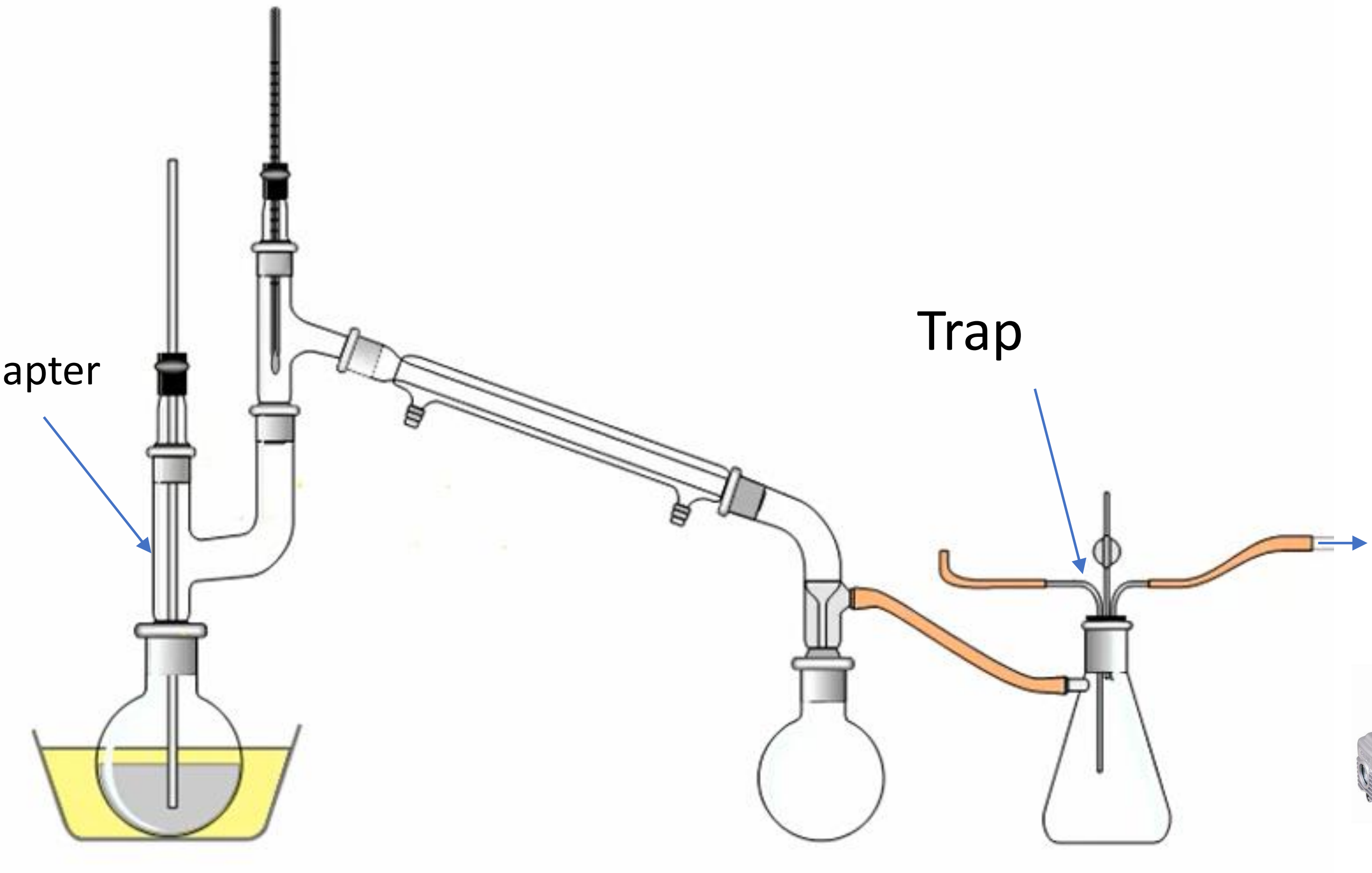
- Effective vacuum is dependent on the vapour pressure of water, which is dependent on the temperature of water
- Dependent on sufficient water pressure
- Cheap and easy
- A trap must be used

Sources of Vacuum

Vacuum pump

- Pressure dependent on the efficiency of the pump
- Pressure of < 1 mm Hg can be reached
- Expensive compared to an aspirator, but more effective

Vacuum distillation apparatus



Claisen adapter

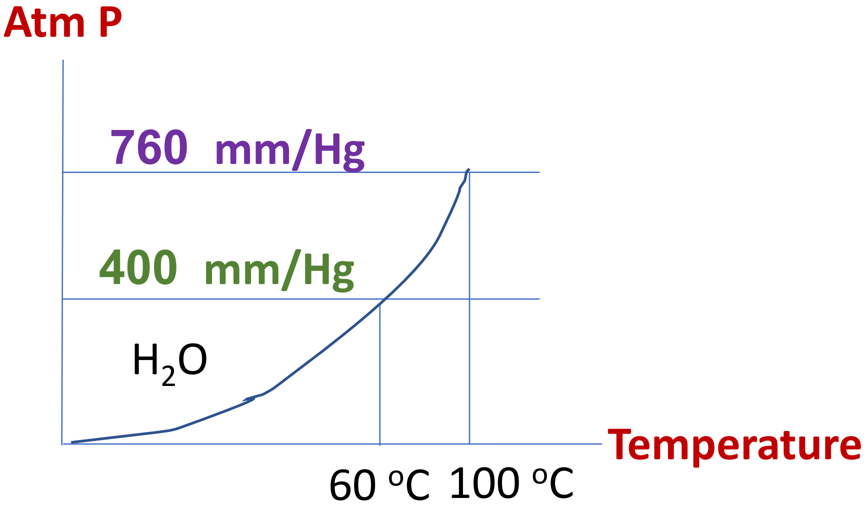
Trap

To low pressure

Why the boiling point decrease by using Vacuum ?

The liquid is boil when it's
vapour pressure = atmospheric pressure

The vacuum decrease the atmospheric pressure (external pressure), so the liquid vapour pressure is decrease.



True or False?

1- Distillation is the process by which a solid forms, into a highly structured form called a crystal

2- Crystallization process is depending on the different solubility of the organic liquid compounds into a various solvents

Complete

3- Solid substance change to vapour stat without passing through liquid state on heating is called ……………..

$$P_{total} = P_{vap(a)} + P_{vap(b)}$$

4- This law is called ………

vapour pressure (P_{vap}) of the mixture is dependant on ………………… of each component

True or False?

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vapour pressure (P_{vap}) of the mixture is dependant on …………………. of each component

Steam Distillation

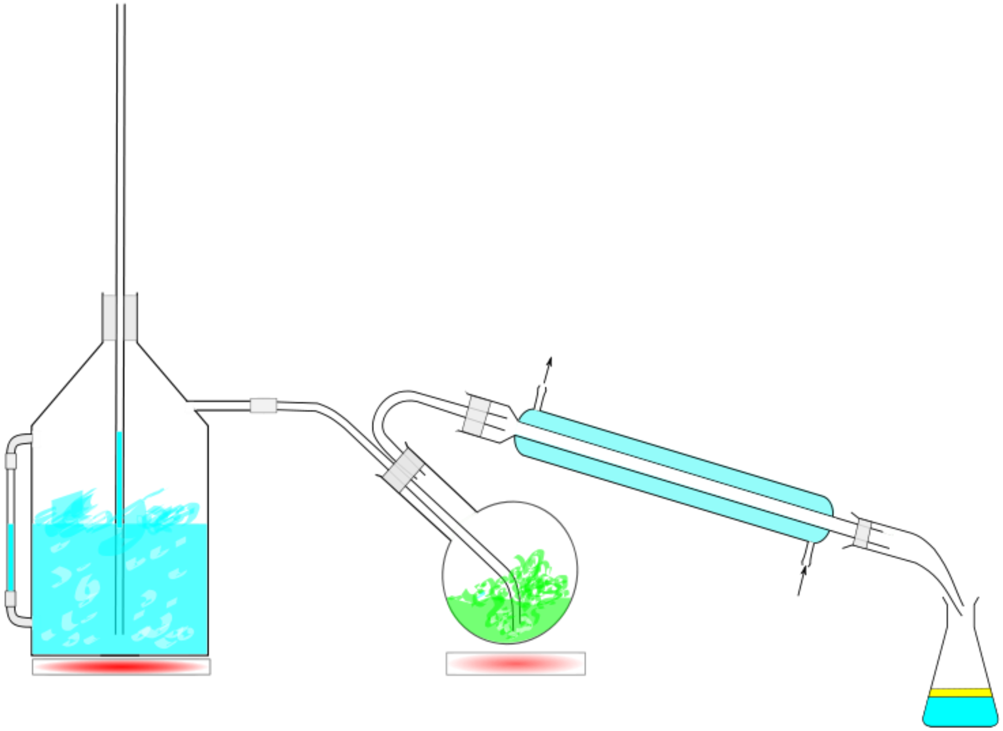
Steam Distillation

Distillation of a liquid in a current of steam, used especially to purify liquids that are **not very volatile, decomposed at their boiling points,** and are **immiscible with water**.

Steam Distillation

Steam distillation is a separation process that consists in distilling water together with other volatile and non-volatile components. The steam from the boiling water carries the vapor of the volatiles to a condenser; both are cooled and return to the liquid or solid state, while the non-volatile residues remain behind in the boiling container.

Steam distillation apparatus



Steam distillation is used in chemical laboratories as one of many substance separation methods.

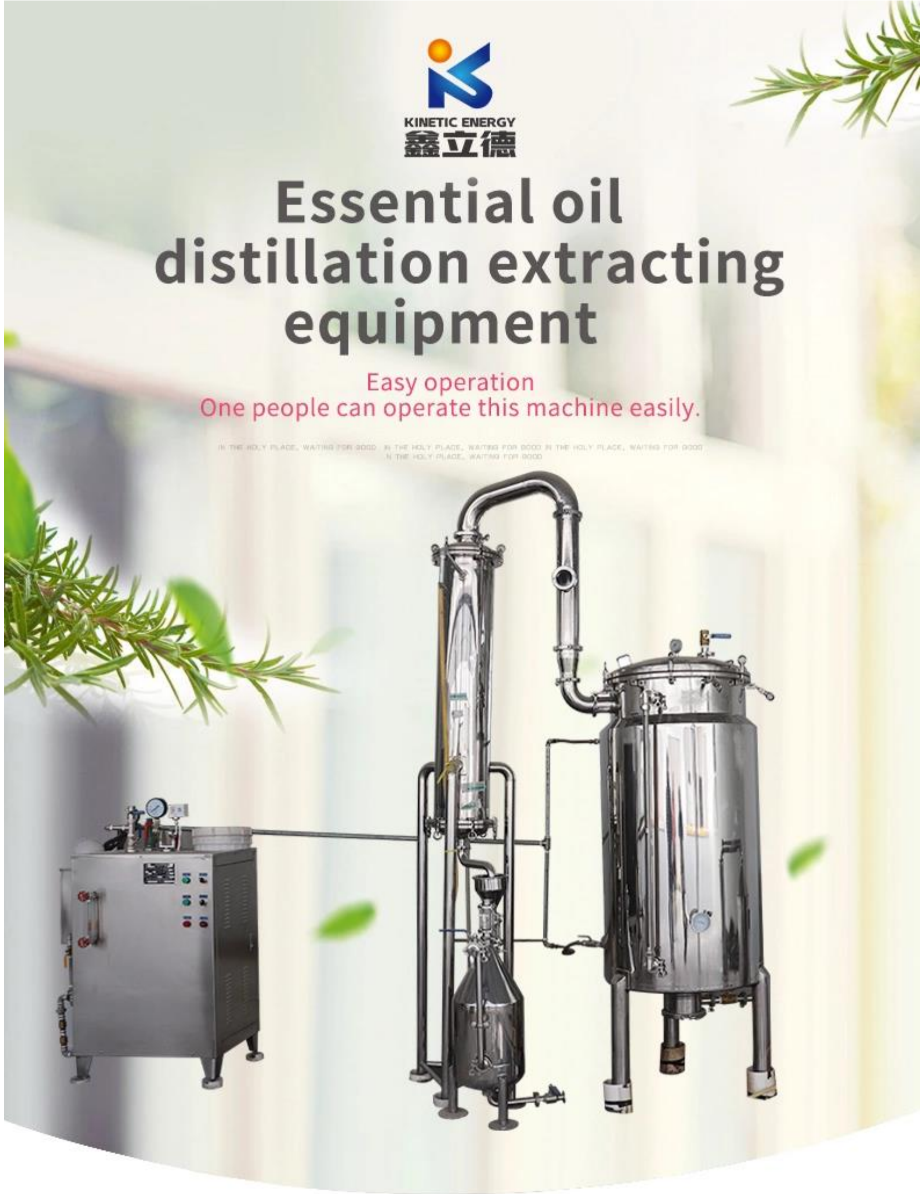
تنقية الأنيلين عن طريق التقطير البخاري

Steam Distillation

Also, this method is used for extraction of **essential oil** from their original plant sources

Ex:

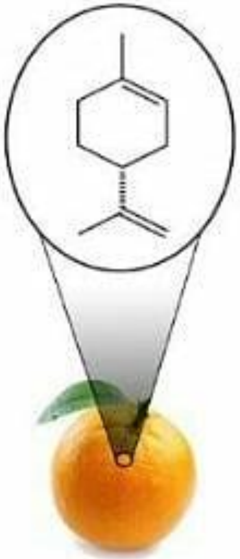
Limonene from orang or lemon – Lavender oil – rose oil ……etc.


KINETIC ENERGY
鑫立德
Essential oil distillation extracting equipment
Easy operation
One people can operate this machine easily.
IN THE HOLY PLACE, WAITING FOR GOOD IN THE HOLY PLACE, WAITING FOR GOOD IN THE HOLY PLACE, WAITING FOR GOOD
IN THE HOLY PLACE, WAITING FOR GOOD


Steam Distillation Process
4
Steam + Essential Oil
Removalble Lid
3
The oil rises with the steam
Raw Material
2
The steam passes through the plant matter, pulling out the oil
1
Water is heated, creating steam
5
Condensation tube (in cool water)
6
Condensed steam exit
Oil
Water
7
in the separator, the oil rises to the top of the water and is extracted
8
Floral water can also be used in beauty and home products

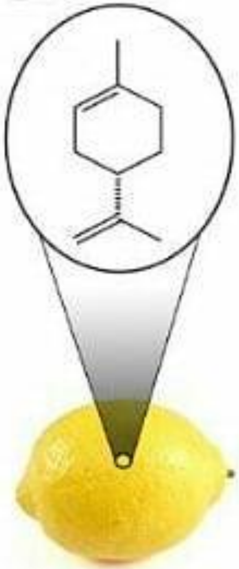
ليمونين
limonene

اللّيمونين مركب تربيني يتواجد طبيعياً في الفواكة الحمضية كالليمون والبرتقال هذا المركب له متماكبان ضونيان هما إس-ليمونين هو المذاق المميز لليمون ، و أر-ليمونين وهو المذاق الخاص بالبرتقال. يمكن أستخلاص الليمونين من قشور الليمون أو البرتقال بأستخدام التقطير البخاري يستعمل الليمونين كمنكة في الأطعمة و في منتجات التجميل وفي صناعة معطرات الجو وغيرها.....



البرتقال

(R)-limonene



الليمون

(S)-limonene

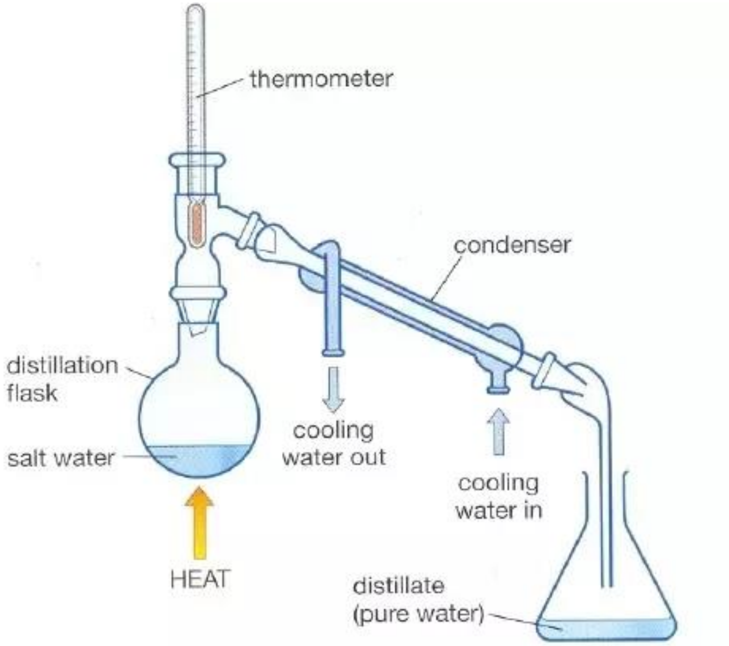
Extraction

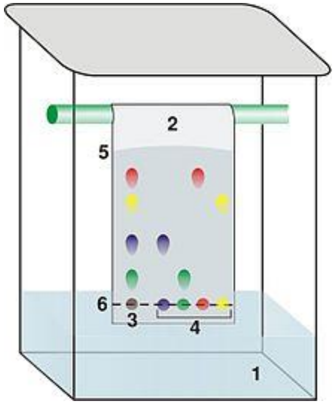
Purification of Liquids

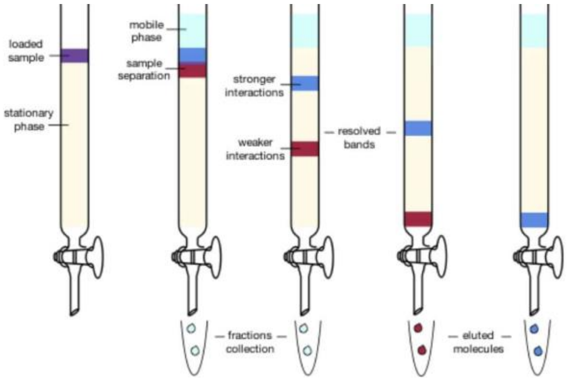
1- Distillation

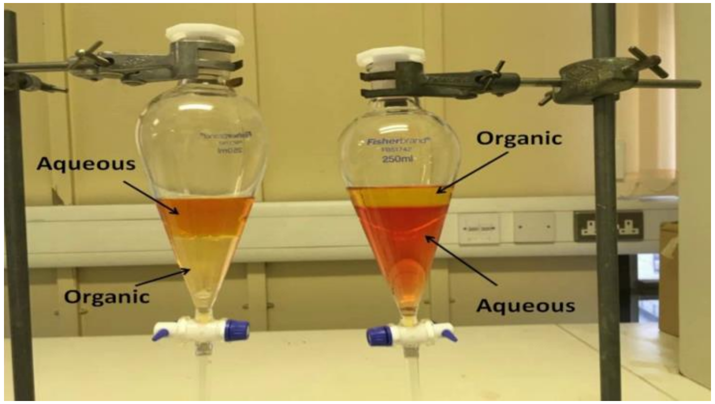
2- Differential Extraction

3- Chromatography







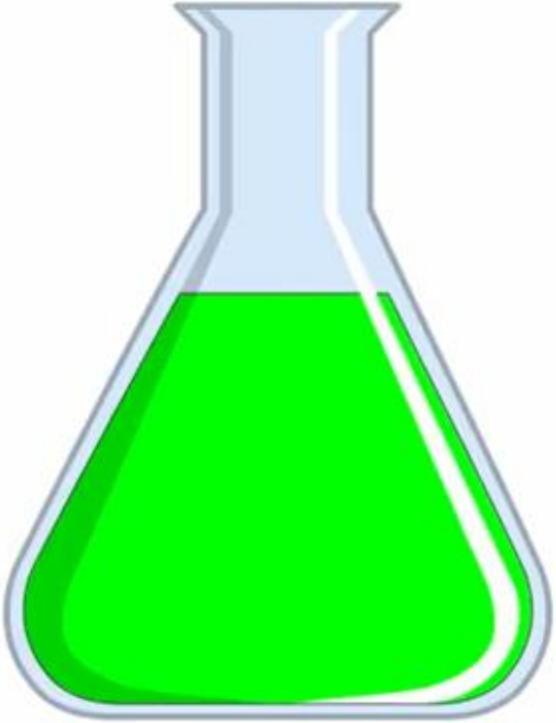


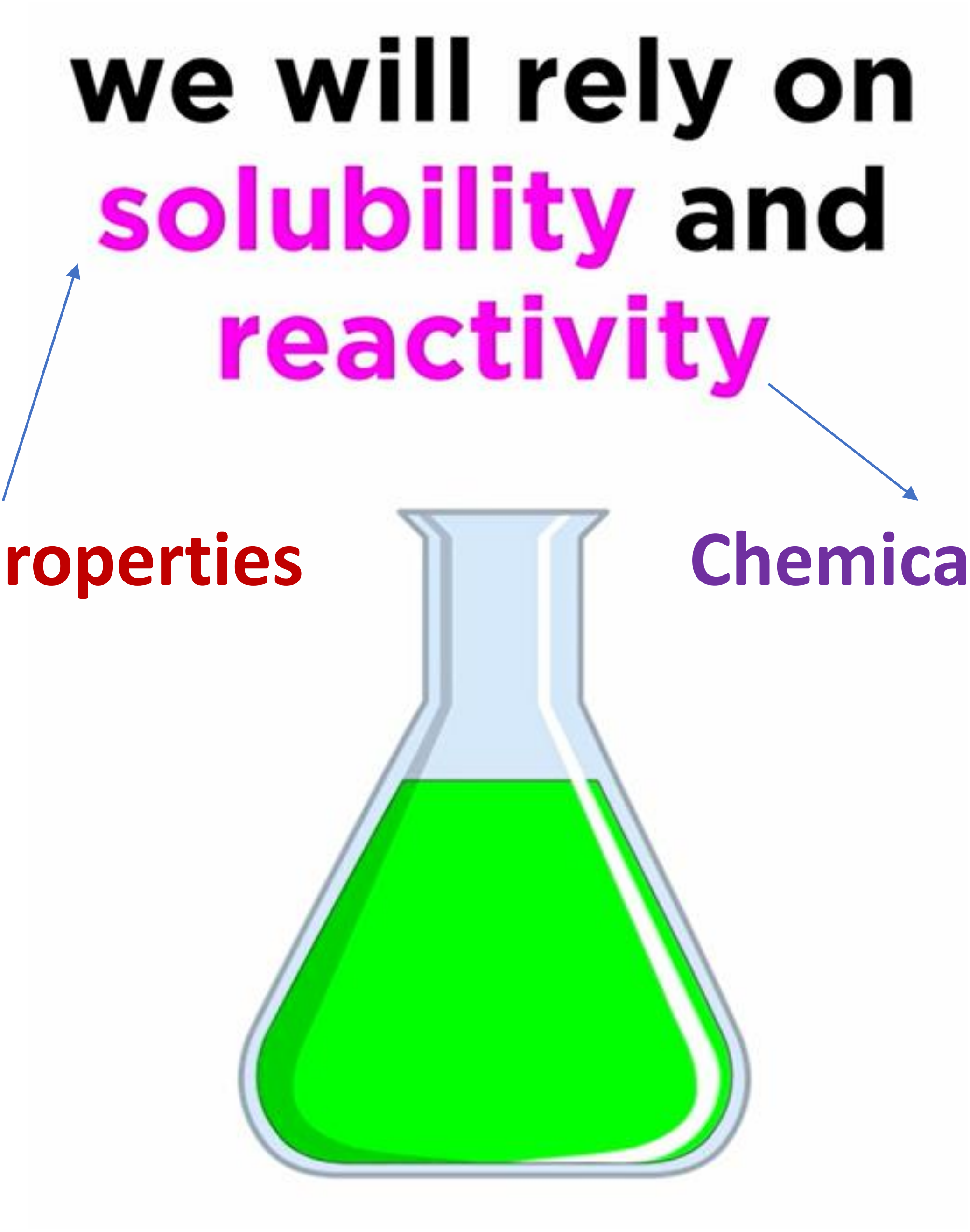
water and sand can be separated by filtration

sand won't fit

water can go through the filter

What about mixtures of only small molecules?





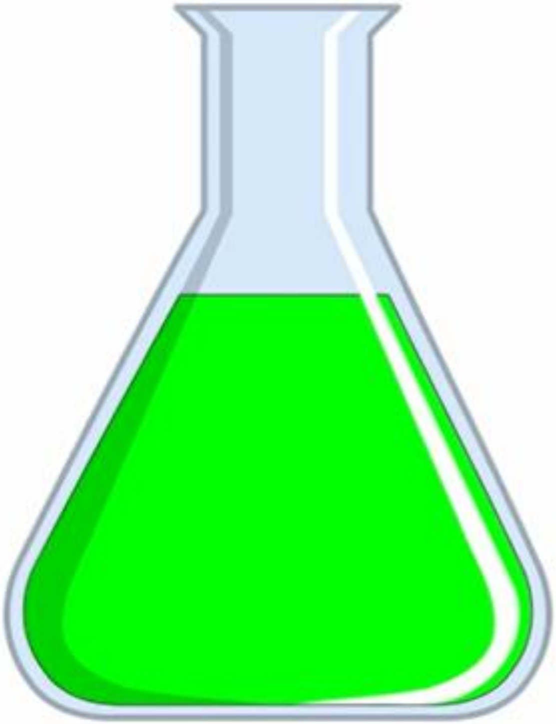
we will rely on **solubility** and **reactivity**

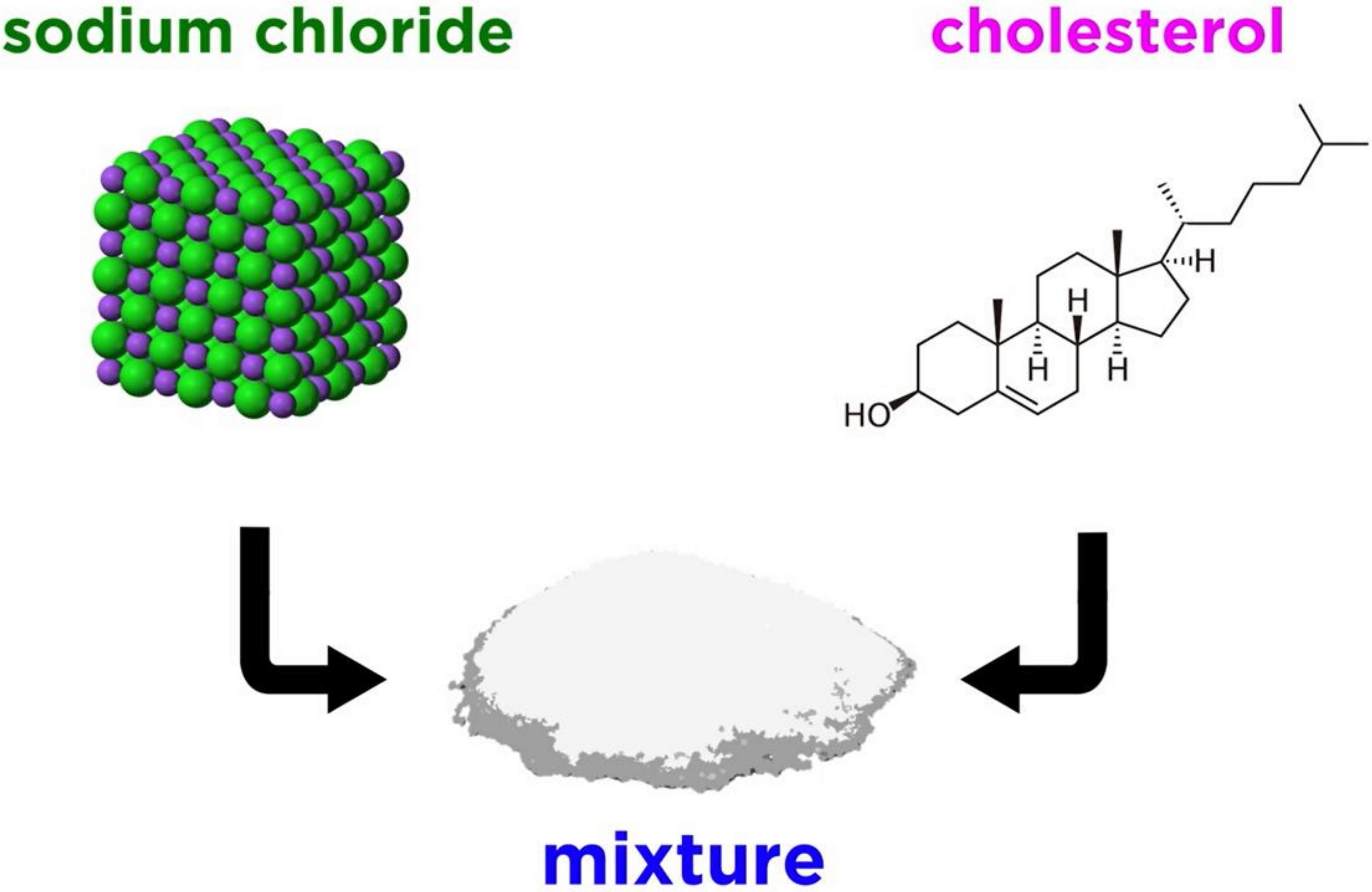
Physical properties

Chemical properties

A Technik to use this is called

extraction



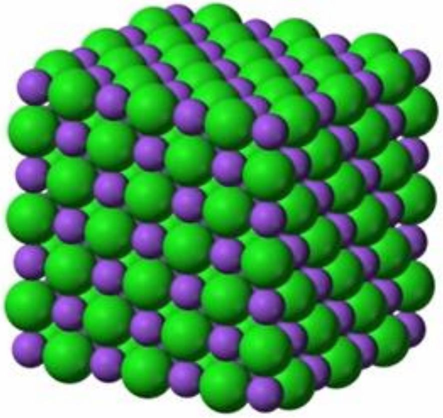


sodium chloride

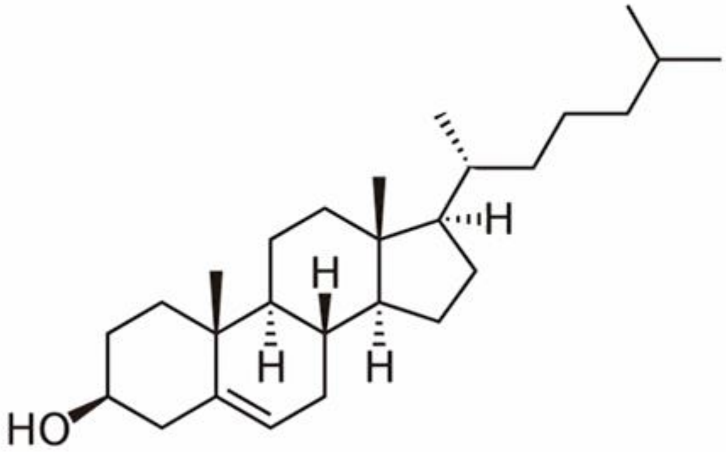
cholesterol

mixture

sodium chloride



cholesterol



ionic compound

water soluble

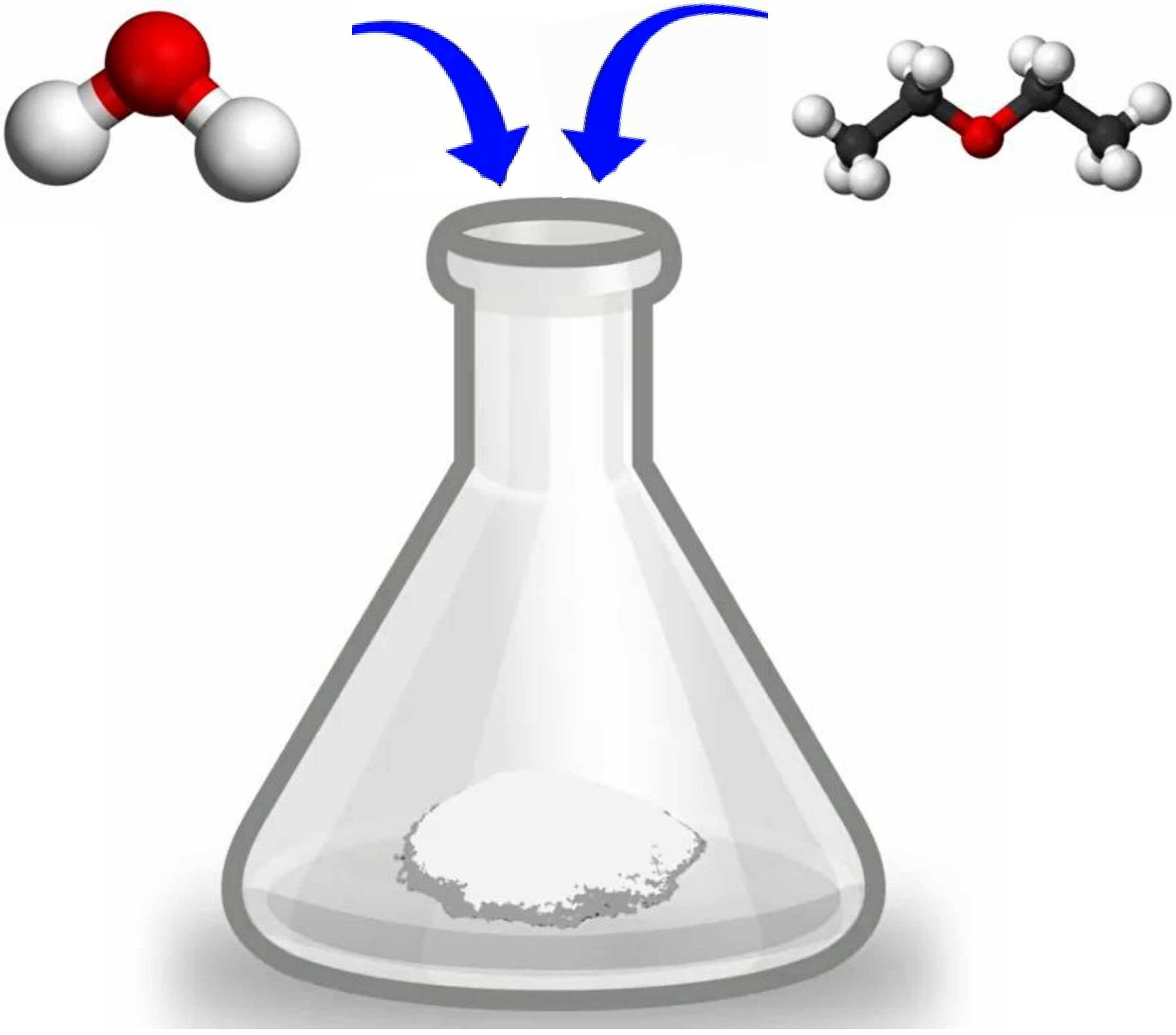
steroid (lipid)

water insoluble

ether soluble

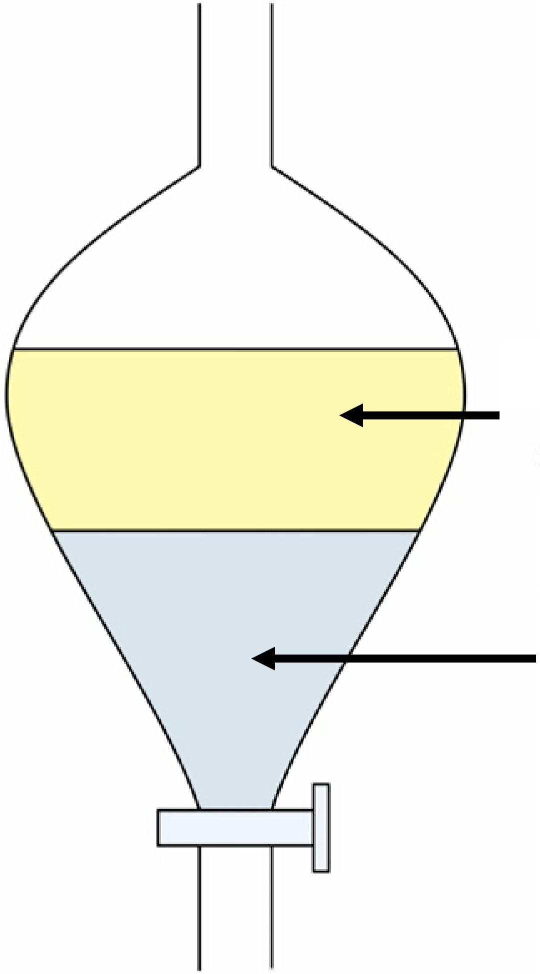
water

ether



separatory funnel

the solvents
are **immiscible**

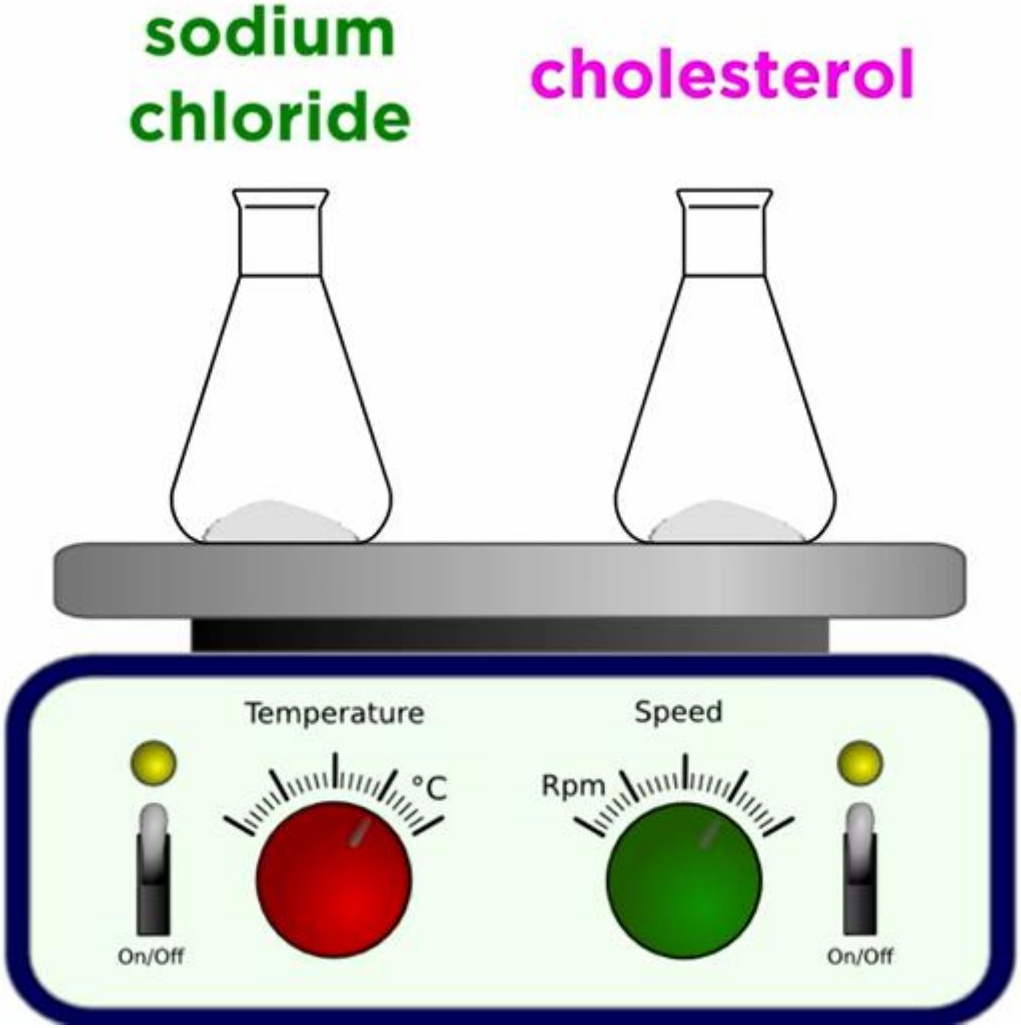


increasing
density

organic layer
(ether + cholesterol)

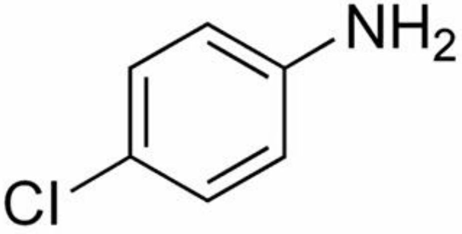
aqueous layer
(water + NaCl)

evaporate the solvents

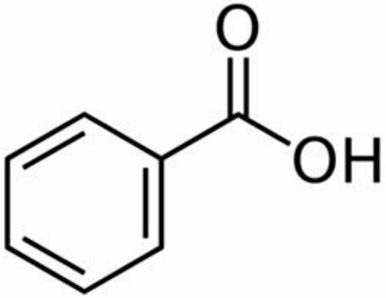


What about if you have this mixture, how can you separate them?

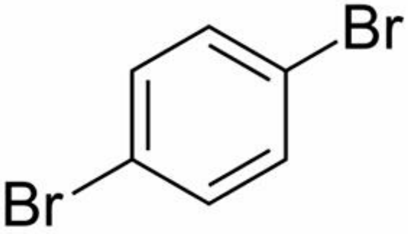
4-chloroaniline



benzoic acid

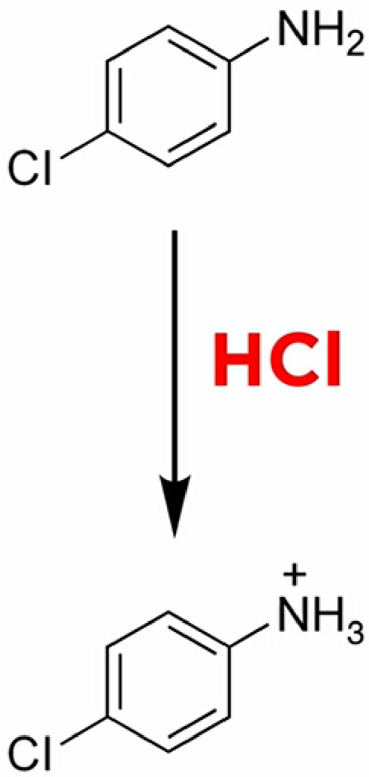


1,4-dibromobenzene

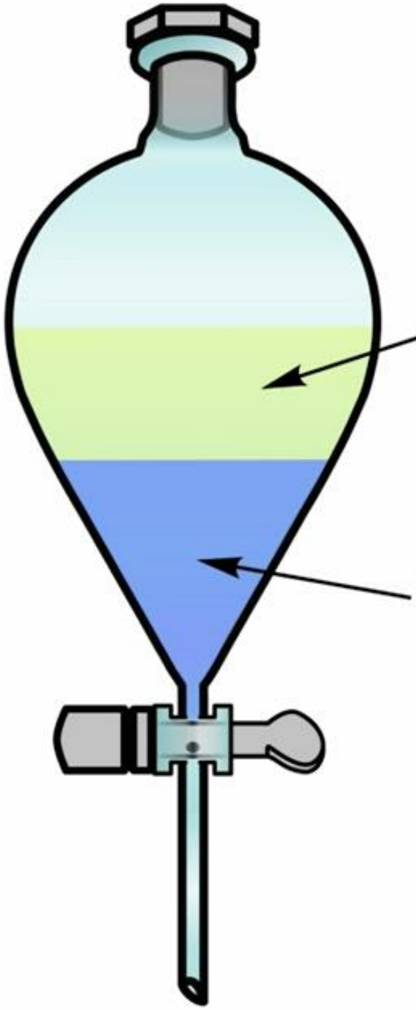


these compounds have similar solubilities

4-chloroaniline



this compound is now water soluble
(ion-dipole interactions)

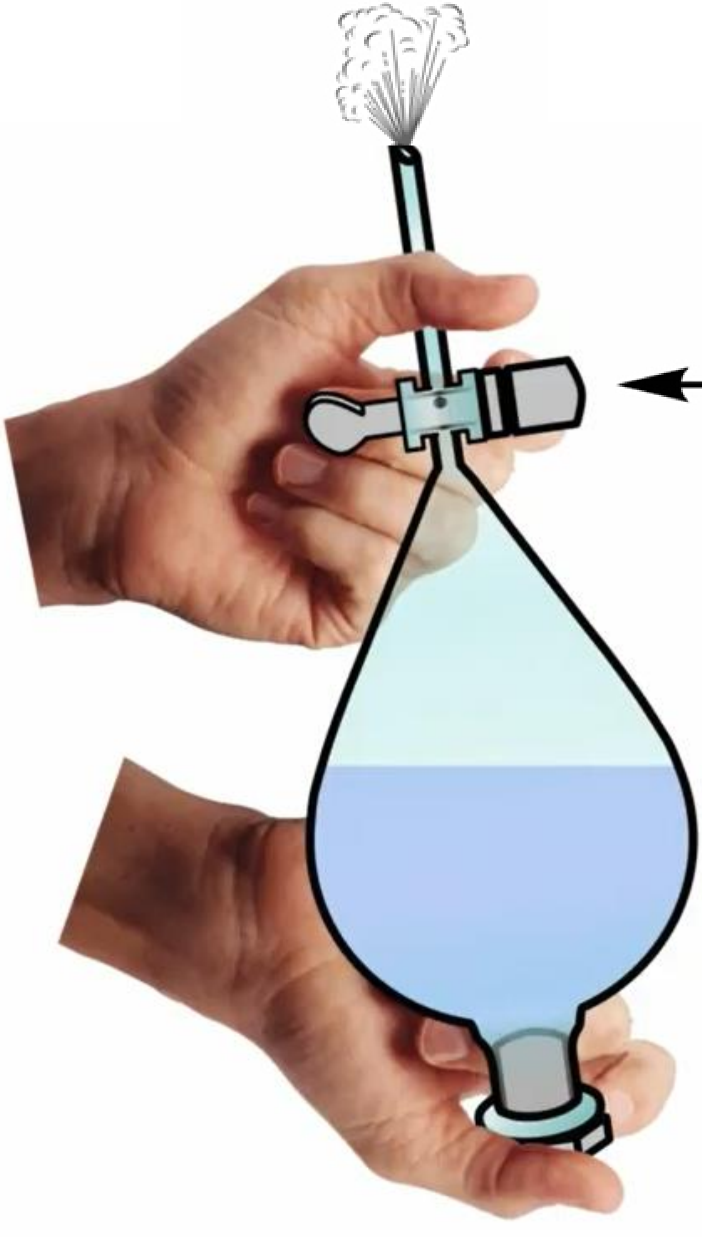


organic layer

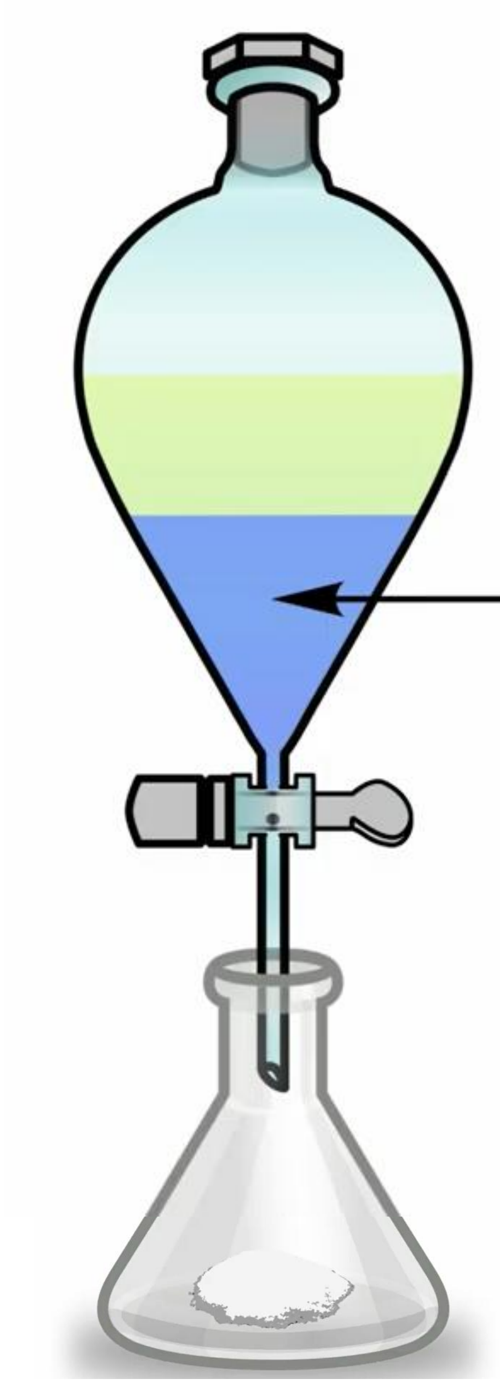
ether
benzoic acid
1,4-dibromobenzene

aqueous layer

water
4-chloroaniline salt



open the stopcock to **vent** the gas



drain the **aqueous layer** into a flask

Repeat this 3 times

Complete the rest of the mixture !

Q1: Choose the correct answer of the following:

Impurities, which impart colour to the solution are removed by adsorbing over ……………………………………….

a) silica Gel (G)
b) silica Gel (F)
c) activated charcoal
d) aluminium

Q2: Choose true or false

The liquid is boil when it’s vapour pressure equal the atmospheric pressure

a) True
b) False

Q3: If you have a binary liquid mixture **X** and **Y** with **40%mol** of **X**, and the pure vapour presser of **X = 300** and **Y = 1000** torr.

Calculate the following:

1- Vapour presser of X and Y.
2- Vapour mol fraction of X and Y.

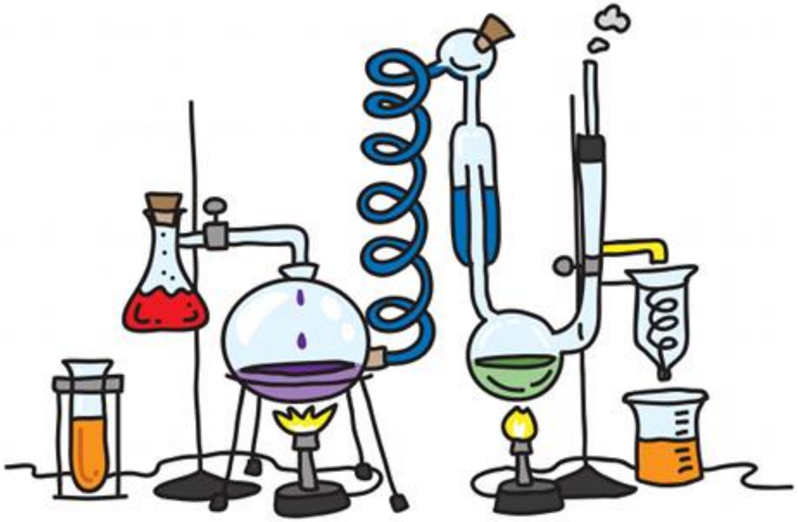
Q3: If you have a binary liquid mixture **X** and **Y** with **40%mol** of **X**, and the pure vapour presser of **X = 300** and **Y = 1000** torr.

Calculate the following:

1- Vapour presser of X and Y.

2- Vapour mol fraction of X and Y.

Purification of Organic Compounds



Dr. Mohamed Y. Mahgoub

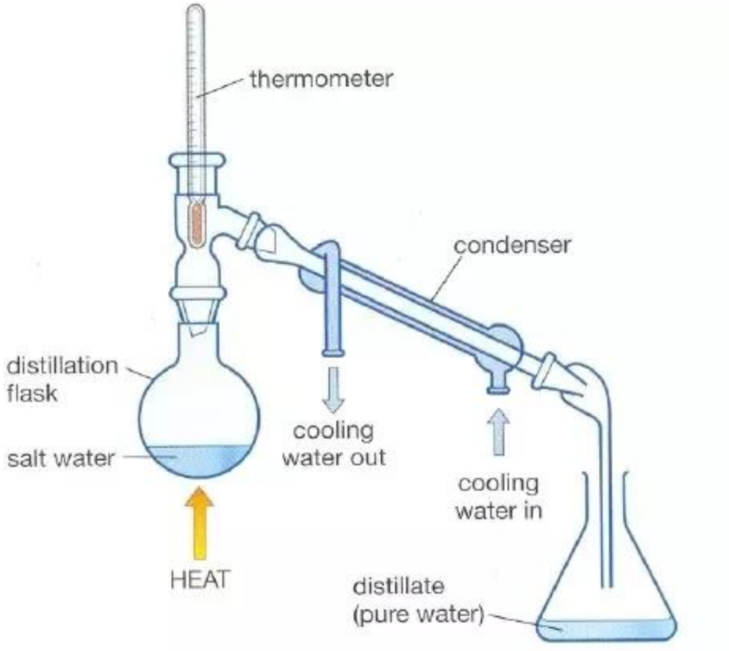
Chromatography

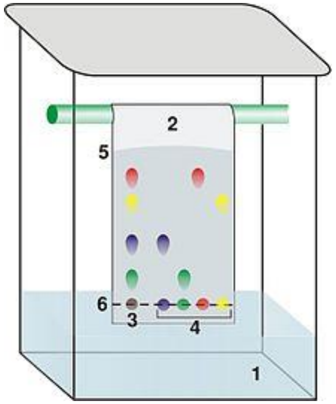
Purification of Liquids

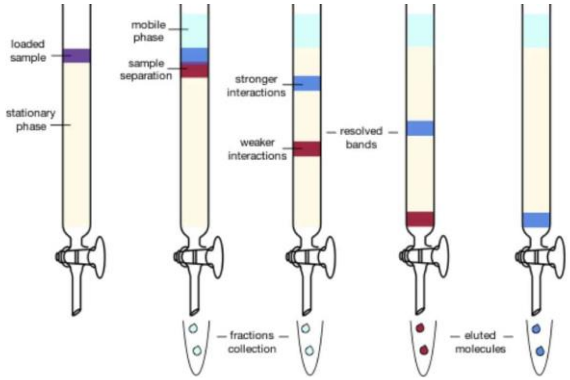
1- Distillation

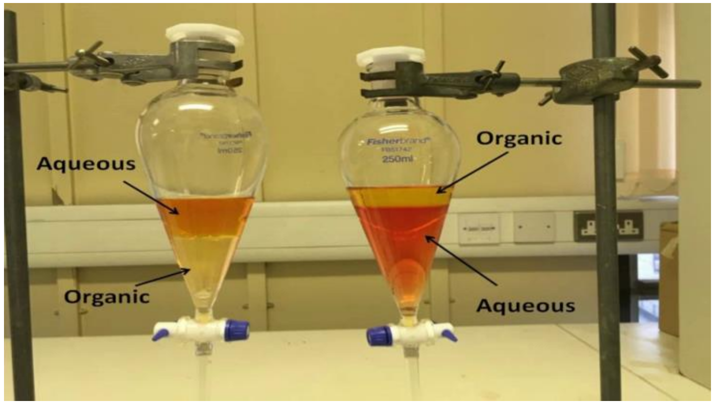
2- Differential Extraction

3- Chromatography









History

Mikhail Tswett

Russian Botanist

- He used chromatography to separate **plant pigments**
- He called the new technique chromatography because the result of the analysis was 'written in color' along the length of the adsorbent column **Chroma** means "**color**" and **graphein** means to "**write**"

Importance

Chromatography has application in every branch of the chemical, physical and biological sciences

12 Nobel prizes were awarded between 1937 and 1972 alone for work in which chromatography played a vital role

Chromatography

Is a physical method of separation in which the components to be separated are distributed between two phases one of which is stationary (**stationary phase**) while the other moves through it in a definite direction (**mobile phase**).

The chromatographic process occurs due to **differences in the distribution constant** of the individual sample components.

Chromatography

Is a technique used to separate and identify the components of a mixture.

- Works by allowing the molecules present in the mixture to distribute themselves between a stationary and a mobile medium.

- Molecules that spend most of their time in the mobile phase are carried along faster.

Classification of Chromatography

According to mobile phase

1- Liquid chromatography: mobile phase is a liquid, (**LLC, LSC**).

2- Gas chromatography : mobile phase is a gas, (**GSC, GLC**).

Classification of Chromatography

According to packing of the stationary phase

1- **Thin layer chromatography** (TLC): the stationary phase is a thin layer supported on glass, plastic or aluminium plates.

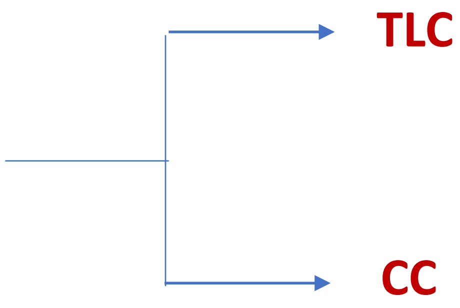
2- **Paper chromatography** (PC): the stationary phase is a thin film of liquid supported on an inert support.

3- **Column chromatography** (CC): stationary phase is packed in a glass column.

Classification of Chromatography

According to the force of separation:

1- **Adsorption chromatography**



TLC

CC

2- Partition chromatography

3- Ion exchange chromatography

4- Gel filtration chromatography

Thin Layer Chromatography (TLC)

Thin Layer Chromatography (TLC)

Is a method for identifying substances and testing the purity of compounds.

- TLC is a useful technique because it is relatively quick and requires small quantities of material.

Thin Layer Chromatography (TLC)

Separations in TLC involve distributing a mixture of two or more substances between a stationary phase and a mobile phase.

- The stationary phase: is a thin layer of adsorbent (usually **silica gel or alumina**) coated on a plate.

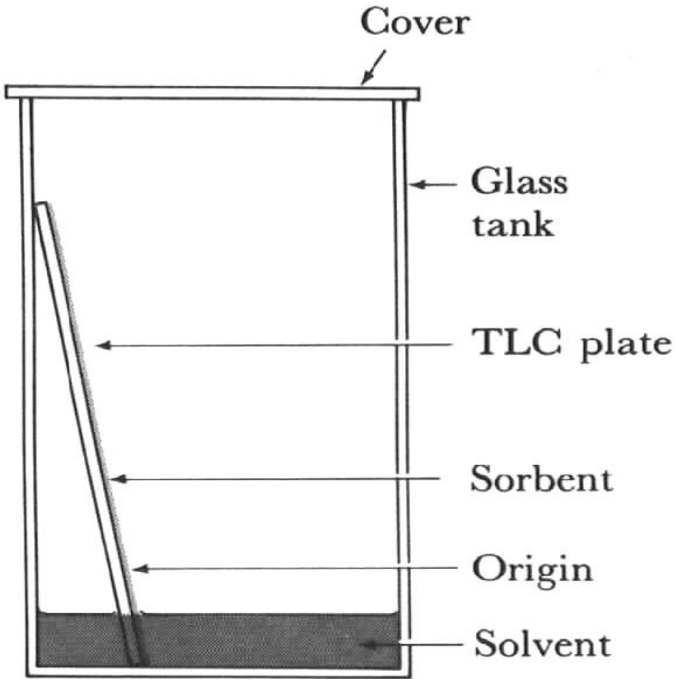
- The mobile phase: is a **developing liquid** which travels up the stationary phase, carrying the samples with it.

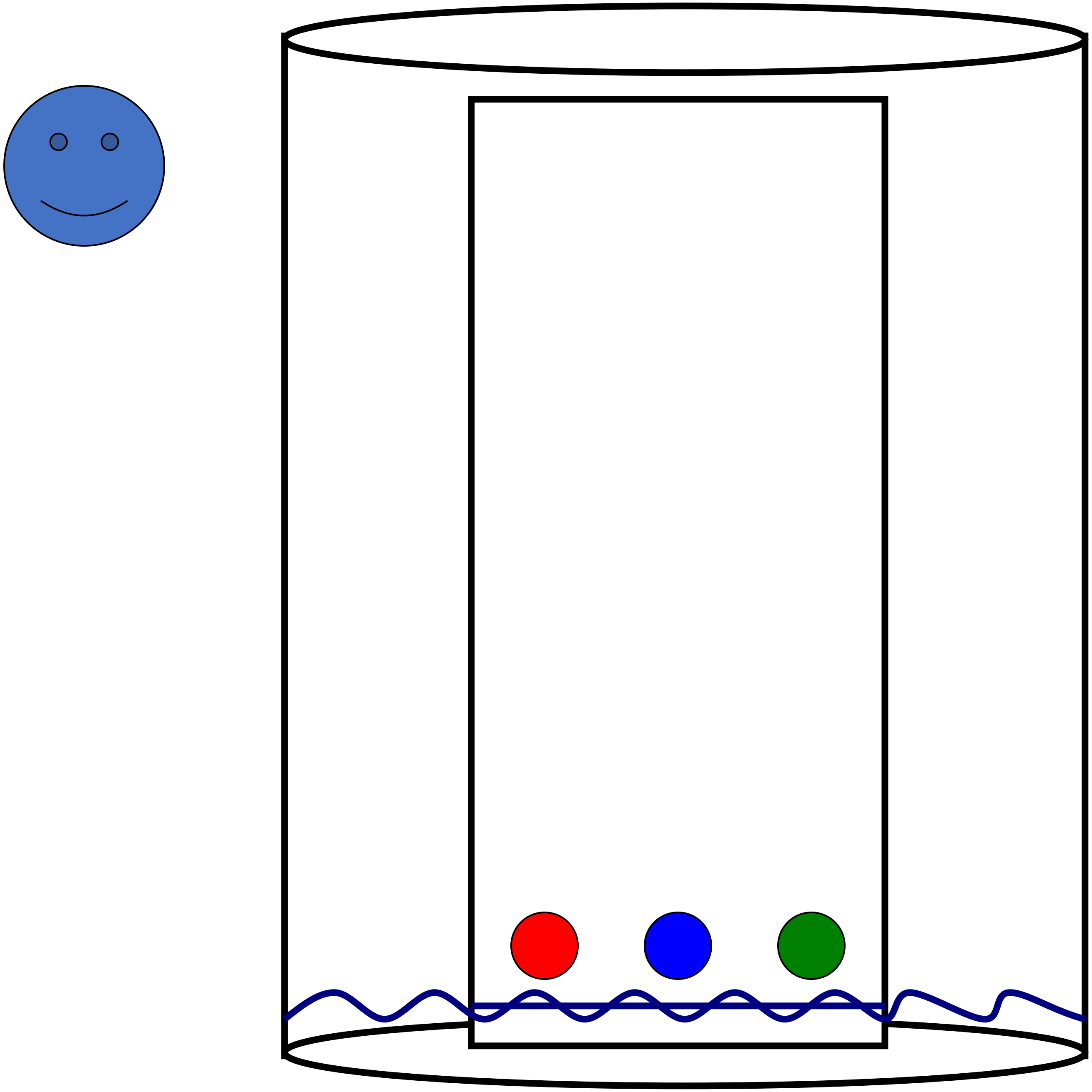
Thin Layer Chromatography (TLC)

Components of the sample will separate on the stationary phase according to

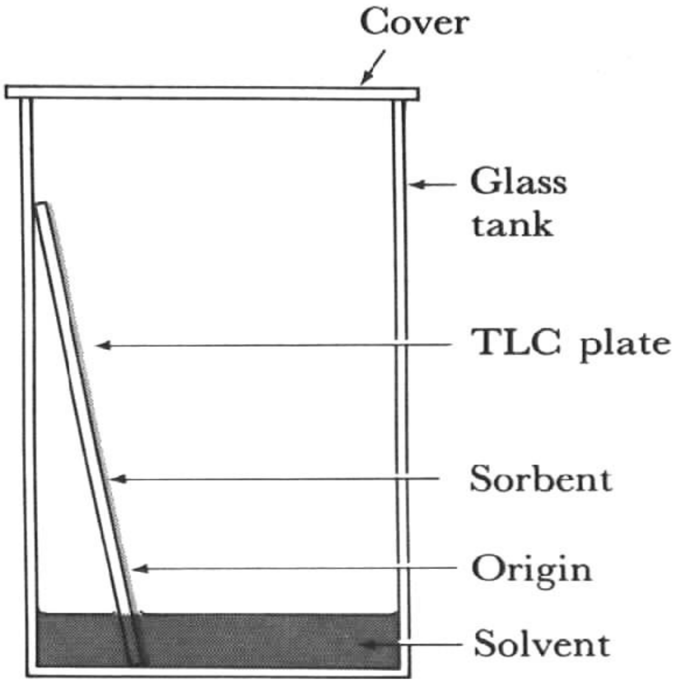
how much they adsorb on the stationary phase **versus** how much they dissolve in the mobile phase.

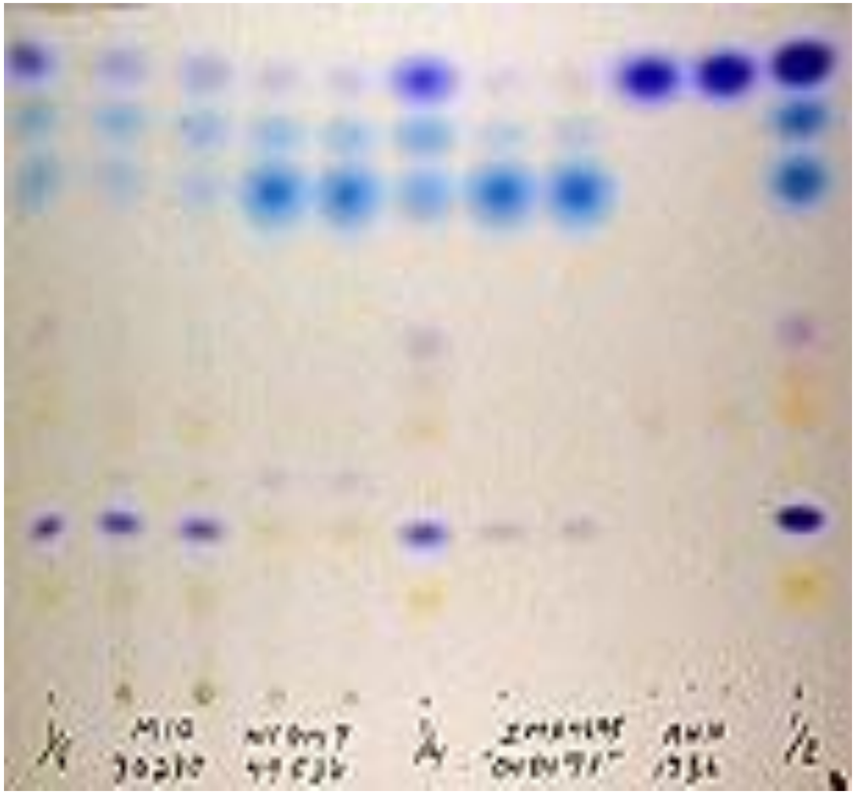
Thin Layer Chromatography (TLC)





Thin Layer Chromatography (TLC)





Applying the TLC

Step 1: Preparing the Chamber

- To a jar add enough of the appropriate developing liquid so that it is 0.5 to 1 cm deep in the bottom of the jar.

- Close the jar tightly, and let it stand for about 10 minutes so that the atmosphere in the jar becomes saturated with solvent.

Applying the TLC

Step 2: **Preparing the stationary phase**

A) Prepare the TLC plate:

Mix:

Adsorbent
Small amount of an inert binder ($CaSO_4 . 0.5H_2O$)
Water (solvent)

Spread a thin layer (no more than a few mm) of the mixture on plate

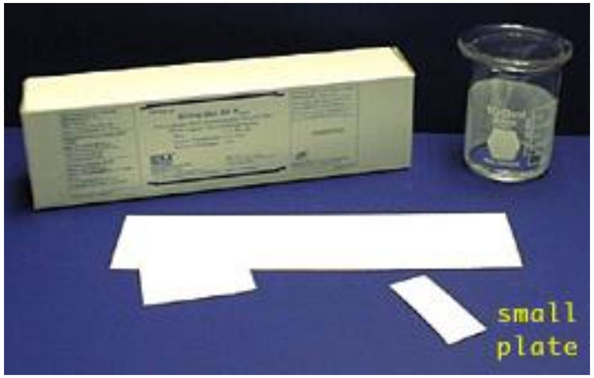
After the plate is dried, it is activated by heating in an oven for approximately 30 minutes at 110˚C

Applying the TLC

Step 2: Preparing the stationary phase

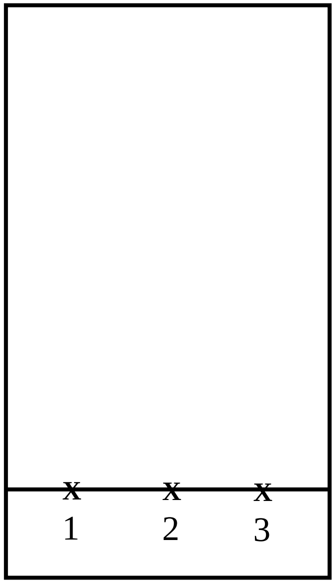
A) Prepare the TLC plate:

TLC plates are also commercially prepared and can be purchased ready for use.



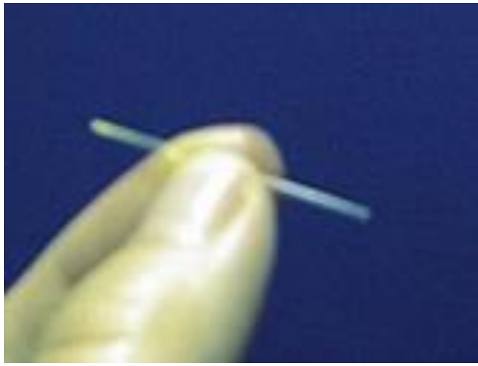
B) Draw a line of origin approximately 0.5 cm from the bottom of the filter paper.

C) Indicate where each sample will be added.



Applying the TLC

Step 3: Spotting the samples



- If the sample isn't in solution, dissolve it in an appropriate solvent.

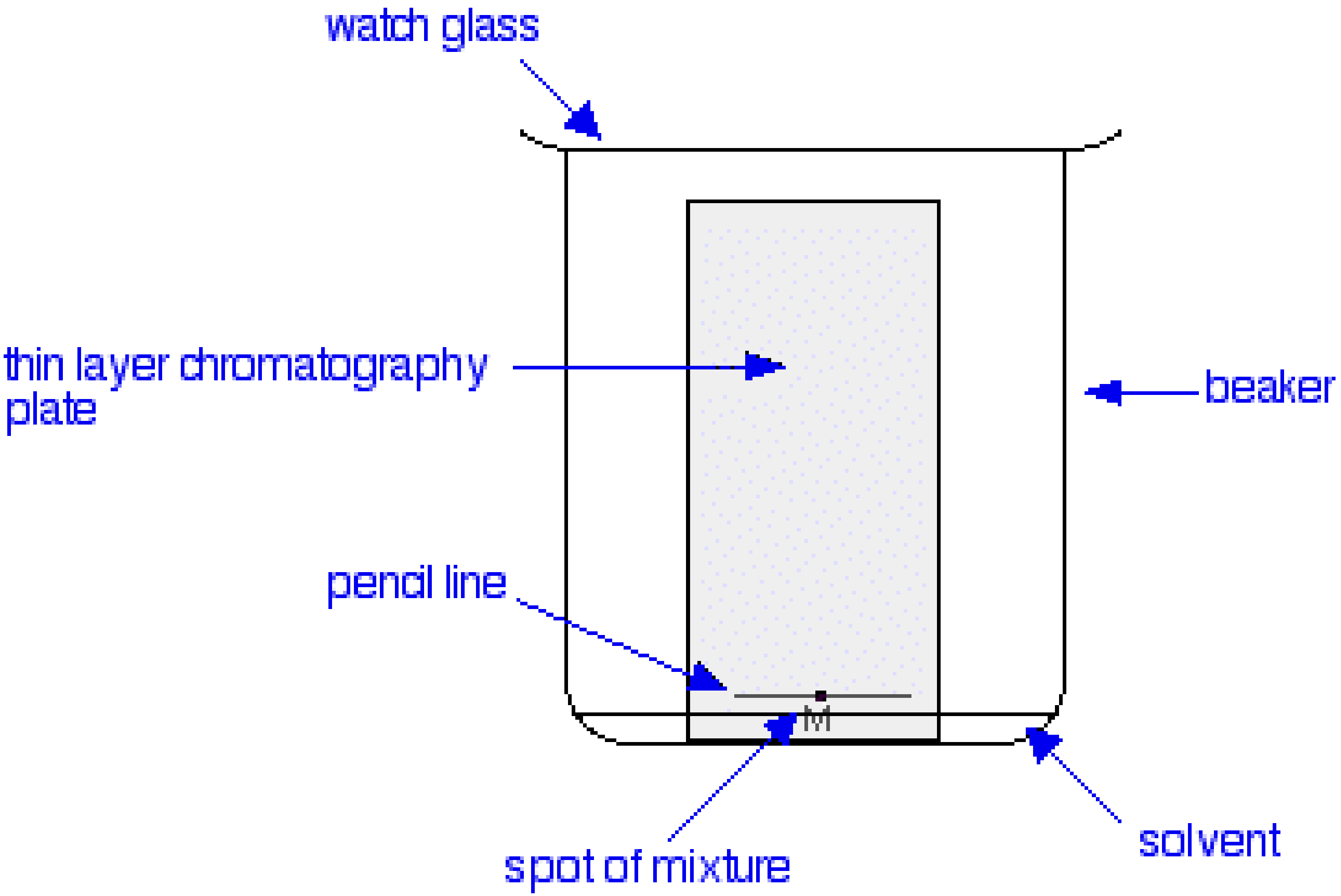
- Spot a small amount of sample onto the plate. Make sure the sample spot is dry before continuing.

Applying the TLC

Step 4: Developing the chromatograms

- When the sample spot has dried, the TLC plate is placed into the chamber containing the solvent.

- It is important that the sample spot is above the level of the solvent.


watch glass
thin layer chromatography plate
beaker
pencil line
M
spot of mixture
solvent

Applying the TLC

Step 4: Developing the chromatograms

- Allow the solvent to rise until it almost reaches the top of the plate.
- Remove the plate from the chamber and mark the position of the solvent and front before it can evaporate.
- If the sample spots are visible, mark their positions.

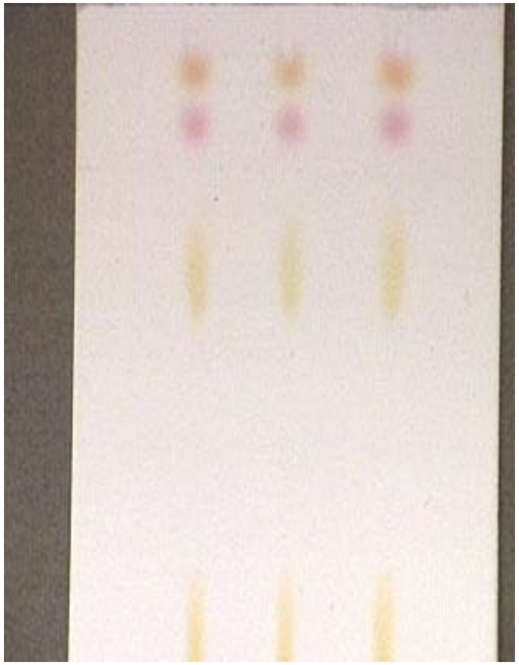
Applying the TLC

Step 5: Identify the spots and interpret the data

If the spots can be seen, outline them with a pencil.

If no spots are obvious, the most common visualization technique is to hold the plate **under a UV lamp**.

Many organic compounds can be seen using this technique, and many commercially made plates often contain a substance which aids in the visualization of compounds.

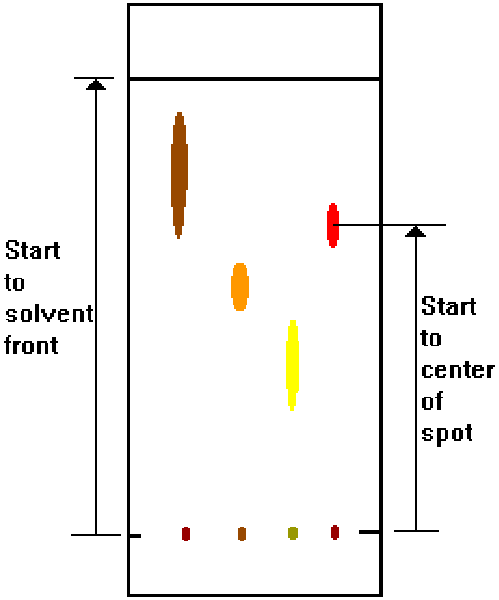


Interpreting the Data

The **R_f** (retention factor) value for each spot should be calculated.

It is characteristic for any given compound on the same stationary phase using the same mobile phase for development of the plates.

$$R_f = \frac{\text{Distance traveled by the compound}}{\text{Distance traveled by the solvent}}$$



R_f values are reported as relative values since they can be affected by:

- the adsorbent used
- the solvent system used
- Temperature
- the thickness of the adsorbent layer
- the amount of sample material spotted

- It can be difficult to keep all of these variables constant from experiment to experiment.

- If two substances **have the same R_f** value they may or may not be the same compound.

- If two substances **have different R_f** values they are definitely not the same compound.

TLC Applications

- ✓ Can be used to determine the number of components in a mixture.
- ✓ Can be used to identify the presence of specific compounds/ unknown compounds.
- ✓ Can be used to monitor the progress of a reaction.
  - Will show if any reactant has disappeared, if any product has appeared, and how many products are present.
  - Often used to monitor organic reactions.

TLC Applications

- Used to determine which conditions are ideal to use in column chromatography.
  - Ex: which solvent system to use
- It is also used to monitor column chromatography.
- Used to quantify the amount of a component present .
  - Area of the spot
  - Spot extraction, then measure the amount
- Used to determine the purity of a sample.
- Can be used to isolate purified substances, and then analyse it further (MS/ IR/ NMR)

Advantages of TLC

- ✓ Low cost
- ✓ Short analysis time
- ✓ Ease of sample preparation
- ✓ All spots can be visualized
- ✓ Uses small quantities of solvents

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