PHARMACY INDIA

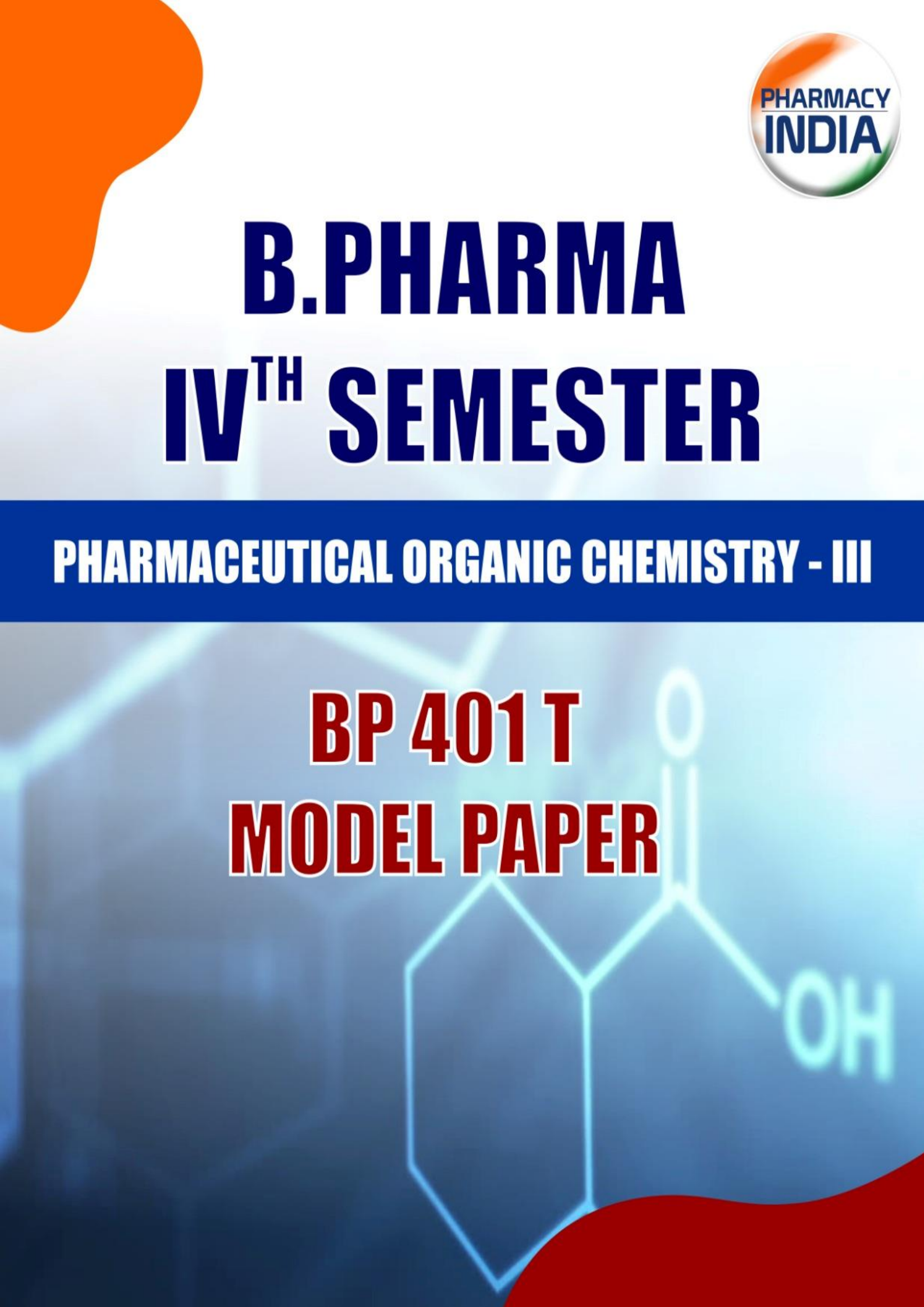
B.PHARMA

IVTH SEMESTER

PHARMACEUTICAL ORGANIC CHEMISTRY - III

BP 401 T

MODEL PAPER



PHARMACEUTICAL ORGANIC CHEMISTRY-II MODEL PAPER

SECTION A

VERY SHORT ANSWERS TYPE QUESTIONS (10 × 2 = 20)

1. **Define enantiomers with examples.**

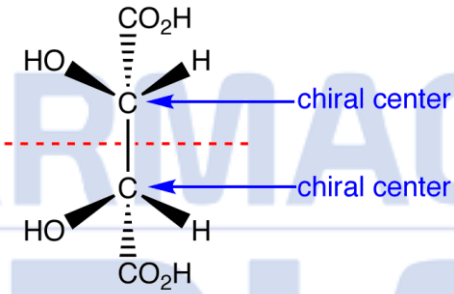
Answer

- Enantiomers are chemical isomers that are non-superimposable mirror images of each other. Therefore, two enantiomers of a chemical compound will have the same chemical bonds but completely opposite three-dimensional structures.
- A common example of a pair of enantiomers is dextro lactic acid and laevo lactic acid.

2. **Define meso compounds with examples.**

Answer

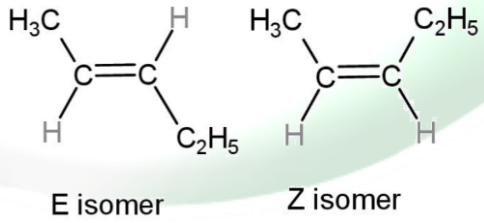
- An achiral compound with chiral centres is known as a meso compound. Although it has two or more stereocenters, a meso compound has an internal plane of symmetry that makes it superimposable on its mirror image and is optically inactive.
- **Example**



3. **Distinguish between E and Z isomer with examples.**

Answer

- E and Z isomers describe the stereo aspects of the carbons attached with double bonds.
- The E isomer consists of the substituted groups on the opposite sides of the double bond, while in Z isomer, the substituted groups are on the same side of the double bonds.
- **Example:** pent-2-ene



4. **Discuss sequence rules.**

Answer

- It is the spatial arrangement of atoms within the chiral molecules that is described in terms of absolute configuration (R) and stereochemistry (S).
- The Sequence Rules were developed by Cahn, Ingold, and Prelog to assign priority orders to the atoms or groups directly attached to stereocenters.

5. **Compare the reactivity and aromaticity of pyrrole, furan and thiophene.**

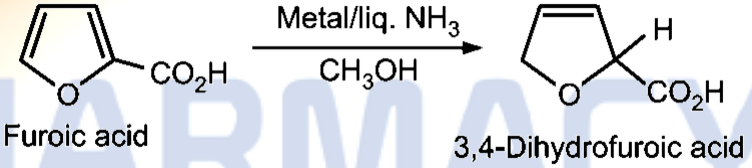
Answer

- These compounds Furan, Pyrrole and thiophene are certainly more reactive than Benzene.
- Out of these, Pyrrole being most aromatic,followed by Furan.
- Furan is comparatively less reactive because O-atom (in furan)can accommodate a positive charge less readily at N-atom (in Pyrrole).
- Thiophene is being followed by these two and is least reactive. It is so because the +M-effect of sulphur is weaker than that of oxygen because overlap of 2p-orbitals of carbon and 3-p orbitals of sulphur is less than 2p -orbitals of C and O -atoms.
- That's why the order of reactivity is Pyrrole>Furan> Thiophene>Benzene.

6. **What is the reduction product of furan? Give its reaction.**

Answer

- **Reduction:** Simple furan is difficult to reduce to a tetra hydrofuran, without ring opening. Furoic acid can be reduced to dihydro derivative.

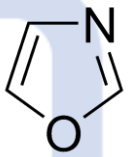


Furoic acid — 3,4-Dihydrofuroic acid

7. **Discuss the structure and pharmaceutical uses of oxazole.**

Answer

Structure of Oxazole



Uses

- Oxazole is one of the important components in penicillin (antibiotic) structure.
- The Oxazole family includes oxazoles, isoxazoles, oxazolines, oxadiazoles, oxazolidones, benzoxazoles, etc.
- Oxazoles display versatile biological activities including antibacterial, antifungal, antiviral, antitubercular, anticancer, anti-inflammatory, analgesic, antidiabetic, etc.

8. **Write the pharmaceutical uses of quinoline and isoquinoline.**

Answer

Uses of Quinolone

- Quinolone is the family of synthesized broad-spectrum antibiotics.
- Quinolone, in comparison to other antibiotic classes, have among the highest risk of causing colonization with MRSA and Clostridium difficile
- The majority of quinolones in clinical use belong to the subset fluoroquinolone.

Uses of Isoquinoline

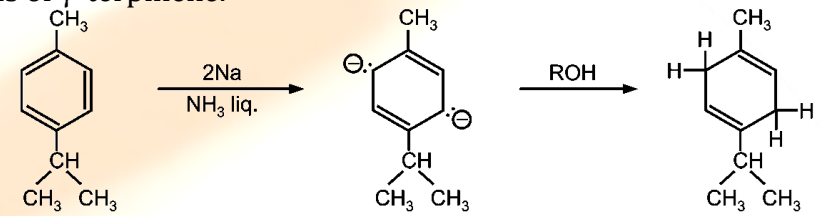
- Bileducts and ureter and for use as a cerebral and coronary vasodilator in subarachnoid- hemorrhage (combined with balloon angioplasty) and coronary artery bypass surgery.
- As an erectile dysfunction drug alone or sometimes in combination, hypertension, congestive-heart-failure vasoconstrictor, angiotensin-converting enzyme.
- Used as an anesthetic.

9. Write the synthetic importance of Birch reduction.

Answer

Synthetic importance of Birch reduction

1. Synthesis of γ-terpinene.



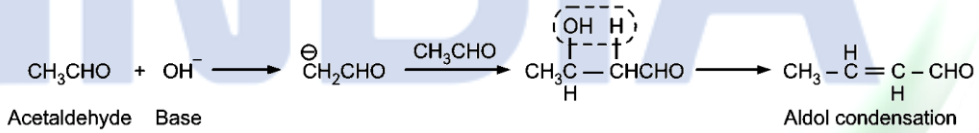
2. The reduction of steroids and terpenoids enone in which the β carbon atom was located at the fusion of two six-membered rings showed that the reaction gives thermodynamically stable isomer.

10. Discuss the Claisen Schmidt condensation reaction.

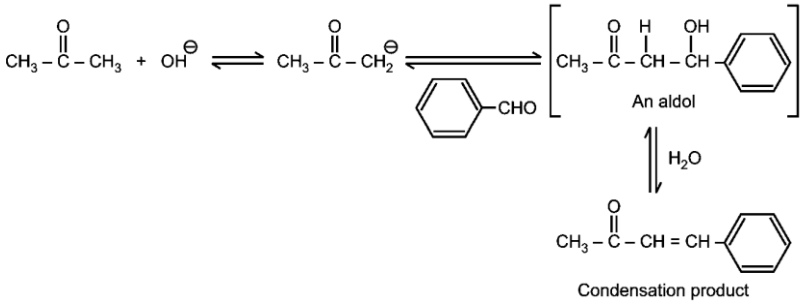
Answer

Claisen Schmidt Condensation Reaction

- The condensation of an aromatic aldehyde with an aliphatic aldehyde or ketone in the presence of a base or an acid to form an α, β-unsaturated aldehyde or ketone is known as Claisen-Schmidt Condensation.



- When an enolate obtained from an aldehyde, normally react with unreacted aldehyde, the reaction is known as Aldol condensation reaction.
- When an enolate from a ketone reacts with an aldehyade, it is called Claisen-Schmidt condensation or crossed aldol condensation.
- In this, the product still has a reactive alpha hydrogen and a hydroxide adjacent to it. Dehydration quickly occurs leading to the condensation product.



SECTION B

LONG ANSWERS TYPE QUESTIONS (2 × 10 = 20)

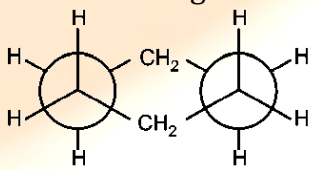
1. Outline the various conformations of cyclohexane in detail.

Answer

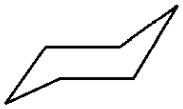
- In cyclohexane all carbon atoms are sp3 hybridized with a bond angle of 109º.
- This leads to two types of conformations.

(i) Chair conformation:

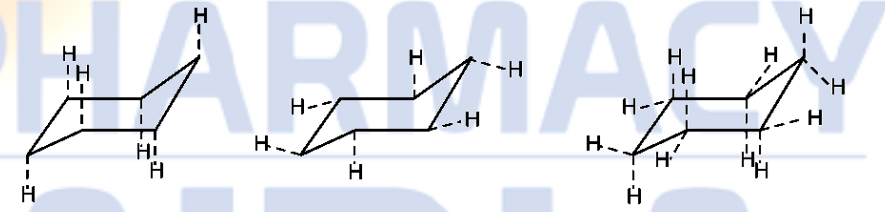
- ✓ It is the most stable form having tetrahedron bond angle of 109º.
- ✓ It adopts staggered arrangement having least torsional strain.
- ✓ Chair cyclohexane has six axial hydrogens perpendicular to the ring (parallel to the ring axis) and six equatorial hydrogens near the plane of the ring.



Staggered arrangement of bonds in chair conformation

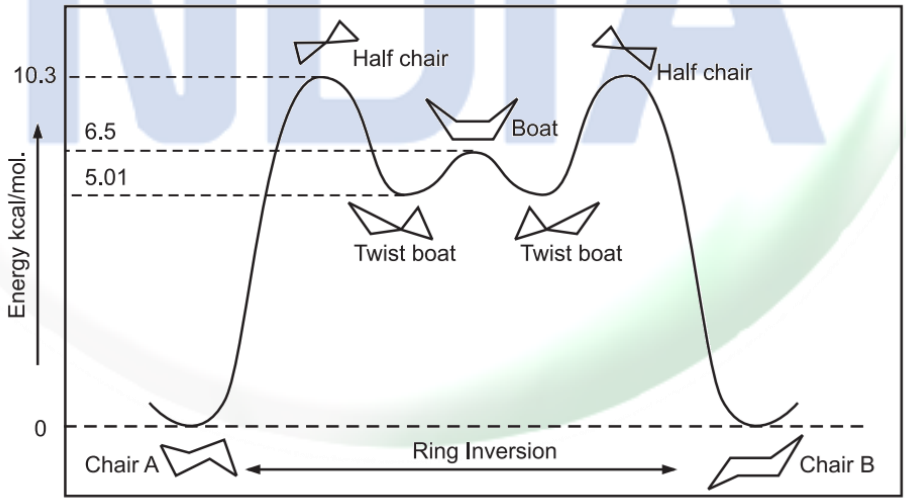


Chair conformation



Axial C – H bonds | Equatorial C – H bonds | Axial and equatorial bonds together

- Six membered rings are almost free of strain in a chair conformation.



(ii) Boat Conformation

- Boat form can be obtained from chair conformation by bending of the bonds. This transformation of chair to boat form occurs through intermittent – half chair and twist boat form.
- In boat conformation, carbon 1 and 4 are bent towards each other while all hydrogens in the chair conformation are staggered, four hydrogens are

eclipsed in the boat conformation. Hence, the boat conformation is less stable than a chair conformation by 6.5 kcal/mol.

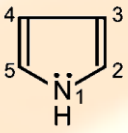
- As a result of simultaneous rotation about all C – C bonds, chair conformations readily get interconverted, resulting in the exchange of axial and equatorial positions. It is known as ring inversion or ring flip. In this process, equatorial bonds become axial and axial becomes equatorial.

2. Classify heterocyclic compounds. Discuss the nomenclature of heterocyclic compounds with suitable example.

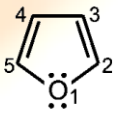
Answer

Classification of Heterocyclic Compounds

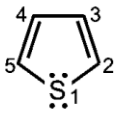
(a) Five membered heterocyclic ring containing one heteroatom:



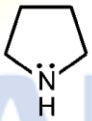
Pyrrole



Furan



Thiophene

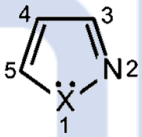


Pyrrolidine

Tetrahydro-furan (THF)

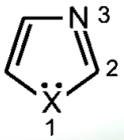
Thiolane

(b) Five membered heterocyclic ring containing two heteroatoms (1, 2 – azoles):



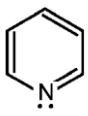
(i) Pyrazole: X = N – H
(ii) Isoxazole: X = O
(iii) Isothiazole: X = S

(c) Five membered heterocyclic ring containing two heteroatoms (1, 3 – azoles

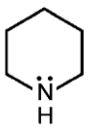


(i) Imidazole: X = N – H (Azole)
(ii) Oxazole: X = O (Oxa)
(iii) Thiazole: X = S (Thia)

(d) Six membered heterocyclic ring containing one heteroatom:

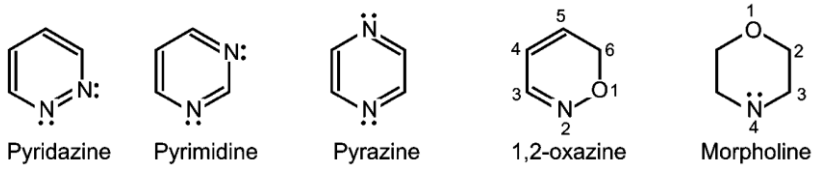


Pyridine

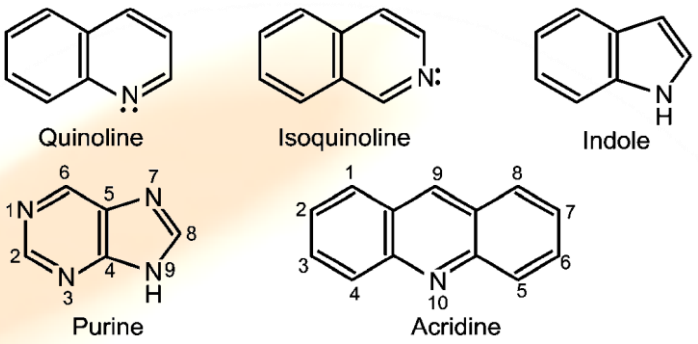


Piperidine

(e) Six membered hetero cyclic ring containing two heteroatoms:



(f) Polycyclic heterocyclic rings:



Nomenclature of Heterocyclic Compounds

The IUPAC rules for nomenclature of heterocyclic rings are as follows:

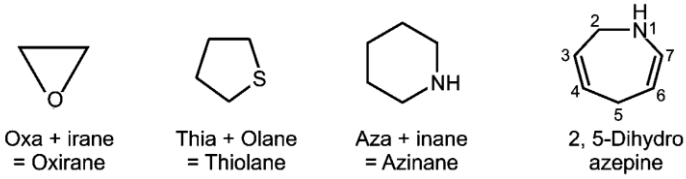
(i) The type of heteroatom is indicated by a prefix as shown below:

Heteroatom	Prefix	Order of priority
Nitrogen	Aza	3
Oxygen	Oxa	1
Sulfur	Thia	2
Phosphorous	Phospha	4

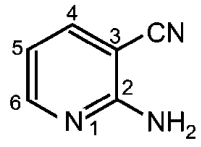
(ii) The ring size is indicated by a suffix as shown below:

Ring Size	Suffix
3	ir (from tri)
4	et (from tetra)
5	ol
6	in
7	ep
8	oc
9	on
10	ec

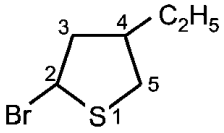
(iii) Unsaturation in the ring may be denoted by prefix such as "dihydro" or "tetrahydro". e.g.,



(iv) The heteroatom is designated as number 1 and the substituents around the ring are numbered so as to have lowest number for the substituents. e.g.,

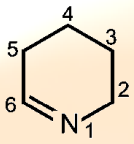


2-Amino-3-cyano azine
(2-Amino-3-cyano pyridine)

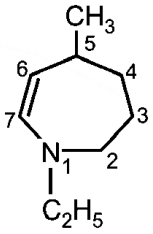


2-Bromo-4-ethyl
thiolane

(v) While numbering, give priority to saturated atoms. e.g.,

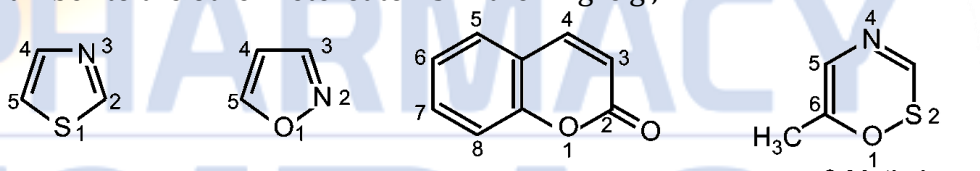


2,4,5,6-Tetrahydro
azine



1-Ethyl-5-methyl
-2,3,4,5-tetrahydro azepine

(vi) In case of ring containing more than one heteroatom, the order of preference for numbering is O, S and N. The ring is numbered from the heteroatom of preference in such a way so as to give the smallest possible number to the other heteroatoms in the ring. e.g.,



6-Methyl
1,2,4-oxathiazine

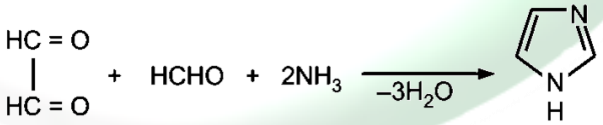
3. Write down the synthesis, reactions and medicinal uses of Imidazole and thiazole.

Answer

Imidazole

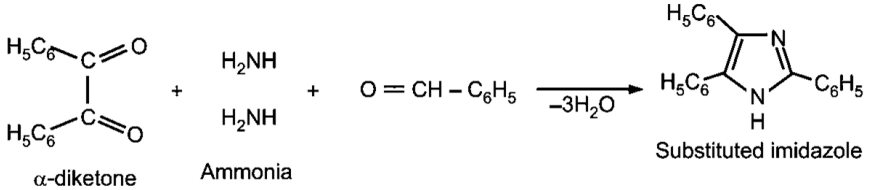
Synthesis

(i) Debus Method: Glyoxal, formaldehyde and ammonia condensed to form imidazole (glyoxaline) in Debus Method reported in 1858. It provides 2-monosubstituted and 2, (3, 4 homo) trisubstituted imidazoles.



Imidazole

(ii) Radiszewski synthesis: It consists of condensing a glyoxal (e.g., benzil), an aldehyde (e.g., benzaldehyde) in the presence of ammonia. Formamide may be used in place of ammonia.

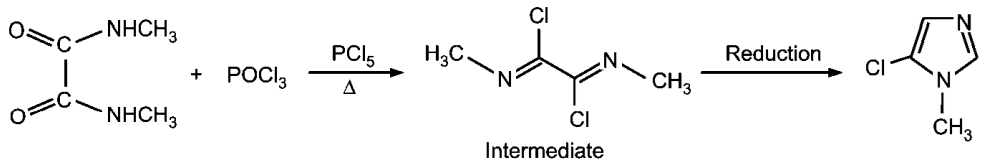


α-diketone
(Benzil)

Ammonia

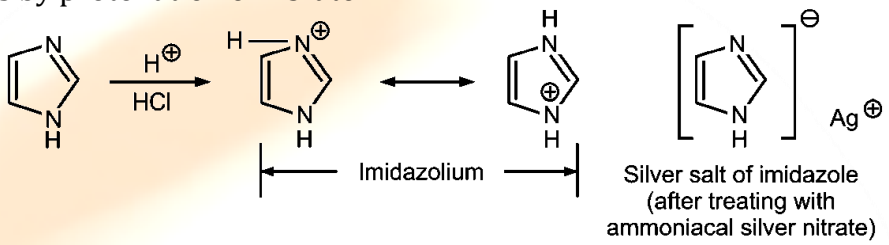
Substituted imidazole

(iii) Wallach Synthesis: The reaction of N, N'-disubstituted oxamide with phosphorus oxychloride gives chlorine containing intermediate which upon reduction with hydriodic acids, gets converted to 1-substituted imidazole. It provides 1, 2-disubstituted chloroimidazoles.



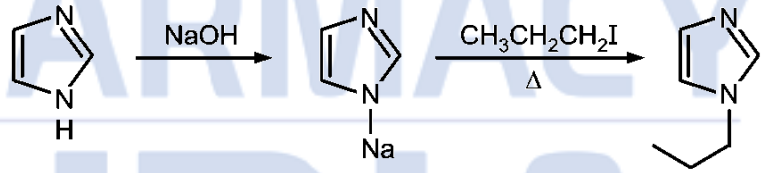
Reactions

(i) Reaction with Acids: Imidazole forms stable crystalline salts with strong acids by protonation of N3-atom.

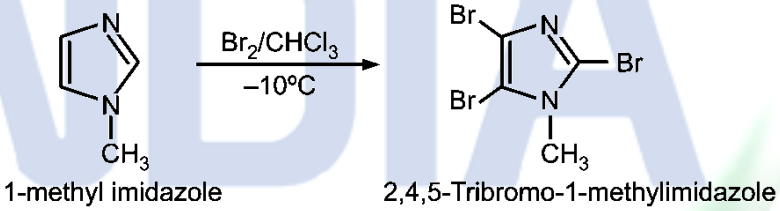


(ii) Electrophilic Substitution reaction:

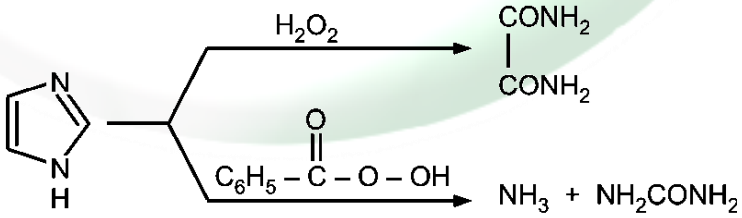
(a) N-alkylation and N-acylation:



(b) Halogention:



(iii) Action of oxidizing agents: Imidazole is stable to auto oxidation and to the action of chromic acid but is attacked by hydrogen peroxide or perbenzoic acid.



Medicinal uses

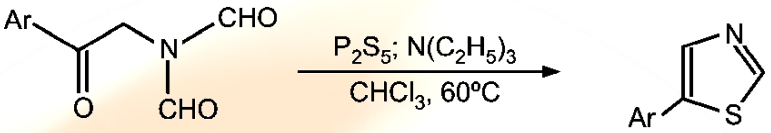
- Imidazole is a parent skeleton in amino acid, histidine and an autacoid, histamine.
- Important drugs containing imidazole ring include ketoconazole (antifungal), midazolam (sedative) and metronidazole (antibiotics).

- It is a main skeleton present in biotin (vitamin), nucleic acid and various alkaloids. Losartan (angiotensin receptor blocker), Eprosartan (angiotensin receptor blocker), azomycin (antibioitic) and clotrimazole (anticancer) also contain imidazole nucleus.

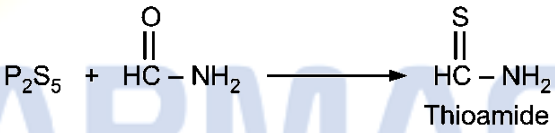
Thiazole

Synthesis

(i) Treatment of N, N-diformylaminomethyl aryl ketones with phosphorus pentasulfide and triethylamine in chloroform gives 5-arylthiazoles.

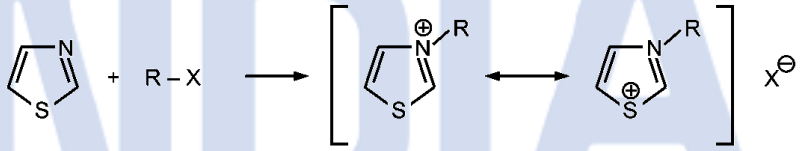


(ii) **Hantzsch's Synthesis:** It is a condensation reaction between α - halo carbonyl compound with an appropriate thioamide or thiourea. The thioamide can be obtained by reacting phosphorus pentasulfide and formamide at room temperature.

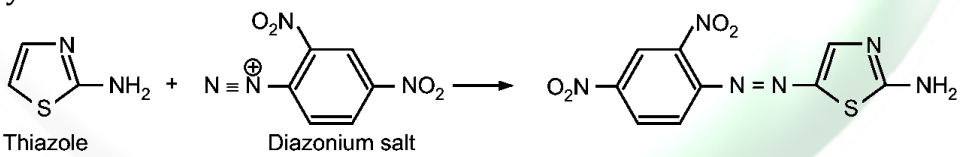


Reactions

(i) N – Alkylation: Thiazoles react with alkyl halides to form thiazolium cations. This cation is resonance stabilized with the positive charge residing mostly on the sulfur atom.



(ii) Diazo Coupling: Thiazoles easily react with diazonium salts to give coloured dyes.



Medicinal uses

- Vitamin thiamine (B1) contains both pyrimidine and thiazole ring systems.
- The ring is also present in meloxicam (non-steroidal anit-inflammatory).
- It is also an important scaffold in antibacterial, antifungal, antidiabetic, anticancer and anticonvulsant drug design.

SECTION C

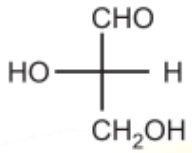
SHORT ANSWERS TYPE QUESTIONS (5 × 7 = 20)

1. Describe DL system of nomenclature of optical isomers with suitable examples.

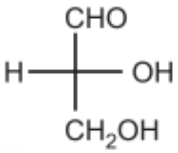
Answer

DL System of Nomenclature

- The d/l system was developed by Fischer and Rosanoff in around 1900. Totally arbitrarily, (+) glyceraldehyde was defined as being D because the OH group attached to the C2 is on the right hand side of the molecule.
- While (–) glyceraldehyde was defined as L because the OH group is on the left hand side.

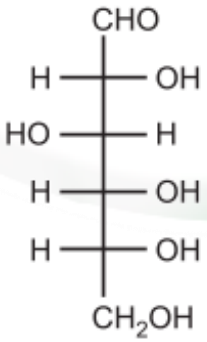


L-Glyceraldehyde



D-Glyceraldehyde

- The d/l system (named after Latin dexter and laevus, right and left) names the molecule by relating them to the molecule glyceraldehyde.
- This system of nomenclature represents an older system for distinguishing enantiomers of amino acids and carbohydrates.
- This arbitrary type of configuration (d/l system) is known as Relative Configuration.
  (a) To name complex amino acids and carbohydrates in Fischer projection, take carbonyl group (aldehyde, ketone or carboxylic acid) on the top and CH2OH on the bottom.
  (b) The D descriptor is used when the –OH or –NH2 on the 2nd carbon (from bottom) points to the right and L is used when the –OH or –NH2 points to the left. Thus, from stereochemistry of only one stereocenter (i.e. 2nd carbon from bottom) the stereochemistry of all other stereocenters in the molecule is defined.
  (c) The d/l nomenclature does not indicate which enantiomer is dextrorotatory and which is levoratatory. It just says that the compound's stereochemistry is related to that of dextro - or levo - enantiomer of glyceraldehyde. For example, d-fructose is levorotatory. Hence, it is stated that all natural amino acids are L while natural carbohydrates are D. Thus, (+) glucose has the D-configuration and (+) ribose has the L-configuration.



D(+)-glucose

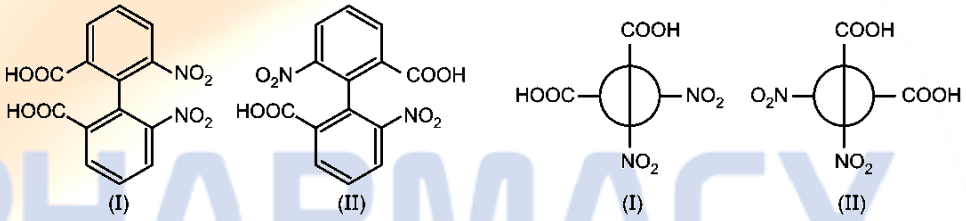
D(+)-ribose

2. Describe stereoisomers in biphenyl compounds and its conditions for optical activity.

Answer

Stereoisomers in Biphenyl Compounds

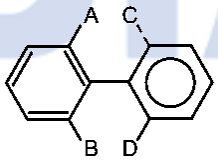
- Atropisomerism is stereochemistry arising from restricted bond rotation that creates a chiral axis.
- Atropisomers are stereoisomers resulting from hindered rotation about one or more single bonds between two planar moieties where the energy barrier to rotation is high enough to allow for isolation of individual conformers.
- The conformers are detectable by NMR if half lives of conformers exceed 10–2 sec. and can be isolated if their half lives are above 1000 sec.
- The name atropisomerism (from Greek, a = not and tropos = turn) was introduced by Kuhn in 1933 but it was first detected in 6,6-dinitro -2, 2'-diphenic acid by Christie in 1922.
- The bulkier groups on ortho position of the biphenyl ring restrict the rotation through C–C bond gives two enantiomers and resolvable at room temperature.



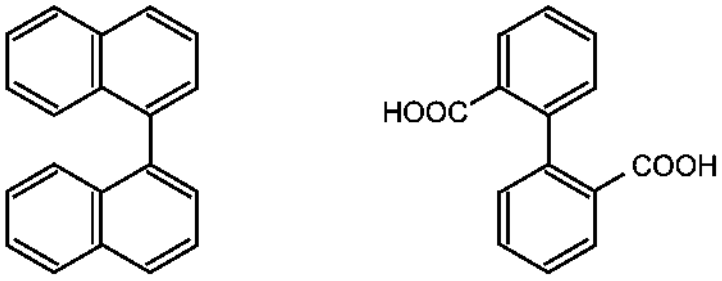
- Atropisomerism induces time dependent inversion of chirality via bond rotation generating atropisomers having different pharmacokinetic, biological and toxicological profiles.

Conditions for Optical Activity

a. The planes of the two aryl groups must be non-planar. It is achieved by placing bulky groups in the ortho positions.



b. In most of the cases, the enantiomers can be resolved.
c. Ortho substituents increase the restricted rotation by their steric repulsion.
d. Mono ortho substituted biaryl compounds do not show atropisomerism at room temperature. e.g.



e. In addition to the substituents at ortho position, the bulky groups adjacent to the ortho substituents increase stability and isolatability of atropisomers.
f. Heteroaromatic system provides chirality even though their ortho substituents are same.

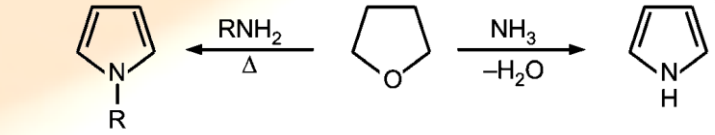
3. Write down the synthesis, reactions and medicinal uses of Pyrrole and thiophene.

Answer

Pyrrole

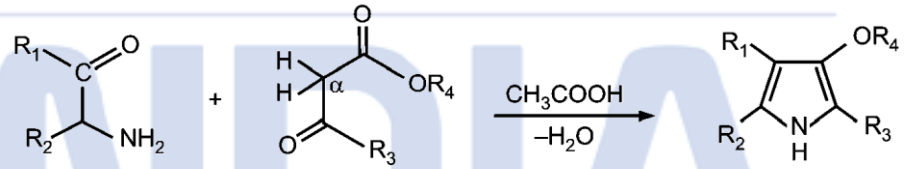
Synthesis

a. Pyrrole is prepared industrially from furan by passing it over ammonia and steam and heated at 400°C in the presence of solid acid catalysts like SiO_2 and Al_2O_3.



1-substituted pyrrole — Furan — Pyrrole

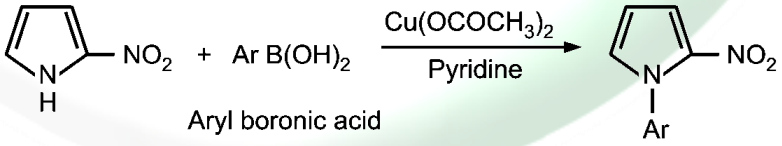
b. **Knorr Pyrrole Synthesis:** In this widely used method, α - amino ketone is condensed with another dicarbonyl compound containing an electron withdrawing group α to a carbonyl group (i.e., activated methylene group) in the presence of acetic acid.



α-Aminoketone — Dicarbonyl compound — Pyrrole

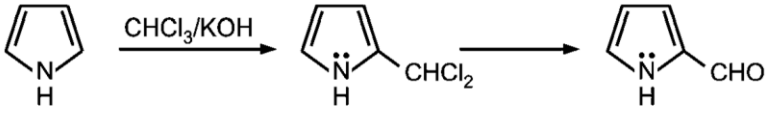
Reactions

a. **Alkylation and arylation:** The sodium/potassium salt of pyrrole reacts with alkyl halide to give corresponding N – alkyl pyrrole. Presence of electron withdrawing substituent on pyrrole ring favours rapid N-alkylation or N-arylation.



Aryl boronic acid

b. **Reimer – Tiemann reaction:** In the presence of a strong base and chloroform, pyrrole undergoes Reimer – Tiemann reaction to form pyrrole – 2 – aldehyde.



Pyrrole — Pyrrole-2-aldehyde

Medicinal Uses

➢ Pyrrole is a structural constituent of haem, chlorophyll, Vitamin B12 and

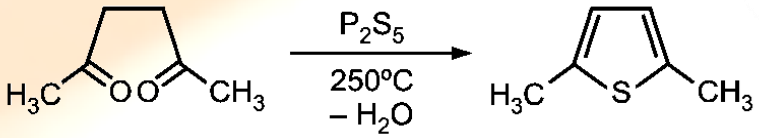
bile pigments.

- Pyrrole ring is also present in the drug tolmetin (NSAID), ketorolac (NSAID), sunitinib (anti-cancer), ageliferin (anti-bacterial), elopiprazole (antipsychotic), procyclidine (antimuscarinic drug to treat parkinsonism) and atorvastatin (lipid lowering agent).
- Pyrrole is widely known as a biologically active scaffold having diversified therapeutic activities such as antipsychotic, β-adrenergic antagonist, anxiolytic, antibacterial, antifungal, antimalarial and anticancer.

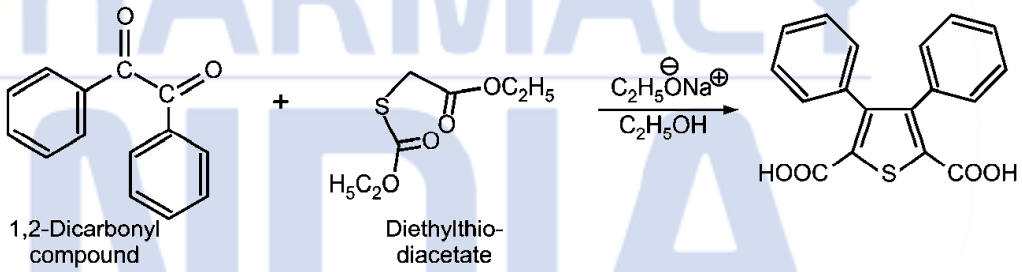
Thiophene

Synthesis

a. **Paal-Knorr Synthesis:** In this method, 1, 4 – dicarbonyl compounds can be heated with phosphorus pentasulfide (a source of sulfur) to give thiophene.

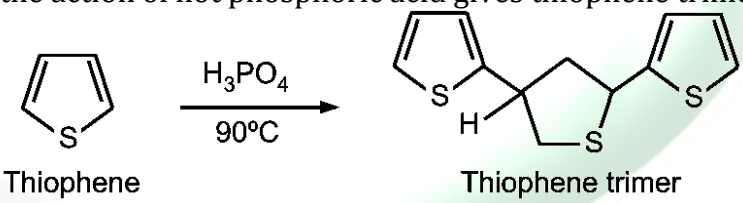


b. **Hinsberg Synthesis:** Two consecutive aldol condensations between 1, 2-dicarbonyl compound and diethylthiodiacetate in the presence of a strong base gives thiophene.

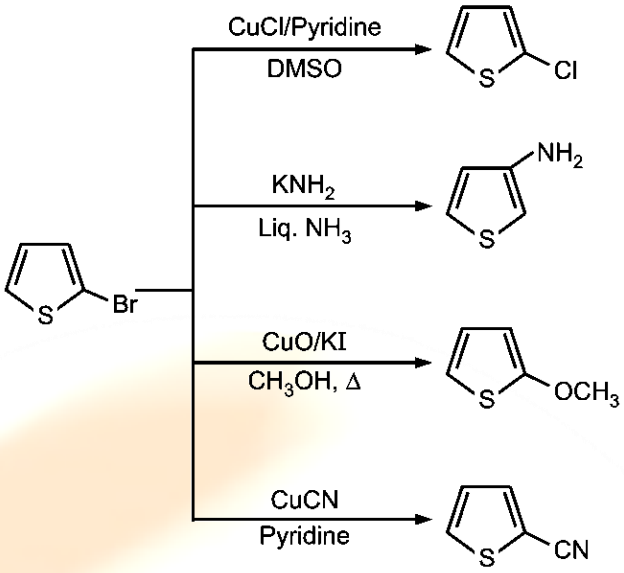


Reactions

a. **Protonation:** Thiophene is very stable to the action of acids. Very strong acids like the action of hot phosphoric acid gives thiophene trimer.



b. **Nucleophilic Substitution:** Thiophene substituted with electron withdrawing substituents are much more reactive to the nucleophilic substitution.



Medicinal Uses

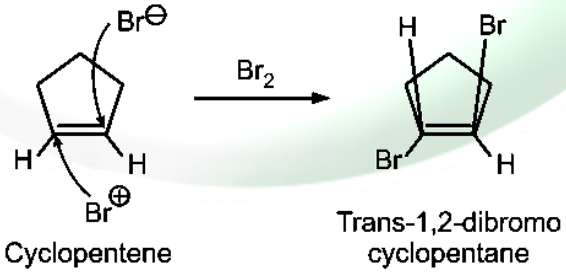
- Thiophene derivatives possess remarkable activites like antibacterial, anti-inflammatory, anti-anxiety, anti-psychotic, anti-arrhythmic and anticancer.
- Examples include lomoxicam (thiophene analog of piroxicam), pyrantel (anti-parasitic), raltitrexed (anticancer), cephalothin (antimicrobial), suproprofen (anti-inflammatory), ticrynafen (anti-hypertensive), clotiazepam (anti-anxiety), ticlopidine (platelet aggregation inhibitor), etc.

4. Describe in detail about the stereoselective and stereospecific reactions with examples.

Answer

Stereospecific Reactions

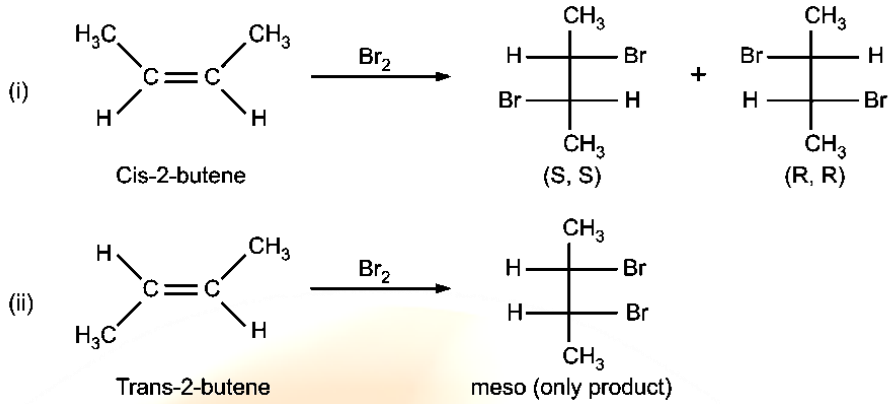
- Stereospecific reaction is a reaction where the stereochemistry of the starting material governs the stereochemistry of the product.
- Only a single stereoisomer is produced in a given reaction rather than a mixture.
- For example, bromination of cyclopentene occurs through stereospecific anti addition to give trans-1, 2-dibromocyclopentane only.



Cyclopentene — Trans-1,2-dibromo cyclopentane

- During the addition of dichlorocarbene to 2-pentene, the cis-2-pentene gives only one product, substituted cis-cyclopropane while the trans-2-pentene gives only one product, substituted trans-cyclopropane.
- In yet another bromination reaction of 2-butene, two geometric isomers (cis and trans) of 2-butene gives three stereoisomeric products where cis-2-butene gives (S, S) and (R, R) 2,3-dibromobutane while trans-2-butene

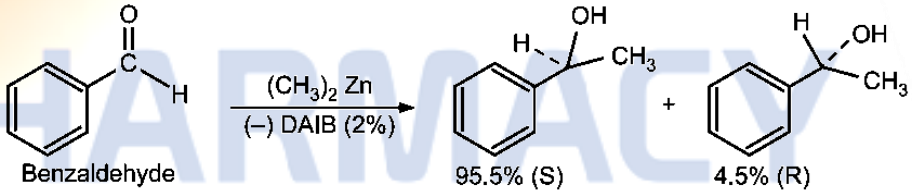
gives meso-2,3-dibromo.ne.



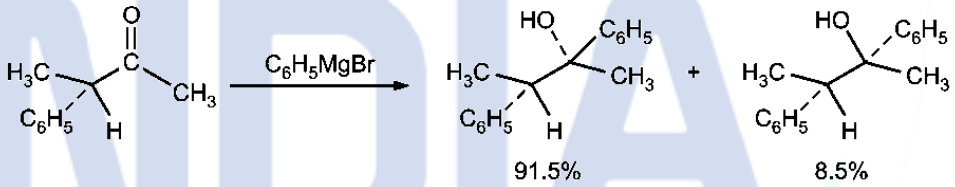
Stereoselective Reactions

- Stereoselective reaction is a reaction where one stereoisomer of a product is formed preferentially over another.
- If enantiomers of a chiral product are formed in unequal amounts, it is called as an enantioselective reaction.

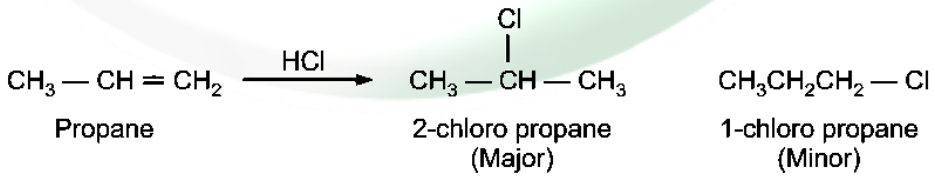
(i) Enantioselective reaction:



(ii) Diastereoselective reaction:



- Similarly, when diastereoisomers are produced in unequal amounts, the reaction is called diastereoselective reaction. In this reaction two diastereoisomers could be formed but one is favoured.
- All stereospecific reactions are stereoselective but stereoselective reactions are not necessarily stereospecific. For example, the reaction of HCl with propene gives 1-chloropropane and 2-chloropropane.

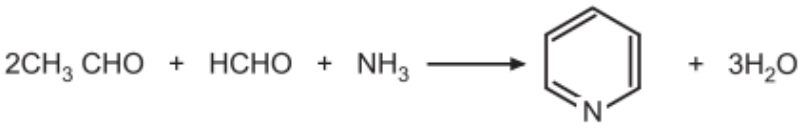


5. Write down the synthesis and medicinal uses of Pyridine also discuss basicity of pyridine.

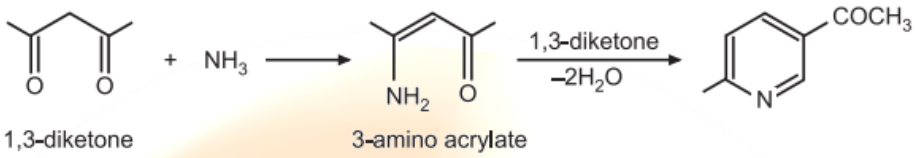
Answer

Synthesis of Pyridine

(1) Pyridine is synthesized by reacting acetaldehyde with formaldehyde and ammonia.



(2) From 1,3-dicarbonyl compound and 3-aminoacrylate: Unsymmetrically substituted pyridine can be synthesized by reaction between a 1,3-dicarbonyl compound with 3-aminoacrylate.

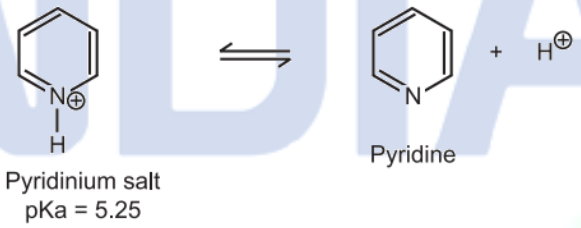


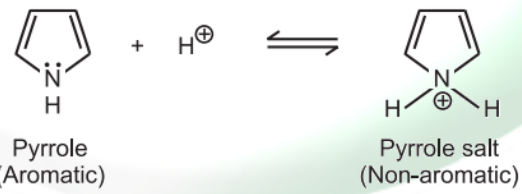
Medicinal Uses

- It is present as a core skeleton in sulfapyridine (antibacterial), tripelenamine, mepyramine (antihistaminic), nicacin, pyridoxine (vitamin), isoniazid (anti – T. B.), etc.

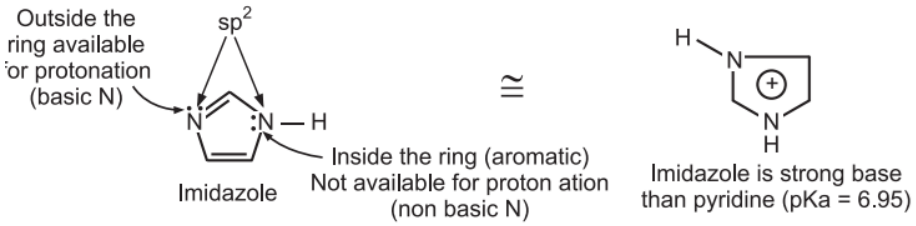
Basicity of Pyridine

- Pyridine is a weakly basic compound. The nitrogen bears a basic lone pair of electrons than lies outside the ring on an sp2 hybrid orbital and is available for protonation.
- In pyrrole, the lone pair on the N-atom is already involved in the aromatic array of pi electrons. Protonation of pyrrole results in loss of aromaticity and is therefore unfavourable.
- Because the lone pair is not part of the aromatic ring, pyridine is a base. Pyridine can act as Lewis base by donating its lone pair of electrons to a Lewis acid, forming pyridinium salts.





- In aniline, the lone pair is on sp3 hybridized nitrogen (less electronegative). This makes pyridine less basic than aniline. Unlike pyridine, however in aniline the lone pair is in resonance with the pi electrons of the phenyl ring. This lowers the basicity of aniline and makes pyridine more basic than aniline.
- Imidazole is about 100 times more basic than pyridine. The increased basicity results from resonance stabilization of the positive charge to both nitrogen atoms present in imidazole.



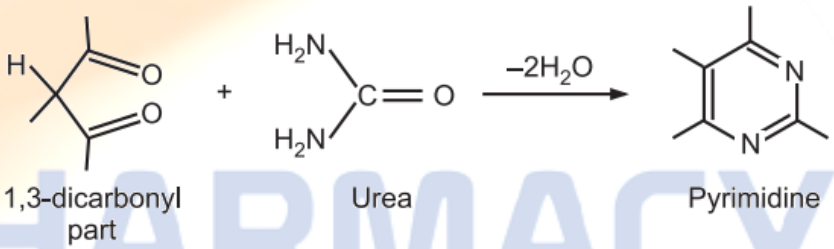
6. Discuss in detail about the synthesis and pharmaceutical uses of Pyrimidine and purine.

Answer

Pyrimidine

Synthesis

- The synthesis of pyrimidine is based on the combination of a 1, 3-dicarbonyl component with an amidine (N-C-N fragment) present either as a urea, amide or guanidine.



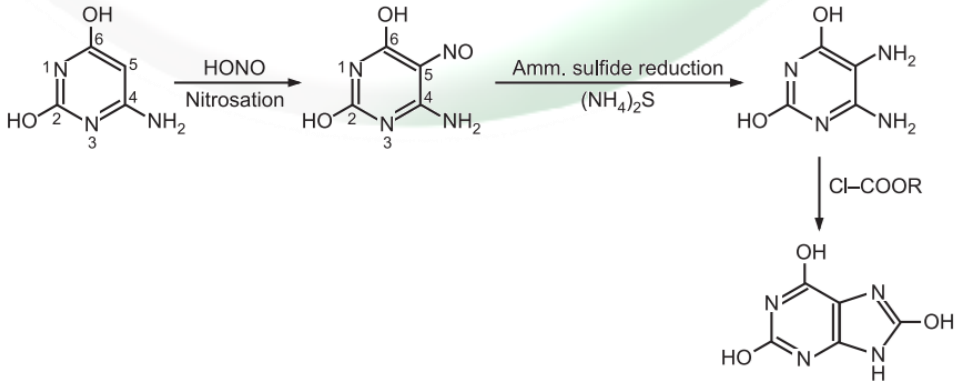
Pharmaceutical Uses

- Thymine, cytosine and uracil are the essential building blocks of nucleic acids RNA and DNA.
- Pyrimidine is an important structural component of cytosine, uracil and thymine (RNA and DNA), vitamin B1 (thiamine), barbiturates (sedative/hypnotics), veranal (hypnotics), sulfadiazine (antibacterial), amicetin (antibiotic), lamivudine (anti-AIDS), flucytosine (antifungal), etc.

Purine

Synthesis

a. **Traube Synthesis:** It begins with 4-amino-6-hydroxy pyrimidine or 4, 5-diamino pyrimidine involving the nitrosation at 5-position, reduction of nitroso to amino group using ammonium sulfide, and ring closure with formic acid or chloro carbonic ester.



Pharmaceutical Uses

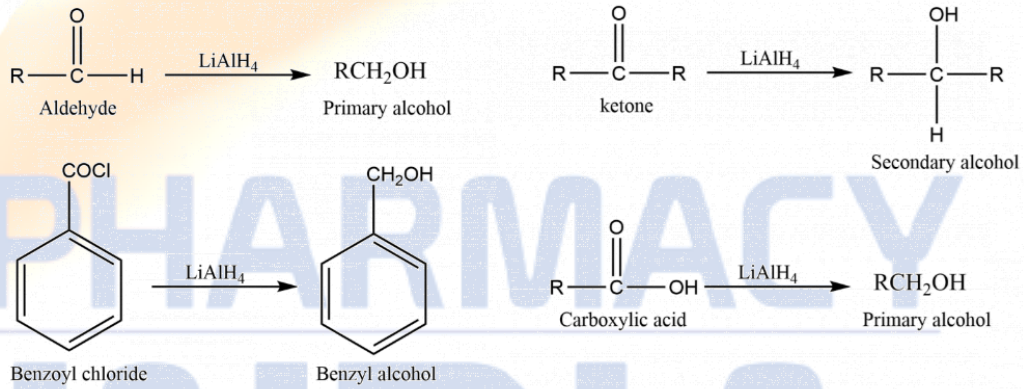
- Purine analogs are having antibacterial, antifungal, antitumor, antiviral and anti-HIV activity.
- Important drugs from purine category include caffline (CNS stimulant), 6-mercaptopurine (anti-cancer), aristeromycin. Drugs having isoster of purine include sildenafil (erectile dysfunction), allopurinol (anti-gout), tubercidin (anti-cancer).

7. Discuss the reaction and mechanism of Metal hydride reduction.

Answer

Reaction and Mechanism of Metal Hydride Reduction

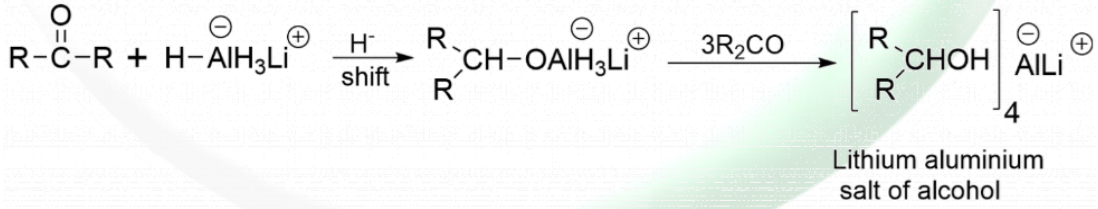
- Aldehydes and ketones are converted to primary and secondary alcohols by metallic hydrides such as lithium aluminum hydride (LiAlH4) and sodium borohydride (NaBH4). Such a reaction is called metal hydride reduction reaction.



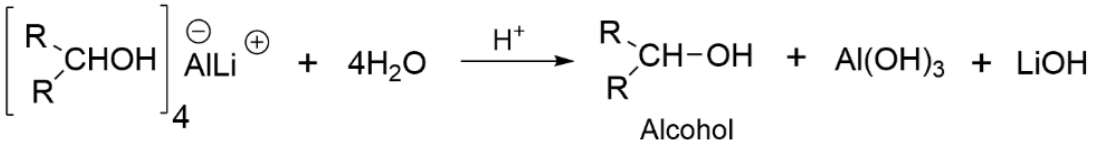
Mechanism

The mechanism of metal hydride reduction can be carried out in the following 2 steps:

Step 1: During nucleophilic addition, lithium aluminum hydride (LiAlH4) or sodium borohydride (NaBH4) provides hydride ions (H–) as a nucleophile that attacks the electron-deficient carbonyl carbon.



Step 2: The excess LiAlH4 is carefully eliminated, and the aluminum salt of alcohol produced in step 1 is hydrolyzed by mineral acid to liberate the appropriate alcohol in a high yield.



PHARMACEUTICAL ORGANIC CHEMISTRY-II MODEL PAPER