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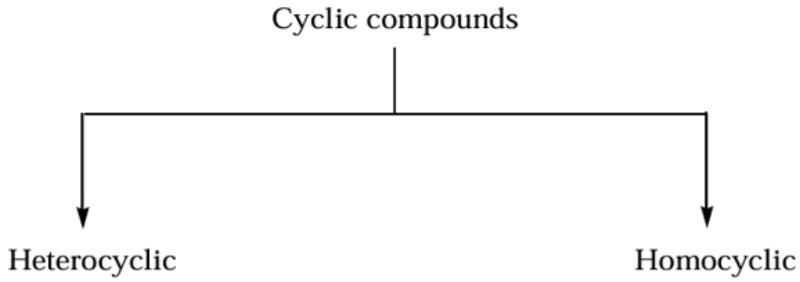
Lecture 9: Cyclic compounds (Heterocyclic)

A **cyclic compound** is a chemical compound in which the atoms are connected to form a **closed ring structure**, rather than an open (linear) chain.

The following scheme illustrates the classification of cyclic compounds



Heterocyclic compounds are organic compounds that contain one or more rings in which at least one atom is not carbon. These non-carbon atoms are called heteroatoms and commonly include nitrogen (N), oxygen (O), and sulfur (S). Heterocyclic compounds are extremely important in organic chemistry, biochemistry, and pharmaceutical sciences due to their wide presence in biological systems and drugs.

Importance of Heterocyclic Compounds

1. They form the core structure of many biologically essential molecules, such as:
   - Nitrogenous bases in DNA and RNA (purines and pyrimidines)
   - Vitamins (e.g., vitamin B1, B6)
2. They are present in a large number of drugs:
   - Antibiotics (e.g., penicillin)
   - Anticancer drugs
   - Drugs acting on the nervous system
3. They are widely used in industry:
   - Dyes and pigments
   - Pesticides
   - Polymers and synthetic materials

Classification of Heterocyclic Compounds

1. According to the type of heteroatom

- Nitrogen-containing heterocycles
- Oxygen-containing heterocycles
- Sulfur-containing heterocycles

2. According to ring size

- Five-membered rings
- Six-membered rings

3. According to aromaticity

- Aromatic heterocycles
- Non-aromatic heterocycles

Five-Membered Heterocyclic Compounds

1. Pyrrole (C_4H_5N)

- A five-membered aromatic ring containing one nitrogen atom.
- The nitrogen lone pair contributes to aromaticity.
- Found in biologically important molecules such as hemoglobin and chlorophyll.

2. Furan (C_4H_4O)

- Contains one oxygen atom in a five-membered ring.
- Aromatic but less stable than pyrrole.

3. Thiophene (C_4H_4S)

- Contains one sulfur atom.
- More chemically stable than furan.

Six-Membered Heterocyclic Compounds

1. Pyridine (C_5H_5N)

- Structurally similar to benzene, with one carbon atom replaced by nitrogen.
- Aromatic and weakly basic.
- Present in vitamin B3 (niacin).

2. Pyrimidine

- A six-membered aromatic ring containing two nitrogen atoms.
- Forms the basis of cytosine, thymine, and uracil in nucleic acids.

3. Purine

- Consists of a fused five- and six-membered ring system.
- Found in adenine and guanine in DNA and RNA.

Chemical Properties

- Many heterocyclic compounds are aromatic and obey Hückel's rule ($4n + 2\ \pi$ electrons).
- Their basicity depends on the type and position of the heteroatom.
- Aromatic heterocycles usually undergo substitution reactions rather than addition reactions.

Biological and Medical Significance

- Heterocyclic structures are essential for enzyme activity and molecular recognition.
- They play a major role in drug design and medicinal chemistry.
- Many biomarkers and metabolites in clinical biochemistry contain heterocyclic rings.

Lecture 10: Cyclic compounds (Homocyclic compound)

Homocyclic compounds are organic compounds that contain one or more rings composed entirely of carbon atoms. No heteroatoms (such as nitrogen, oxygen, or sulfur) are present in the ring structure. For this reason, homocyclic compounds are also known as **carbocyclic compounds**.

Importance of Homocyclic Compounds

1. They represent the basic structure of aromatic compounds, especially benzene.
2. They are widely used in industry, including:
   - Fuels and petroleum products
   - Organic solvents
   - Polymers and plastics
3. They have biological and medical significance:
   - Steroid hormones
   - Drug molecules derived from carbocyclic rings
4. They help in understanding fundamental concepts such as ring strain, aromaticity, and stability.

Classification of Homocyclic Compounds

1. According to aromaticity

- **Alicyclic compounds** (non-aromatic)
- **Aromatic compounds**

2. According to the number of rings

- Monocyclic compounds
- Polycyclic compounds

3. According to saturation

- Saturated compounds
- Unsaturated compounds

Alicyclic Compounds (Non-aromatic)

Alicyclic compounds are homocyclic compounds that resemble alkanes or alkenes but have a ring structure.

Examples:

1. **Cyclopropane (C_3H_6)**
   - Three-membered ring
   - Highly strained and less stable
2. **Cyclobutane (C_4H_8)**
   - Four-membered ring
   - Moderate ring strain
3. **Cyclohexane (C_6H_{12})**
   - Most stable alicyclic compound
   - Exists mainly in the chair conformation

Biological and Medical Significance

- Carbocyclic rings are present in many biologically important molecules, including:
  - Steroid hormones (e.g., cortisol, testosterone)
  - Vitamin D
- Some polycyclic aromatic hydrocarbons (PAHs) are toxic and carcinogenic.
- Homocyclic compounds are essential scaffolds in medicinal chemistry and drug design.

Why Cyclic Structure Controls Metabolic fate

Structural Feature	Metabolic Effect
Aromaticity	High stability, slow degradation
Ring size	Enzyme specificity
Heteroatoms	Determine oxidation pathways
Planarity	Receptor and DNA interaction

When Is a Compound Cyclic and When Is It Linear in the Human Body?

Glucose

In Blood and Cells:

- >99% of glucose exists in the cyclic form (α- and β-D-glucopyranose)
- <1% exists in the linear aldehyde form

Why the Cyclic Form Dominates:

- Intramolecular reaction between the aldehyde group and a hydroxyl group
- Formation of a stable six-membered ring
- Reduced chemical reactivity and greater stability in water

Enzymes bind the cyclic form, but temporarily open the ring inside the active site when a reaction requires the linear form.