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A BRIEF REVIEW ON THE SYNTHESIS OF HETEROCYCLES USING FRUIT EXTRACTS AS CATALYSTS

BADRI.SIREESHA^{*1}, CH.PRASUNA², M.ASHVITHA², B.ASRITHA², D.SRAVANI²

^{*1}Department of Pharmaceutical Analysis, Dr. Samuel George Institute of Pharmaceutical Sciences, Tarlupadu Road, Markapur, Markapur Dt. ,Pincode: 523316

²B. Pharmacy. Dr. Samuel George Institute of Pharmaceutical Sciences Tarlupadu Road, Markapur , Prakasam dt. Pin code 523316

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*CORRESPONDING AUTHOR

Badri.Sireesha

Department of Pharmaceutical Analysis, Dr. Samuel George Institute of Pharmaceutical Sciences, Tarlupadu Road, Markapur, Markapur Dt. ,Pincode: 523316

ABSTRACT

The uses of organic compounds impact our lives daily in medicine, agriculture, and general life. Considering the enormous breath of the subject, it is not common for chemistry educators to cover the history of organic chemistry in any depth due to time limitations, and textbooks do not devote much space to it. Non-systemic nomenclature of organic compounds like common name, trivial name etc are described in individual chapters. The chemical properties of organic compounds are determined by its functional group, whereas the remaining structure of the compound determines its physical properties. The synthesis of heterocyclic compounds is a fundamental aspect of organic chemistry due to their wide applications in pharmaceuticals, agrochemicals, and functional materials. Fruit extracts, rich in bioactive constituents such as organic acids, flavonoids, enzymes, and vitamins, can effectively catalyze a variety of organic transformations under mild and eco-friendly conditions.

Keywords: *Organic Compounds, Catalysts, Heterocyclic Compounds, Nomenclature.*

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INTRODUCTION

Organic chemistry is a branch of chemistry that deals with the study of carbon and its compounds. Carbon is now known to form an almost unlimited number of compounds. Organic compounds play an important role in our daily lives, especially in areas like medicine, agriculture, and general applications. Because the subject is very vast, teachers usually do not explain the history of organic chemistry in detail due to time constraints, and textbooks also give it limited importance. As a result, many students may not clearly understand why the subject is called "Organic Chemistry" or why scientists are called organic chemists.

This discussion explains the origin of organic chemistry and traces the meanings of the terms "organic" and "inorganic," which have changed over time. The word "organic" is derived from the Greek word *organon*, meaning instrument, and it dates back to Aristotle (384-322 BC). Aristotle differentiated between living and non-living things, stating that the living body acts as an instrument of the soul, just as the eye is an instrument of vision. Later, Berzelius followed this idea and used the term in a similar way. The meaning of the word "synthesis" has also evolved [1]. Originally, it meant

simply putting things together, not necessarily forming chemical compounds as understood today.

Organic chemistry specifically studies carbon and its compounds, and it is now a well-established fact that carbon can form an unlimited number of compounds. Therefore, the field of organic chemistry continues to grow as new discoveries are made worldwide. The importance of organic compounds is increasing in many areas such as medicine, agriculture, polymers, and petroleum products. Today, organic chemistry is a highly developed field with great potential for future advancements. However, due to the large amount of information and theories available, students need to put in significant effort to understand the subject. Although it may seem complex, organic chemistry is very interesting and begins with basic concepts such as structure and bonding.

In earlier times, scientists named compounds based on their origin or historical background. For example, methanol was called "wood spirit" because it was obtained from wood, and later it was named methanol using Greek words. Similarly, acetic acid got its name from vinegar, as it is the main component of vinegar. These types of names are called common or trivial names.

However, as more compounds were discovered, this method of naming became difficult, leading to the need for systematic naming methods [2].

The term "organic" originates from the Greek word *organon*, meaning instrument, and dates back to the ideas of Aristotle, who distinguished between living and non-living things. Later, scientists like Berzelius adopted this concept when studying compounds derived from living organisms. Over time, the meanings of "organic" and "inorganic" have evolved. Similarly, the term "synthesis," originally meaning simply "putting together," has developed into its modern meaning of forming chemical compound.

HISTORY

As the number of organic compounds increased, naming them based on historical origin became difficult. Therefore, a systematic method of naming compounds became necessary. The first attempt to standardize chemical names was made at the International Congress of Chemists held in Geneva in 1892, where a rational system called the Geneva system of nomenclature was introduced. Later, this system was revised and improved from time to time. One such revision took place at Liege (Belgium) in 1930 by the International Union of Chemistry, and it became known as the IUC system of nomenclature. This was further modified in 1958 by the International Union of Pure and Applied Chemistry, leading to the development of the IUPAC system of nomenclature.

The IUPAC system provides a set of standard rules for naming organic compounds, and most compounds are named according to these rules today. However, some common or trivial names are still in use. Therefore, chemists should be familiar with both systematic (IUPAC) names and common names. Non-systematic naming methods, such as common and trivial names, are discussed separately in different chapters.

In earlier times, compounds were named based on their source or historical background. For example, methanol was originally called "wood spirit" because it was obtained from the distillation of wood, and later it was named methanol using Greek words. Similarly, acetic acid got its name from vinegar, as it is the main component of vinegar. These types of names are known as common or trivial names. As more compounds were discovered, this naming method became impractical, which led to the development of systematic nomenclature.

THE ROLE OF ORGANIC CHEMISTRY IN PHARMACEUTICALS

Pharmacy Pharmacy is the science of preparing, compounding, and dispensing medicines. It also involves studying how drugs interact with the human body and how they help in treating diseases. Pharmacists perform many roles, such as developing new drugs and providing medicines to patients. Chemistry plays a very important role in pharmacy. Pharmacists use chemistry to understand the composition of drugs and how different compounds interact with each other and with the human body. This knowledge helps in designing safe and effective medicines. Chemistry in pharmacy is not limited to organic chemistry alone. Other branches like analytical

chemistry help in checking the purity and quality of drugs, while physical chemistry helps in studying drug stability and shelf life. However, organic chemistry is the most important branch for drug design and development. Organic chemistry mainly deals with the study of carbon compounds and their reactions. Carbon has the ability to form a large number of compounds, and all living organisms are made up of carbon-based molecules [4].

Organic chemistry is divided into several sub-branches, each focusing on a specific area:

- **Biochemistry:** Study of chemical processes in living organisms
- **Medicinal chemistry:** Design and development of drugs
- **Polymer chemistry:** Study of large molecules called polymers
- **Environmental chemistry:** Study of chemical processes in the environment
- **Physical organic chemistry:** Study of the relationship between structure and reactivity

Carbon is a unique element that can form strong bonds with other atoms, allowing the formation of a wide variety of compounds. Therefore, the main aim of organic chemistry is to understand and predict the behavior of carbon compounds.

CLASSIFICATION OF ORGANIC COMPOUNDS

Organic Organic compounds are divided into two categories. First, we'll examine organic compounds that are based on "Structure," and then we'll talk about organic compounds that are based on "Function." Now we'll take a closer look at these organic compound classifications.

- I. Acyclic or open chain compounds
- II. Closed-chain or cyclic compounds

I. Acyclic or open chain compounds:

Because Acyclic compounds are those in which the molecules do not form a ring structure. Instead, they have a linear arrangement of atoms, so they are called open chain compounds. These compounds include aliphatic compounds such as alkanes. Open chain compounds are of two types: straight-chain and branched-chain compounds. Straight-chain compounds do not have any side chains, whereas branched-chain compounds have one or more side chains attached to the main chain.

Acyclic/Aliphatic Compounds

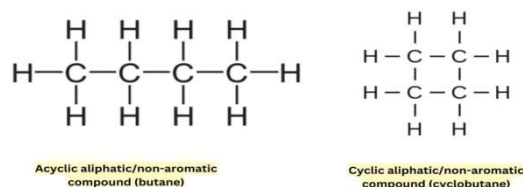


Figure 01: Acyclic / aliphatic compounds

II. Closed-chain or cyclic compounds: Closed-chain compounds are also known as cyclic compounds or ring compounds. In these compounds, atoms are connected in such a way that they form a closed ring. The size of the ring may vary from one compound to another.

Cyclic compounds are commonly found in daily life and are very important. These compounds are further classified into two types:

1. Heterocyclic compounds
2. Homocyclic compounds

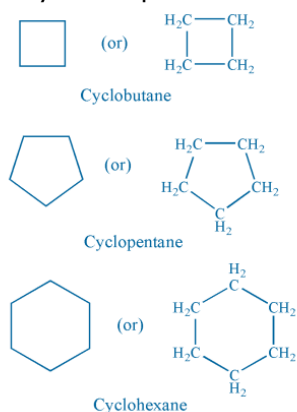


Figure 02: Homocyclic compounds

HETEROCYCLE COMPOUNDS

Heterocyclic compounds are a class of cyclic organic compounds that contain at least one hetero atom (an atom other than carbon) in their ring structure. The most common heteroatoms present in these compounds are nitrogen (N), oxygen (O), and sulphur (S). These compounds are widely found in plants and animal products and make up nearly half of all known natural organic compounds [6].

Many important natural substances such as alkaloids, natural dyes, drugs, proteins, and enzymes belong to the group of heterocyclic compounds. These compounds can be classified based on their electronic structure and are mainly divided into saturated and unsaturated types.

Saturated heterocyclic compounds behave similarly to open-chain compounds but show some differences due to steric effects. Examples of such compounds include piperidine and tetrahydrofuran, which are similar to amines and ethers.

On the other hand, unsaturated heterocyclic compounds, especially those with 5- and 6-membered rings, are widely studied because they are stable and less strained. Important examples include pyridine, thiophene, pyrrole, and furan, along with their benzene-fused derivatives. Some examples of benzo-fused heterocycles are quinoline, isoquinoline, indole, benzothiophene, and benzofuran [7].

Heterocyclic compounds have wide applications in pharmaceuticals, agrochemicals, and veterinary products. Many of these compounds are essential for human life. Substances such as hormones, alkaloids, antibiotics, essential amino acids, hemoglobin, vitamins, dyes, and pigments contain heterocyclic structures.

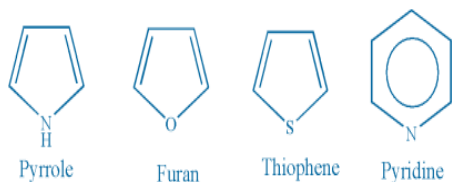


Figure 03: Heterocyclic compounds

CLASSIFICATION OF HETEROCYCLIC COMPOUNDS

Heterocyclic compounds are classified into two categories based on their structure and electronic arrangement:

1. Aliphatic heterocyclic compounds
2. Aromatic heterocyclic compounds

Aliphatic Heterocyclic Compounds

Aliphatic heterocyclic compounds include cyclic amines, cyclic amides, cyclic ethers, and cyclic thioethers. These compounds do not contain double bonds and are therefore known as saturated heterocycles. The properties of these compounds are mainly influenced by the strain present in the ring.

Aromatic Heterocyclic Compounds

Aromatic heterocyclic compounds are similar to benzene in structure and behavior. These compounds follow Hückel's rule of aromaticity. According to this rule, an aromatic compound must be cyclic, planar, and contain conjugated double bonds with $(4n + 2)$ π electrons.

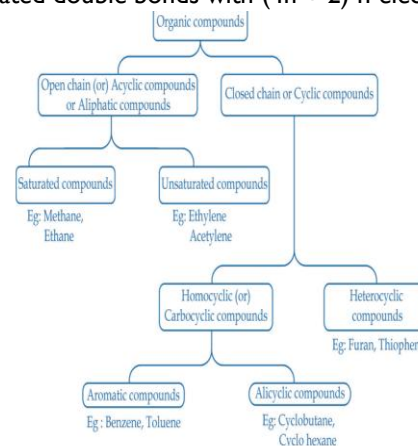


Figure 04: Classification of Organic Compounds

ORGANIC COMPOUNDS NOMENCLATURE

The total number of carbon atoms in a compound is counted to determine its base name. The following prefixes are used: Meth- (1 carbon), Eth- (2 carbons), Prop- (3 carbons), But- (4 carbons), Pent- (5 carbons), Hex- (6 carbons), Hept- (7 carbons), Oct- (8 carbons), Non- (9 carbons). To this prefix, the suffix -ane is added to name alkanes. The prefix n- is used when all carbon atoms are arranged in a straight chain. The prefix iso- is used for branched-chain alkanes, and neo- is used when the alkane contains a tert-butyl group [9]. The total number of carbon atoms is first identified, and then the corresponding alkane name is assigned. In some cases, the suffix 'ylene' is added to the prefix as required.

IUPAC SYSTEM OF NOMENCLATURE

The IUPAC name of a compound consists of a base name with or without a prefix. The base name is made up of (i) root or stem and (ii) prefix or suffix. For example, in 2-methyl-1-nitropropane, the base name is nitropropane, where propane is the root and nitro is the prefix.

IUPAC Rules

1. If the base name of a compound is the name of an actual compound, the prefix is directly attached to it. Example: Nitropropane. If the base name is not an actual compound name, a space is left between the prefix and base name. Example: Methyl ethanoate.

2. To select the base name, the parent part of the molecule must be identified. The parent part includes the main carbon chain and the most important functional group.
3. The nature of the base chain and the number of carbon atoms determine the root of the base name. The general rules are:
 - (a) In open chain compounds, the base chain is a straight carbon chain, and the root is taken from the corresponding alkane.
 - (b) In alicyclic compounds, the root is derived from the corresponding cycloalkane.
 - (c) In aromatic compounds, the base chain may include rings such as benzene, naphthalene, anthracene, or biphenyl, and the root is derived from the name of the ring.
 - (d) In heterocyclic compounds, the root is derived from the parent ring structure.
4. The suffix or prefix is added after or before the root to form the base name. Each carbon atom in the main chain is numbered in sequence.
5. The method of numbering differs based on the type of compound:
 - (a) In open chain compounds, numbering starts from the end nearest to the primary functional group to give it the lowest number. If both ends are equal, numbering is done to give the lowest sum of substituent positions.
 - (b) In alicyclic and benzene compounds, numbering begins from the carbon with the main substituent and proceeds in the direction giving the lowest numbers.
 - (c) In polynuclear compounds, a special numbering system is used, following the lowest sum rule.
 - (d) In heterocyclic compounds, numbering starts from the heteroatom.
6. The position (locant) of the primary functional group is indicated and joined to the base name using a hyphen.
7. (a) If the position of the primary functional group is fixed and obvious, its locant is not written.
8. (b) If the primary functional group is part of the main chain and its carbon is numbered as 1, the locant is not shown. This occurs in groups like $-\text{CHO}$, $-\text{COOH}$, $-\text{CONH}_2$, $-\text{COX}$, etc.
9. Functional groups other than the primary one and substituents are indicated as prefixes to the base name [10].

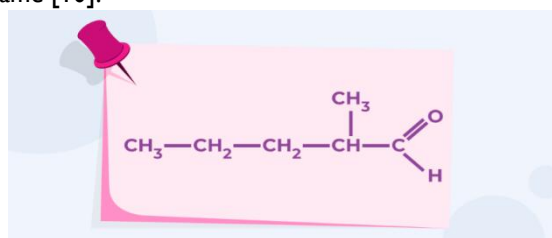


Figure 05: 2-methyl pentanal

This rule has exceptions:

- i. Double bond
- ii. Triple bond
- iii. Two or more identical functional groups
 - (a) Branches are always indicated by prefixes. To represent a branch or functional group as a prefix, its

- (b) position (locant) is written before its name with a hyphen, and then it is attached to the base name [11].

(b) If the base name already contains the locant of the primary functional group, the prefix is also joined to the base name using a hyphen.

If two or more substituents are present, each substituent is written along with its locant. These are arranged either alphabetically or in order of increasing complexity and connected by hyphens. The last substituent is joined directly to the base name if the base name does not contain any locant.

If a substituent itself contains another substituent, it is called a **compound substituent**. In such cases, numbering is done within the substituent starting from the point of attachment to the base chain, which is given number 1, and the lowest sum rule is followed [12,13].

Classification of Organic Compounds Based on Organic Molecules

Organic molecules are made up of carbon along with other elements such as hydrogen, oxygen, nitrogen, and others. When these atoms combine with carbon in different ways, they form a wide variety of organic compounds.

Hydrocarbons

Hydrocarbons are organic compounds that consist only of carbon and hydrogen atoms. Their structure is formed by the bonding between carbon atoms. It is believed that all other organic compounds are derived from hydrocarbons by replacing one or more hydrogen atoms with other atoms or functional groups. Hence, hydrocarbons are considered the parent compounds of organic chemistry.

Characteristics of Hydrocarbons

Lower hydrocarbons like methane and ethane exist as gases at room temperature. Hydrocarbons are generally colorless and odorless. The boiling point of hydrocarbons increases as the number of carbon atoms increases. They undergo combustion with oxygen to produce carbon dioxide (CO_2) and water [14]. Among hydrocarbons, alkanes are the least reactive, while alkynes are the most reactive due to the presence of triple bonds. Alkanes are saturated compounds, whereas alkenes and alkynes are unsaturated compounds. Hydrocarbons are insoluble in water.

Hydrocarbons are classified into three types:

1. Alkanes
2. Alkenes
3. Alkynes

Alkanes

Alkanes are hydrocarbons that contain only single covalent bonds between carbon atoms. Their general formula is $\text{C}_n\text{H}_{2n+2}$. In alkanes, each carbon atom is sp^3 hybridized and forms four sigma bonds ($\text{C}-\text{C}$ or $\text{C}-\text{H}$), resulting in a tetrahedral structure. The longest continuous chain of carbon atoms is called the carbon skeleton or backbone, and the number of carbon atoms determines the size of the alkane.

Alkenes

Alkenes, also known as olefins, are hydrocarbons that contain one or more double bonds. Their general formula is C_nH_{2n} (where $n \geq 2$). In alkenes, carbon atoms are sp^2 hybridized and have a trigonal planar shape with bond

angles of about 120° . Alkenes are usually colorless and non-polar compounds and are more reactive than alkanes [15].

Alkynes

Alkynes are hydrocarbons that contain carbon-carbon triple bonds ($C\equiv C$). They are unsaturated compounds with the general formula C_nH_{2n-2} . In alkynes, carbon atoms are sp hybridized, and the bonds are arranged linearly with a bond angle of 180° .

CLASSIFICATION OF ORGANIC COMPOUNDS BASED ON FUNCTIONAL GROUPS

The structure of organic compounds is mainly made up of carbon and hydrogen, which are less reactive. However, when other atoms or groups of atoms are present, they increase the reactivity of the compound and determine its chemical properties. These atoms or groups are called **functional groups**. The chemical properties of organic compounds depend on the functional group, while the remaining part of the molecule mainly influences its physical properties.

NOMENCLATURE OF HETEROCYCLIC COMPOUNDS

The nomenclature of heterocyclic compounds is divided into two categories:

A. Trivial method of nomenclature

B. Systematic method of nomenclature However, most heterocyclic compounds are commonly known by their trivial names.

Trivial Method of Nomenclature

In the early stages of organic chemistry, heterocyclic compounds were named based on their source, method of preparation, or characteristic properties. Many compounds were named according to the source from which they were obtained, so the name depended on their origin [16].

For example, picoline is derived from coal tar, and its name comes from the Latin word *pictus*, meaning tarry. Some compounds were also named based on their properties. For instance, pyrrole is basic in nature, and its name originates from a Greek word meaning fiery red, referring to the red color it produces when tested with a pine splint dipped in hydrochloric acid. Similarly, furfural is named based on its source, as it was obtained from the distillation of bran, and the name means "bran oil." The trivial nomenclature system was the earliest method used and played an important role in the development of heterocyclic chemistry. However, it has certain limitations, as it does not provide any structural information about the compounds. At present, only about 60 trivial names are officially recognized by the IUPAC system. These names are still important because they serve as the basis for naming more complex compounds, including polycyclic compounds and their derivatives.

SYSTEMATIC METHOD OF NOMENCLATURE

This is the most commonly used system for naming monocyclic heterocyclic compounds, especially those having rings of three to ten members. These compounds may have different levels of saturation and may contain one or more heteroatoms. This method provides clear structural information about the compound [17].

The system recommended by IUPAC for naming

heterocyclic compounds is the Hantzsch-Widmann system. This system specifies the type, number, position, and nature of heteroatoms, as well as the size of the ring. The naming generally follows the pattern:

Name = Prefix + Stem + Suffix

Important rules to follow:

1. The name is formed by combining a prefix (indicating heteroatom), a stem (indicating ring size and saturation), and a suffix. The final "a" in the prefix is dropped when followed by a vowel.
2. Naming starts with the heteroatom that appears first in priority.
3. If different heteroatoms are present, prefixes are written in a specific order.
4. If identical heteroatoms are present, prefixes like di-, tri-, etc., are used.
5. The position of saturated atoms is indicated by "H-" with numbering following the lowest number rule.
6. The ring size is indicated by the stem name.

Chemical Properties

Pyrrole undergoes various reactions:

- Reduction gives dihydropyrrole and pyrrolidine
- Oxidation forms maleimide
- Ring expansion occurs under heating
- Reimer-Tiemann reaction forms pyrrole-2-aldehyde
- Electrophilic substitution mainly occurs at C-2 position

It is used in medicines such as antifungal, antibiotic, anti-inflammatory, and anticancer drugs.

NATURALLY OCCURRING NITROGEN HETEROCYCLIC COMPOUNDS

Plants contain many nitrogen heterocyclic compounds called alkaloids. These are weak bases and form salts with acids. More than 8000 alkaloids are known, and many new ones are discovered every year [8].

They occur in different parts of plants and often exist as related compounds.

Example: nicotine is a major alkaloid found in tobacco.

CATALYST

Catalysis is the process in which the rate and/or outcome of a chemical reaction is affected by the presence of a substance called a catalyst. A catalyst is not consumed during the reaction and can be removed at the end so that it does not remain as an impurity in the final product. Catalysis provides an alternative pathway for a chemical reaction with lower activation energy. The substance that plays an important role in this process without being used up is known as a catalyst. In many catalyzed reactions, the catalyst first forms an intermediate compound and later gets regenerated to its original form.

Enzymes are natural catalysts that help in the formation of a large number of biomolecules. They are considered efficient and environmentally friendly chemical agents.

1. **Coordination of reactants to the metal center:** Reactants bind to the metal, forming a complex that facilitates the reaction.
2. **Activation of reactants:** The metal center activates the reactants, often through redox processes or ligand exchange.
3. **Transformation into products:** The activated reactants undergo transformation into products,

which may involve rearrangements, insertions, or eliminations.

4. **Release of products and regeneration of the catalyst:** The products are released, and the catalyst is regenerated for further cycles.

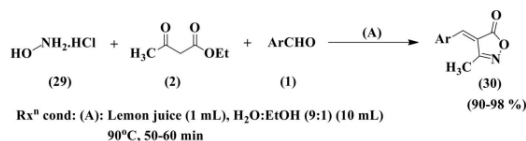


Figure 06: Lemon juice catalyzed multi-component synthesis of 1-amidoalkyl-2-naphthols.

EXTRACTION

Extraction is a process used to separate active constituents from solid or liquid substances using a suitable liquid solvent. It involves removing the medicinally active components from plant or animal tissues while leaving behind the inactive or inert materials by using selective solvents. In this method, the desired substances dissolve in the solvent, which is called the menstruum, while the remaining undissolved material is known as the marc. After the extraction process, the unwanted substances are removed. Extracts are usually prepared using ethanol or other suitable solvents [9].

Extract: Extracts are defined as preparations obtained from crude drugs that contain all the components which are soluble in a particular solvent.

Extraction

Extraction is a process used to separate active components from plant or animal materials using a suitable solvent. The solvent used is called menstruum, and the remaining solid is called marc. After extraction, unwanted materials are removed.

Types of Extracts

Dry extract – used in tablets and capsules (e.g., belladonna)

Soft extract – used in ointments (e.g., glycerhiza)

Liquid extract – used as tinctures

Mechanism of Extraction

The solvent enters plant cells, causing swelling. The active substances dissolve and diffuse out of the cells into the surrounding liquid. Finally, equilibrium is established between the solution inside and outside the cells [20].

Fruit Juice of Lemon

Lemon juice contains citric acid, vitamin C, and other components. Due to its acidic nature, it acts as a natural catalyst in organic reactions. It is used in reactions like Knoevenagel, Biginelli, and Hantzsch synthesis. It is eco-friendly, non-toxic, and supports green chemistry. It helps in forming heterocyclic compounds under mild conditions.

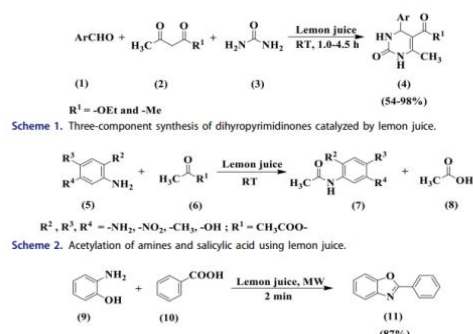


Figure 07: Synthesis of lemon

FRUIT JUICE OF TOMATO

Tomatoes contain bioactive compounds, including alkaloids like tomatine. These compounds are useful in medicinal and agricultural studies. They help in understanding plant defense mechanisms and are used in developing safer pesticides and drugs. Tomatoes also serve as models in biochemical research [21].

CONCLUSION

Extraction is important for obtaining chemical constituents from natural sources. The use of fruit extracts as catalysts is a modern and eco-friendly approach in organic chemistry. These natural catalysts are cost-effective, safe, and reduce environmental pollution. They follow the principles of green chemistry and improve reaction efficiency and product yield. Organic chemistry plays a vital role in understanding the structure, properties, and reactions of carbon-containing compounds. The study of heterocyclic compounds, in particular, has significantly contributed to advancements in medicinal chemistry, agriculture, and industrial applications. Their diverse structures and reactivity make them indispensable in the synthesis of pharmaceuticals and biologically active molecules.

The development of systematic nomenclature systems has greatly simplified the identification and classification of organic compounds. It ensures uniformity and avoids confusion, especially with the increasing number of newly discovered compounds. Green chemistry approaches, such as the use of natural extracts from fruits as catalysts, highlight the shift toward sustainable and eco-friendly chemical processes.

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