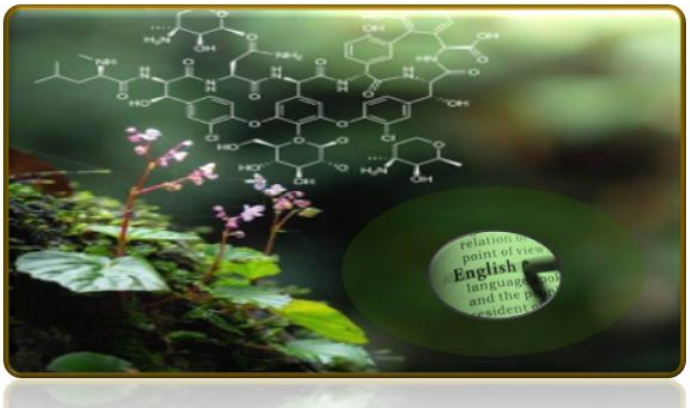
People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research
University of Constantine 1 – Frères Mentouri
Faculty of Exact Sciences
Department of Chemistry

English for Pharmaceutical Chemists Master II

Title: English

Course Authored by

Dr. Ahlem BOUSETLA



2024-2025

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Credit: 1

Coefficient: 1

Teaching unit: UED 2

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Course Objectives:

- To improve English language skills.
- To acquire a good and new vocabulary related to scientific research.
- To learn some useful scientific research methods and techniques used in chemistry.
- To learn about scientific research paper.

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Preface

"**English**" is a semestrial course for second year Master (M2) students of pharmaceutical chemistry at the Department of Chemistry, Faculty of Exact Sciences, University of Constantine 1 – Frères Mentouri.

The present course aims to enhance students understanding and use of scientific vocabulary in chemistry, particularly pharmaceutical and organic chemistry, equip them with the necessary key knowledge of educational systems such as theories, assumptions, elements, phases and various practices and eventually help them demonstrate their ability to apply such knowledge into practice.

The course is made up of four chapters to be covered in **semester three** (it is a semestrial course for M2), over a period of approximately 14 to 16 weeks. The course is delivered once a week in **one session**, each lasts for 90 minutes. The sessions are managed in the form of **lecture-workshop** and are delivered in the form of teacher-student interaction.

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Introduction

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Introduction:

English is a widespread and important language in the world today. In the era of globalization, English communication for scientists (chemists, physicians, and engineers) whose native language is not English has become as important as their major priority to improve their careers.

Up-to-date technologies and scientific ideas continue to be exchanged all around the world. In this context, it is imperative that scientists (including students and graduates of technical and science universities) develop the language skills necessary to be active and contributive students and researchers.

English gained a great role dominating the world of research and knowledge as an international language of communication. Certain reasons led to this dominance:

- **Flexibility:** it is the ability to accept words from different languages and the ability to create new words also.
- **Economy:** it is the use of fewer but more effective words to express the intended message. It's often building words by combining smaller word parts, each with its own meaning. If you understand these smaller parts, it becomes easier to understand complex scientific terms (e.g., polyatomic, polymer, and polyprotic).
- **Clarity:** in scientific English each sentence must convey a clear idea and facts; it must be unambiguous, not redundant, and not use exaggerated words and expressions.
- **Objectivity:** scientific writers strive to be objective after they design experiments and collect and analyze data without being swayed by biases and other personal opinions or interests.
- **Preciseness:** it means what is said is what actually happened; no approximation, no doubt, no uncertainty.

English for science is an English language course for use in scientific field, it is a program designed to prepare students to participate in special science courses. The handout is written for Master's students of English as a second language. It integrates the two important language skills reading and writing besides the two complimentary skills listening and speaking, in order to facilitate the leap from basic English to academic English and to prepare students to comprehend and use science material.

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As regards the structure of the course, it is organized into **four chapters**, besides an introduction and a conclusion.

Chapter One: Science and chemistry

This chapter unifying two terms Science and chemistry and aims to acquire some definitions and vocabulary besides using examples that occur frequently in science texts in these two domains.

Chapter two: Specific terms in chemistry

In this chapter a specific list of chemistry terms has been chosen as key terms and definitions relevant to chemistry in general and commonly used in organic chemistry, phytochemistry and pharmaceutical chemistry.

Chapter three: Lab equipment

Laboratory tools is also expected to be able to increase students' insights about the function of chemical laboratory tools so that experiments will be conducted smoothly in practicum.

Chapter four: Scientific English paper

This chapter deals with the basic notions and the keys concepts of a Scientific English paper with the format commonly used in scientific articles known as AIMRaD format. It provides a comprehensive guide for efficiently reading a scientific paper or article in chemistry

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Chapter 1: Science and chemistry

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1. Science and chemistry

1.1 Science

1.1.1 Definition of science

Science is a kind system of knowledge that is concerned with the physical world and its phenomena and that entails or requires unbiased observations and systematic experimentation. In general, science involves a pursuit of knowledge covering general truths besides realizing the operations of fundamental laws.

The word science derived from Latin "***Scientia***" which mean "**knowledge**". It is a systematic arrangement that builds and organizes knowledge in the form of testable explanations and predictions about nature and the universe. Such knowledge or such a system of this concept concerned with the physical world and its phenomena known as natural science which can be rationally explained and reliably applied.

A practitioner of science is called a scientist, as well as that a person learned and trained in science and especially natural science is known as a scientific researcher.

1.1.2 The nine main characteristics of science

The nine main characteristics of science are the following:

1. Objectivity

   Scientific knowledge is objective. It means the ability to see and accept facts as they are. Being objective in science means approaching research, experiments, and analysis in a way that minimizes bias, personal opinions.

   Objectivity requires that the practitioner of science must put aside all kinds of subjective considerations and prejudices.

2. Verifiability

   Science relies on sensory data, which is data collected through our senses, namely the eyes, ears, nose, tongue, and touch. Scientific knowledge is based on verifiable evidence, through concrete factual observations so that other observers can observe, weigh or measure the same phenomenon and examine observations for accuracy.

<u>Examples of verifiable statements</u>

Example 1

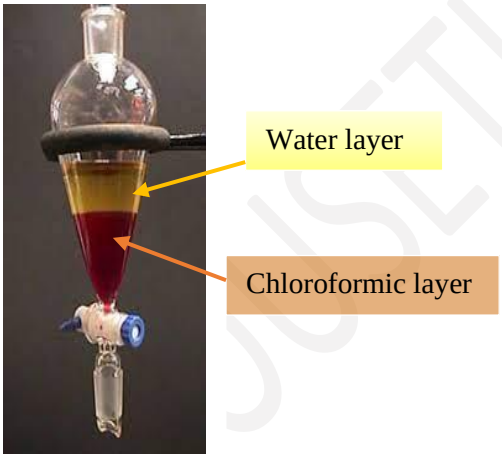
Water (H_2O) boils at **100°C** at sea level	→	This can **be measured** and **tested** anywhere.

Example 2

Vitamin C (ascorbic acid) improves immune function based on a study with 500 participants.	→	The study can be **replicated** to verify the result.

Example 3

Chloroform is denser than water, so water will float on top of chloroform.	→	This can be **observed** by the eyes.



3. Ethical neutrality

Science is ethically neutral. Science only seeks knowledge. Knowledge can be used differently. How this knowledge will be used and will be determined by social values. Ethical neutrality does not mean that scientists have no value. It simply means that they must not allow their values to change the design and behavior of his research.

Example: phytochemistry and drug development

- **Scientific Knowledge**: Research on plant-derived compounds and their medicinal properties.
- **Ethically Neutral Aspect**: Studying plant chemistry to understand its effects is purely scientific.
- **Different Applications** :

  - **Positive Use**:

Medicinal plants like *Artemisia annua* were used to produce antimalarial drugs such as artemisinin that saved millions of lives.

  - **Negative Use**:

Some plant compounds like the poppy plant were used to extract and produce drug as morphine and cocaine leading to addiction crisis.

- **Ethical Consideration**: Phytochemists study plant compounds objectively, but pharmaceutical companies and governments decide how these compounds are marketed and distributed.

4.Systematic exploration

A scientific study adopts certain sequential procedures, organized plans or research designs to collect and analyze facts about the problem under study. Generally, this path includes several scientific steps, such as formulating hypotheses, gathering facts, analyzing facts, and interpreting results.

5. Reliability

Reliability in science refers to the consistency and repeatability of research results. A study is considered reliable if the same experiment, under the same conditions, produces the same results multiple times.

Reliability is crucial for ensuring that scientific findings are trustworthy and not due to random chance or errors.

Example

- A pH meter should give the same reading for a solution each time it is used, provided conditions remain unchanged.

6. Precision

Scientific knowledge must be precise. Precision refers to how closely a set of repeated measurements are to one another. It is frequently distinguished from accuracy, which refers to how closely a measurement is to an actual value. In science, mathematics, and other fields where measurements yield data, researchers generally use methods that allow for measurements that have both high precision and high accuracy, with values that are both close together and close to a known value. Often, the spread or range of values can indicate the precision of measurements.

Examples

- If a balance always measures **1.020 g** for a **1.000 g s*ample***, it is **precise** but not **accurate**.

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- If it measures **1.000 g** exactly each time, it is both **precise** and **accurate**.

7. Accuracy

Scientific knowledge is characterized by its accuracy. Accuracy is defined as the truthfulness of a statement, the accurate description of things as they are, without jumping to unwarranted conclusions. Clear data and evidence are essential for ensuring accuracy.

8. Abstract

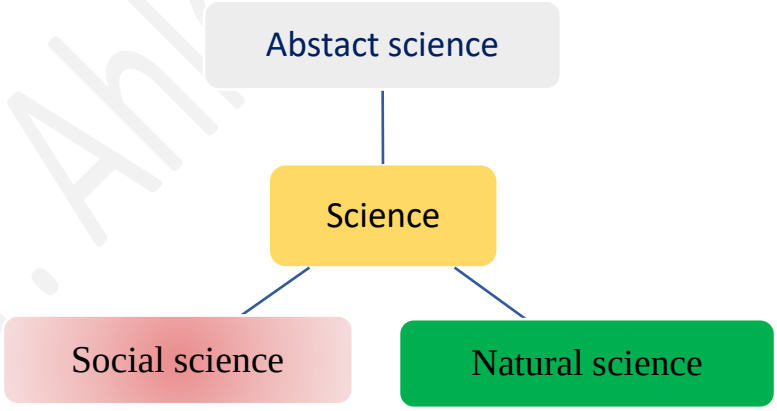
General scientific principles are abstract. The use of abstract thinking in the field of science is an essential skill for critical thinking and problem solving along with the ability to reason and solve problems in unique ways. This type of thinking is also is considered as a type of higher-order thinking.

9. Predictability

Scientists not only describe the phenomenon being studied, but also try to explain and predict it. They usually use vital information and important details besides statistical modeling.

1.1.3 The Branches of Science and their Meaning

On the basis of fields it occupies, science is divided into three main categories: abstract science, social science, and natural or applied science.



Abstract science: study of relationship of magnitude and numbers (e.g., mathematics, statistics, etc.).

Social science: social science, any branch of academic study or science that deals with human behavior in its social and cultural aspects., e.g., sociology, political science, economics, geography, etc.

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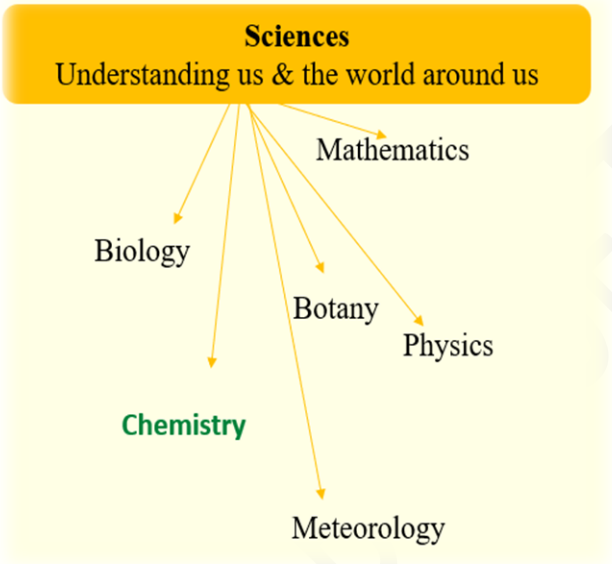
Natural science: also called applied science. It is one of the branches of science concerned with the description, understanding and prediction of natural phenomena, based on empirical evidence from observation and experimentation. it is the study of facts of natural phenomena and laws. According to the subject matter of the study, natural science is divided in several domains such as **chemistry**, physics, biology, geology and meteorology, etc.



1.1.4 Scientific method

Science often starts when we observe something and it makes us wonder. One way to explore the questions is to use the scientific method.

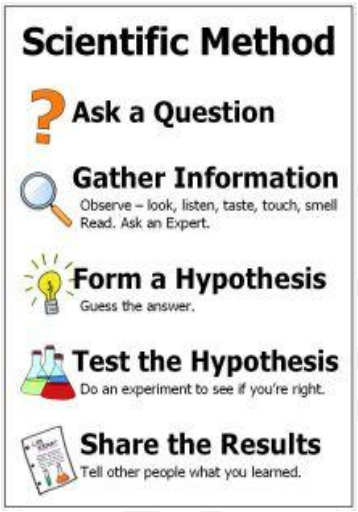
The scientific method is a process for experimentation that is used to explore observations and find answers to questions. It is a way of thinking. It is about the study of observed phenomena and the seeking of a correlation between them based on the philosophy that there is an order and consistency in the universe. Observations about the universe and how it changes have been made for many centuries, but it is the essentially scientific process of discovering a pattern behind these observations that has led to the technological progress of the last century or so.

The scientific method creates a framework for logically and systematically experimenting in order to find answers and it has several steps.

Steps of the scientific method:

- Define a question.
- Gather information and resources (observe).
- Form an explanatory hypothesis.

- Test the hypothesis by performing an experiment and collecting data in a reproducible manner.
- Analyze the data.
- Interpret the data and draw conclusions that serve as a starting point for a new hypothesis.
- Publish or communicate the results.
- Retest the experiment (frequently done by other scientists).



Scientists do use the scientific method, but not always exactly as laid out in the organized steps. A scientist may modify the scientific method by skipping steps, jumping back and forth between steps, or repeating a subset of the steps because he is dealing with variables conditions. Nevertheless, scientists always strive to keep to the core principles of the scientific method by using observations, experiments, and data to support or reject explanations of how a phenomenon works.

1.2 Chemistry

1.2.1 The study of chemistry

Everything we hear, see, smell, taste, and touch involves chemistry and chemicals, and hearing, seeing, tasting, and touching all involve intricate series of chemical reactions and interactions in our body. With such an enormous range of topics, it is essential to know about chemistry in order to understand the world around us.

Most people think chemistry is practiced in a laboratory by someone in a white coat who studies things in test tubes. This description is fine but Chemistry is largely an experimental science, and a great deal of knowledge comes from laboratory research. In addition, however,

today's chemist may use a computer to study the microscopic structure and chemical properties of substances.

Chemists participate in the development of new drugs and in agricultural research. They are seeking solutions to the problem of environmental pollution along with replacements for energy sources. Indeed, most industries have a relation in chemistry, whatever are their products. For example, chemists developed the polymers (macromolecules) that manufacturers use to make a wide variety of goods, including clothing, cooking utensils, artificial organs, and Polystyrene.

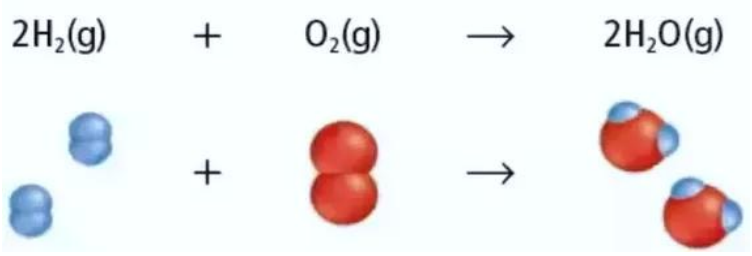
It is important to remember that teachers, together with students, books, internet, and the laboratory is one of the most important variables in the teaching and learning of the sciences.

1.2.2 How to study chemistry?

Compared with other subjects, chemistry is commonly perceived to be more difficult, at least at the introductory level. There is some justification for this perception. For one thing, chemistry has a very specialized vocabulary. Listed here are some suggestions to help you form good study habits and master the material:

- Attend classes regularly and take careful notes.
- Always review the topics you learned in class.
- Think critically.
- Ask yourself if you really understand the meaning of a term or the use of an equation. A good way to test your understanding is for you to explain a concept to a classmate or some other person.
- Do not hesitate to ask your teacher for help.

Chemists generally use standardized symbols and equations in recording their measurements and observations. This form of representation not only simplifies the process of keeping records, but also provides a common basis for communications with other chemists. This is an example for the reaction between hydrogen gas and oxygen gas to form water.



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1.2.3 Matter in chemistry

Definition of Matter

Matter is anything that has mass and occupies space (e.g., pen, oil, and air).

Chemistry focusses on the study of matter, including its composition, its properties, its structure, the changes that it undergoes, and the laws governing those changes. Any material object large or small, is composed of matter. In contrast, light, heat, and sound are forms of energy.

The phases of Matter

All matter, at least in principle, can exist in three states: solid, liquid, and gas.

Solids are rigid objects with definite shapes.

Liquids are less rigid than solids and are fluid. They are able to flow and assume the shape of their containers.

Gases are fluid, but unlike liquids, they can expand indefinitely.

 Solid  Liquid  Gaz

To understand matter and how it changes, we need to be able to describe matter.

There are two basic ways to describe matter: physical properties and chemical properties.

Physical properties are characteristics that describe matter as it exists. Some of many physical characteristics of matter are shape, phase, color, size, and temperature.

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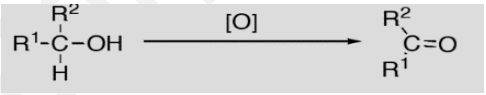
Physical properties of gold	
Appearance	Soft, malleable, yellow metal
Phase at STP	Solid
Density (g/cm^3)	19.3
Melting Point (K)	1337.58
Molar heat capacity	25.418J/mol. K
Pauling Negativity Number	2.54
Oxidation States	3, 1 (the oxidation states -1, +2, and +5 exist but are rare).
Crystal structure	Face-centered cubic

Chemical properties are characteristics of matter that describe how matter changes form in the presence of other matter. For example, the chemical properties of alcohol can be oxidation, combustion and esterification.

Oxidation reaction of alcohol:

Alcohols produce aldehydes and ketones on oxidation. The reaction is given below:



Combustion of Alcohol:

The complete combustion of ethanol gives carbon dioxide and water. The reaction is given below:

$$C_2H_5OH\ (l) + 3\ O_2\ (g) \rightarrow 2\ CO_2\ (g) + 3\ H_2O\ (l)$$

Esterification reaction of alcohol:

Ethanol reacts with carboxylic acids to produce ethyl esters and water. The reaction is given below:

$$RCOOH + HOCH_2CH_3 \rightarrow RCOOCH_2CH_3 + H_2O$$

A sample of **matter** that has the same physical and chemical properties throughout is called a substance.

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Substance or pure substance has a definite or constant composition and distinct properties. Examples are water, silver, and carbon dioxide. Substances differ from one another in composition and can be identified by their appearance, smell, taste, and other properties.

Chemistry recognizes two different types of substances: elements and compounds.

An **element** is the simplest type of chemical substance; it cannot be broken down into simpler chemical substances by ordinary chemical means. There are about 118 elements known to science, of which 80 are stable. Each element has its own unique set of physical and chemical properties. Examples of elements include carbon, iron, and gold.

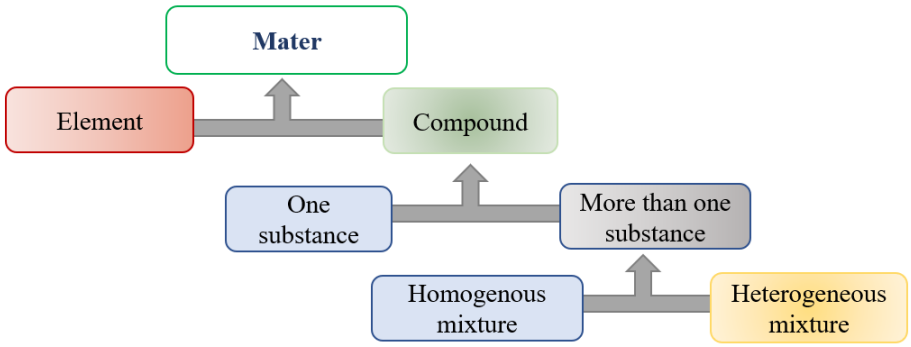
A **compound** is a combination of more than one element. The physical and chemical properties of a compound are different from the physical and chemical properties of its constituent elements; that is, it behaves as a completely different substance. Examples of compounds include glucose, and sodium chloride (the chemical name for common table salt).

Elements and compounds are not the only ways in which matter can be present. We frequently encounter objects that are physical combinations of more than one element or compound. Physical combinations of more than one substance are called **mixtures**.

Mixtures consist of two or more pure substances, there are two types of mixtures.

A **heterogeneous mixture** is a mixture composed of two or more substances. It is easy to tell, sometimes by the naked eye, that more than one substance is present.

A **homogeneous mixture** is a combination of two or more substances that is so intimately mixed that the mixture behaves as a single substance. This flow chart shows how matter can be described.



1.2.4 Periodic table of the elements

People have known about elements like carbon and gold since ancient time. The elements couldn't be changed using any chemical method. Each element has a unique number of protons. If you examine samples of iron (Fe) and silver (Ag), you can't tell how many protons the atoms have. However, you can tell the elements apart because they have different properties. You

might notice there are more similarities between iron and silver than between iron and oxygen (O). So, could there be a way to organize the elements so you could tell at a glance which ones had similar properties?



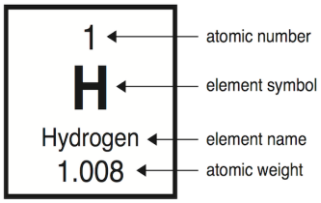
The atomic numbers of iron and silver

"Dmitri Mendeleyev" was the first scientist to create a periodic table of the elements similar to the one we use today. This table showed that when the elements were ordered by increasing atomic weight, a pattern appeared where properties of the elements repeated periodically. This periodic table is a chart that groups the elements according to their similar properties.

The periodic table helps predict some properties of the elements compared to each other. Atom size decreases as you move from left to right across the table and increases as you move down a column. The energy required to remove an electron from an atom increases as you move from left to right and decreases as you move down a column.

The ability to form a chemical bond increases as you move from left to right and decreases as you move down a column.

The most important difference between Mendeleyev's table and today's table is that the modern table is organized by increasing atomic number, not increasing atomic weight.



The atomic weight of hydrogen is 1.008 amu

Why was the table changed?

In 1914, **"Henry Moseley"** demonstrated experimentally that the major properties of an element are determined by the atomic number, not by the atomic weight, and firmly established the relationship between atomic number and the charge of the atomic nucleus. Once atomic numbers had significance, the periodic table was reorganized.

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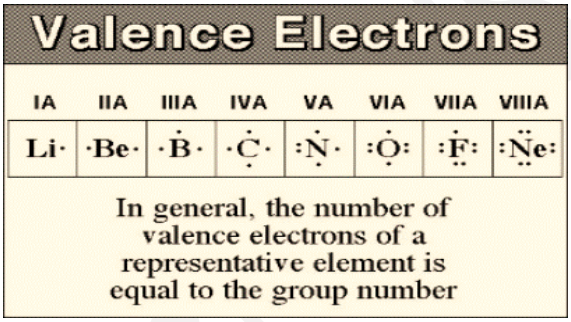
Elements in the periodic table are arranged in periods (rows) and groups (columns). The atomic number increases as you move across a row or a period.

Rows of elements are called periods. The period number of an element signifies the highest unexcited energy level for an electron in that element. The number of elements in a period increases as you move down the periodic table because there are more sublevels per level as the energy level of the atom increases.

Columns of elements help define element groups. Elements within a group share several common properties. Groups are elements which have the same outer electron arrangement. The outer electrons are called valence electrons. Because they have the same number of valence electrons, elements in a group share similar chemical properties. The Roman numerals listed above each group are the usual number of valence electrons. For example, a group (VA) element will have 5 valence electrons.



The valence electrons

There are two sets of groups:

Groups 13-18 are the main group elements, listed as A in the table.

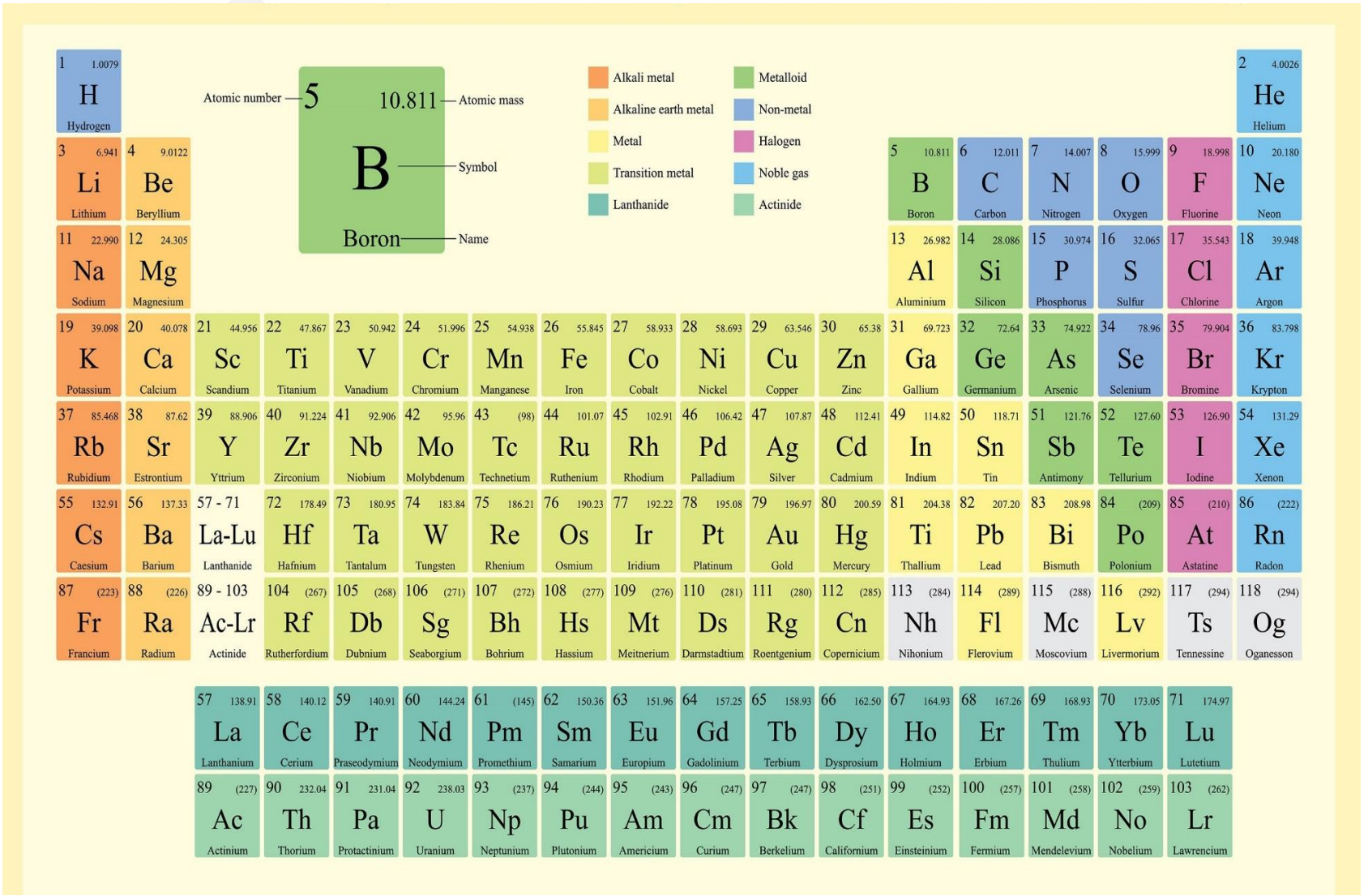
Groups 3-12 are in the middle of the periodic table and are the transition elements, listed as B table.

Each square on the periodic table gives information about an element. On many printed periodic tables you can find an element's symbol, atomic number, and atomic weight.

Elements are classified according to their properties. The major categories of elements are the metals, nonmetals, and metalloids (semi-metals).

Metals share some common properties. They are lustrous, malleable, and are good conductors of heat and electricity. These properties result from the ability to easily move the electrons in the outer shells of metal atoms. Metals are divided into groups: alkali metals, alkaline earth metals, and transition metals. The transition metals can be divided into smaller groups, such as the lanthanides and actinides.

The Periodic Table of Elements



Chapter 2: Specific terms in chemistry

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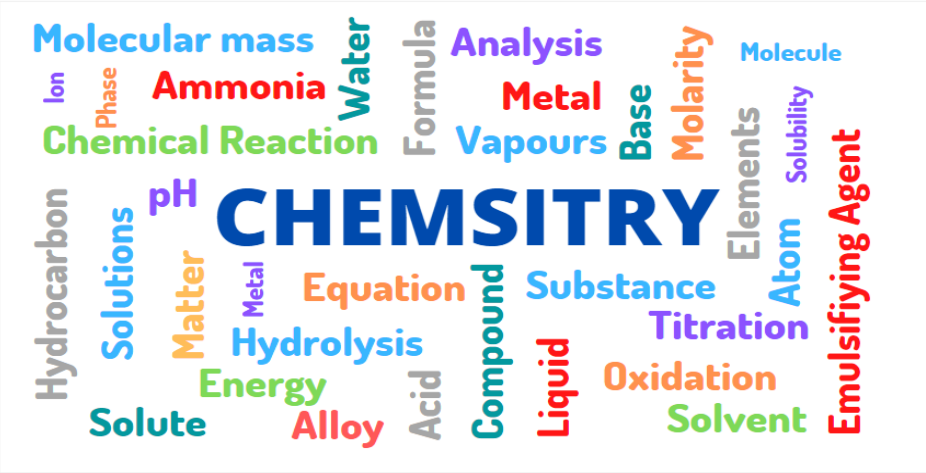
2. Specific terms in chemistry



2.1 Introduction

Chemistry is one of the fundamental sciences which enables students and researchers to solves problems, understanding the phenomena they study, and explore new ideas. It establishes a solid foundation of essential knowledge and skills, besides providing the cognitive resources necessary for future academic study and research.

One of the important factors in learning chemistry is the use English for chemistry, which includes technical terms, accurate definitions, and experimentation methods. Therefore, below is a list of key and specific terms and definitions relevant to chemistry in general and frequently used in phytochemistry and pharmaceutical chemistry presented in a clear and educational manner.

2.2 Increase vocabulary by reading

A good vocabulary will help you with every aspect of communication, it will improve your reading and listening comprehension and will enable you to speak and write better.

when you first study a language, you learn everyday words that are repeated so often that they soon become part of your permanent vocabulary. However, after you have acquired a basic vocabulary, there is always a decline in vocabulary growth rate.

Reading and speaking the language will increase your fluency but will not automatically increase your vocabulary; this is because the words you are learning appear less frequently and

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are thus more difficult to remember. At this stage of language development, you must make a special effort to acquire new words.

2.3 Specific terms used in chemistry

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Absorption: the incorporation of a substance in one state into another of a different state. Liquids can be absorbed by a solid or gases can be absorbed by a liquid. Also, the imbibing or attracting into its mass of one substance by another so that the absorbed substance disappears physically. The phenomenon may be due either to molecular or chemical action but is distinct from "adsorption" which is characterized by surface tension and condensation.

absorption apparatus: certain forms of apparatus which are used especially in gas analysis by means of which a portion of the sample under examination is absorbed and its quantity thus determined.

Absorption peak: a wavelength of maximum electromagnetic absorption by a chemical sample. It is used to identify specific elements, radicals, or compounds.

Acetic acid (CH_3COOH): known as ethanoic acid, a clear, colorless liquid or crystalline mass with a pungent odor, miscible with water or alcohol; crystallizes in deliquescent needles; a component of vinegar.



Vinegar is at least 5% acetic acid by volume

Acetimetry: the process of determining the acetic acid strength of vinegar.

Acetimeter: an instrument for estimating the amount of acetic acid in vinegar.

Acetone $(CH_3)_2CO$: a colorless, volatile, extremely flammable liquid and the simplest example of the ketones. Acetone is miscible with water and serves as an important solvent in its own right, typically as the solvent of choice for cleaning purposes in the laboratory.

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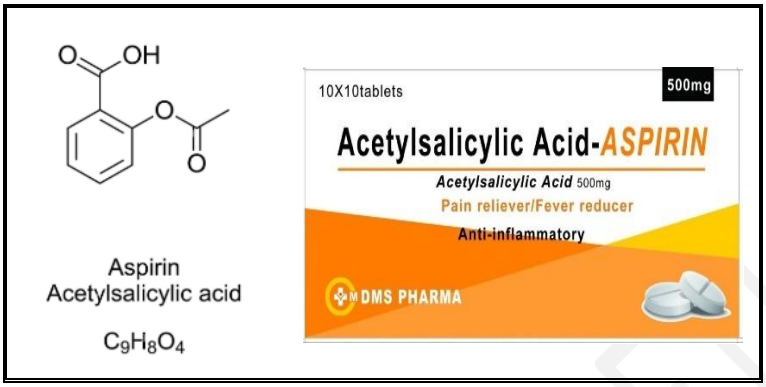
Acetylsalicylic acid ($CH_3COOC_6H_4COOH$): a white, crystalline, weakly acidic. Also known as *Aspirin*, is a commonly used drug for the treatment of pain and fever due to various causes. Acetylsalicylic acid has both anti-inflammatory and antipyretic effects. This drug also inhibits platelet aggregation and is used in the prevention of blood clots stroke.

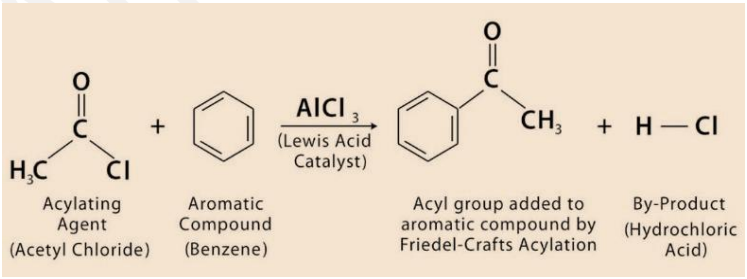


Acetylsalicylic acid known as Aspirin

Acid: a molecule or ion capable of either donating a proton (H^+), known as a Brønsted-Lowry acid, or forming a covalent bond with an electron pair, known as a Lewis acid.

Acyl: a generic term used to designate organic acid radicals (e.g., acetyl, benzoyl, salicyl, etc.).

Acylation: in organic chemistry, acylation is a broad class of chemical reactions in which an acyl group (R−C=O) is added to a substrate. The compound providing the acyl group is called the **acylating agent**. The substrate to be acylated and the product include the following: alcohols, esters, amines, amides, or arenes.



Friedel-Craft acylation

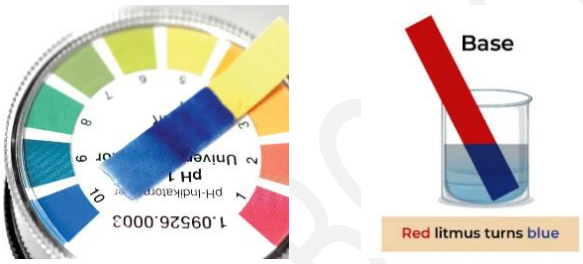
Alcohol: any member of a class of organic compounds in which a hydrogen atom of a hydrocarbon has been replaced by a hydroxy (-OH) group. The common name for ethyl alcohol is ethanol (C_2H_5OH).

Aldohexose: a hexose, such as glucose or mannose, containing the aldehyde group.

Aldoses: a class of sugars belonging to the monosaccharose group and which contain an aldehyde group.

Aliquot part: a portion of a sample taken for analysis such a manner that the quantity taken shall be a simple fraction of the whole quantity. Used in certain analysis where the bulk of the sample is inconveniently large for treatment as a whole or where more than one analysis is desired from one sample. The results obtained are calculated to the whole sample.

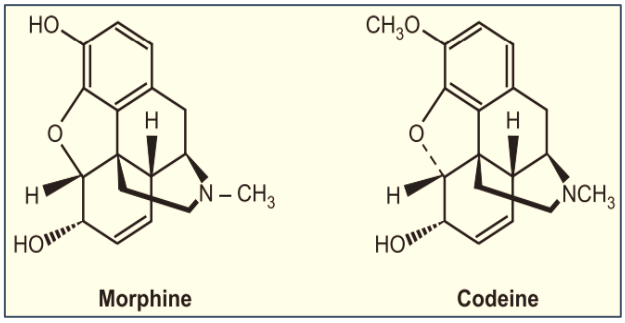
Alkali: compound having highly basic qualities. Also, any of the soluble hydroxides of the alkali metals such as sodium, potassium, and cesium. Alkalis are strong bases that turn litmus paper from red to blue; they react with acids to yield neutral salts; and they are caustic and in concentrated form are corrosive to organic tissues.



Red litmus turns blue in alkali solution

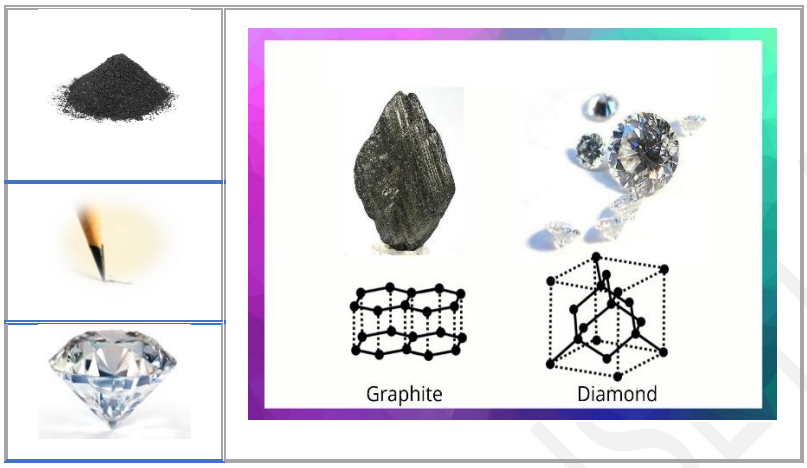
Alkalimetry: the process of determining the amount of an alkali present in a sample by titration against a standard acid solution. The volume of reagent necessary exactly to neutralize the alkaline solution measures the number of gram-molecules of alkali present.

Alkaloid: organic substances occurring naturally, which are basic, forming salts with acids. The basic group is usually an amino function. It is any compounds found in plants, often with strong pharmacological effects, such as quinine, morphine and codeine.



Morphine and codeine are alkaloids

Allotropy: the isomerism of the elements, a property of certain elements by which they exist in two or more modifications distinct in physical, some chemical properties. A good example of allotropy is furnished by carbon which exists in three forms, amorphous carbon or black carbon, graphite and the diamond.



Allotropes of carbon

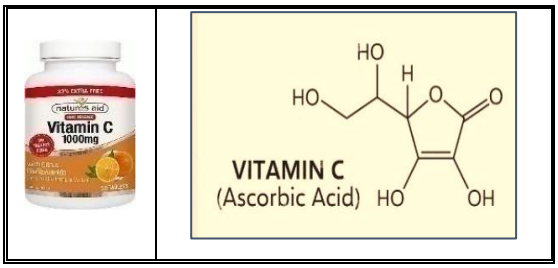
Amount: in chemistry, the amount of any substance is measured in units of mass (g or kg), volume (L) and mole (mol). Unit interconversions are based on the definitions of the units, and converting amounts from g or kg into mol is based on atomic masses of the elements.

Analyte: the sample being analyzed. The specific component that is being measured in a chemical analysis.

Anthraquinone: a yellow crystalline aromatic organic compound with formula $C_{14}H_8O_2$ often derived from anthracene and used especially in the manufacture of dyes. Anthraquinone can cause cancer (according to The National Toxicology Program).

Anti-enzymes: substances able to inhibit the normal action of the enzymes. Many drug molecules are enzyme inhibitors that inhibit an aberrant human enzyme or an enzyme critical for the survival of a pathogen such as a virus, *bacterium* or parasite.

Antioxidant: a substance that inhibit oxidation which is a chemical reaction that can produce free radicals. Antioxidants are found in certain foods, beverages, and cosmetic products to prevent some of the damage caused by free radicals by neutralizing them. These include the nutrient antioxidants, vitamins A, C and E, and the minerals copper, zinc and selenium.

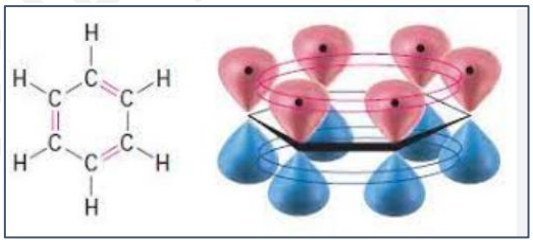


Vitamin C is a powerful antioxidant

Aqua Regia: a *Latin* term for 'royal water. It is a mixture of three parts of hydrochloric acid (HCl) with one part of nitric acid (HNO_3). A solvent for gold, this mixture was given its name literally by the alchemist because of its ability to dissolve gold.



Aromatic: an aromatic molecule or ion possesses aromaticity. Aromaticity is the special property of planar (or nearly planar) cyclic, conjugated systems having (4n+2) conjugated π(*pi*) electrons. The delocalization of the (4n+2) π electrons give them special stability. For benzene, the most common aromatic system (n = 1, therefore 6 π electrons).



Benzene and aromaticity

Asteraceae: the aster, daisy, or composite family of the flowering-plant order Asterales. With more than 1,620 genera and 23,600 species of herbs, shrubs, and trees distributed throughout the world. Asteraceae is one of the largest plant families. It is important primarily for its many garden ornamentals, such as asters, chrysanthemums, dahlias and marigolds.

Assay: a form of analysis in which certain constituents of a mixture only are determined, the others being usually neglected. Applied particularly to minerals and drugs.

Balance: to bring a chemical equation into balance so that reaction substances and reaction products obey the laws of conservation of mass and charge.

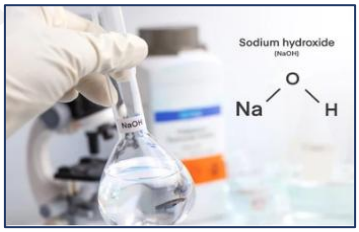
Balance: also known as a scale, it is a device used to measure weight or mass, also known as mass scales, weight scales, mass balances and weight balances. In laboratory we used an analytical balance (or chemical balance) is a kind of balance designed to measure small mass in the sub-milligram range.



Lab balances scales

Balsam: an oleoresin obtained by incising the trunk of a tree or naturally exuding form it. Balsams contain resins and essential oils in varying proportions.

Base: a base in chemistry is defined as a molecule in an aqueous solution that can accept protons or donate electrons, also a base is a substance which dissociates in aqueous solution to form hydroxide ions (OH^-**)** , such as sodium hydroxide. Bases are usually bitter to taste, slippery to touch, and have a pH greater than 7 on the pH scale.



NaOH is a base

Benzoic acid (C_6H_5COOH): an aromatic carboxylic acid that melts at 122.4°C, boils at 250°C, and is slightly soluble in water and relatively soluble in alcohol and ether; derivatives are valuable in industry, commerce, and medicine.

Benzyl acetate: a chemical compound that is commonly found in various fruits, flowers, and essential oils. It is widely known for its pleasant, sweet, and fruity fragrance. The scent of benzyl acetate resembles that of certain fruits, contributing to their distinctive aroma.

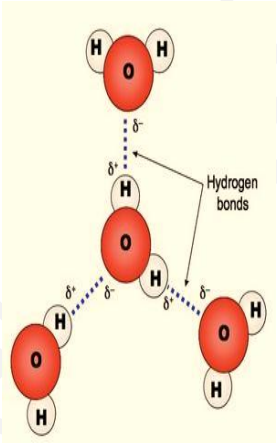
Bioactivity: the effect of a phytochemical on biological systems, such as antibacterial, antifungal, antioxidant, anticancer activities, etc.

Biochemistry: that branch of chemistry which deals with the processes of living organisms and the products derived from them.

Bioassay: a method for quantitatively determining the concentration of a substance by its effect on the growth of a suitable animal, plant, or microorganism under controlled conditions.

Boiling point: abbreviated bp. The temperature at which the transition from the liquid to the gaseous phase occurs in a pure substance at fixed pressure.

Bond: the strong attractive force that holds together atoms in molecules and crystalline salts. Also known as chemical bond (e.g., hydrogen bonds).

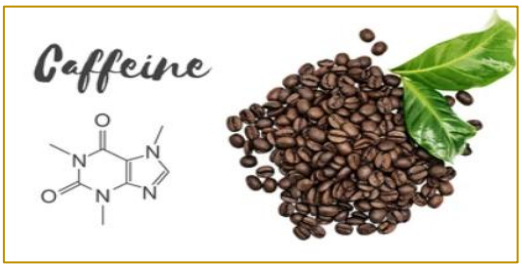


Hydrogen bonds

Buffers: solution that can resist pH change upon the addition of an acidic or basic components. It is able to neutralize small amounts of added acid or base, thus maintaining the pH of the solution relatively stable. This is important for processes and/or reactions which require specific and stable pH range

Caffeic acid ($C_9H_8O_4$): a polyphenol and yellow crystalline. The molecule consists of both phenolic and acrylic functional groups (i.e., prop-2-enoic acid) that melts at 223-225°C soluble in water and alcohol.

Caffeine ($C_8H_{10}O_2N_4$): an alkaloid found in a large number of plants, such as tea, coffee, cola, and mate.

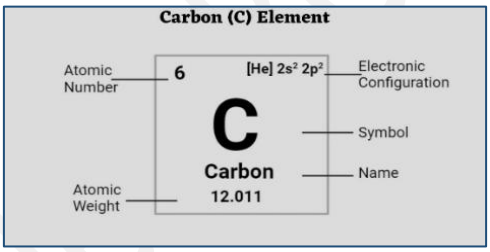


Caffeine in an alkaloid

Cane sugar: a species of tall, perennial grass in the genus *Saccharum* that is used for sugar production.

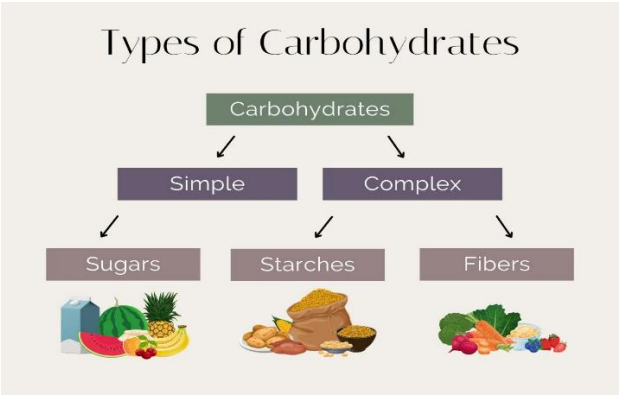
Capric acid ($CH_3(CH_2)_8COOH$): a fatty acid found in oils and animal fats.

Carbon: a nonmetallic chemical element. It has symbol C, atomic number 6, and atomic weight 12.011 u. It occurs in three well known form diamond, graphite, and coal.



Carbocation: a carbon atom bearing a positive charge.

Carbohydrates: a type of macronutrient found in certain foods and drinks. Sugars, starches and fiber are carbohydrates.



Types of carbohydrates

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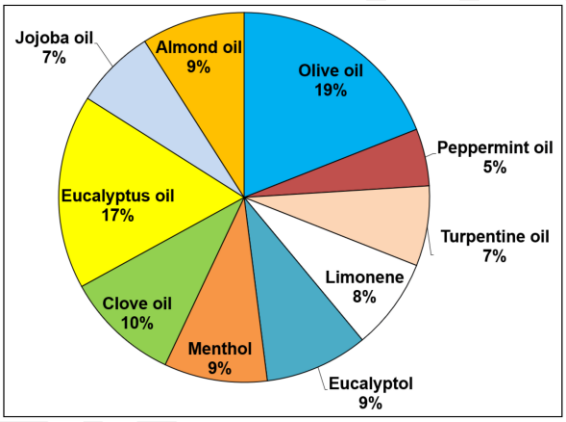
Carotene: namely, (β)-carotene is a plant pigment that gives red, orange, and yellow vegetables their vibrant color. It has powerful antioxidant properties. It is considered a provitamin carotenoid, meaning that the body can convert it into vitamin A (retinol).

Catalysis: a phenomenon in which a relatively small amount of substance augments the rate of a chemical reaction without itself being consumed.

Cellulose: cellulose, a complex carbohydrate, or polysaccharide, consisting of 3,000 or more glucose units. It is the basic structural component of plant cell walls and it is the most abundant of all naturally occurring organic compounds.

Chart: a graphical representation of data, in which "the data is represented by symbols, such as bars in a bar chart, lines in a line chart, or slices in a pie chart". A chart can represent tabular numeric data, functions or some kinds of qualitative structures.

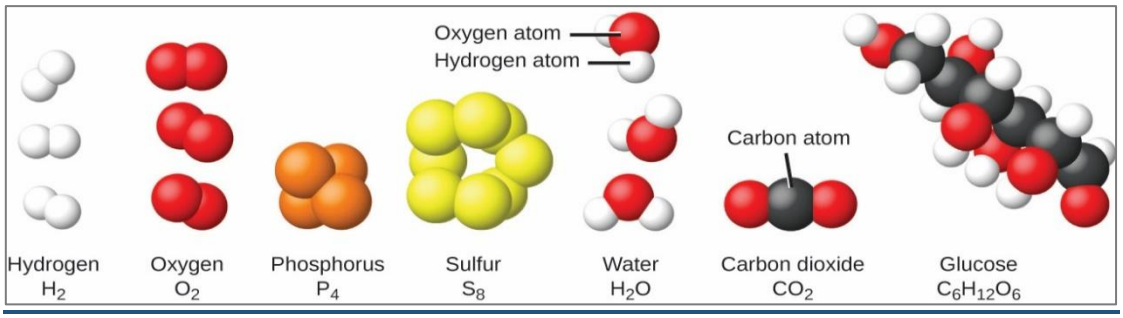


The most frequently used essential and carrier oils in pharmaceutical dosage formulations

Chemical: these are substances that are used in a chemical process or made by a chemical process.

Chemical energy: energy of a chemical compound which by the law of conservation of energy, must undergo a change equal and opposite to the change of heat energy in a reaction; the rearrangement of the atoms in reacting compounds to produce new compounds causes a change in chemical energy.

Chemical composition: the elements that compose the molecular (e.g., H_2O, indicates that the molecule contains one oxygen and two hydrogen atom).

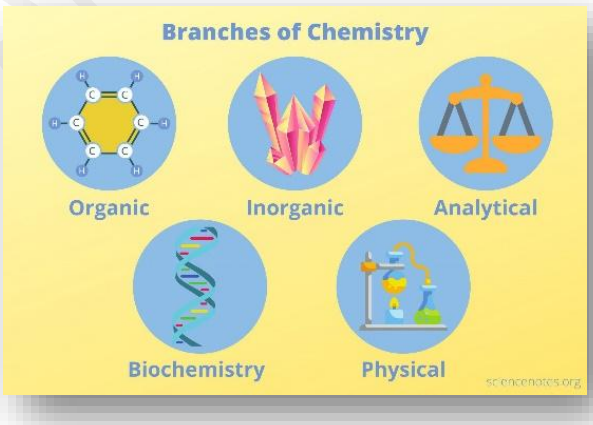


Chemical composition of some elements

Chemical properties: characteristics of matter that describe how matter changes form in the presence of other matter. A chemical change always produces one or more types of matter that differ from the matter present before the change. The formation of rust for example is a chemical change because rust is a different kind of matter than the iron, oxygen, and water present before the rust formed.

Chemist: a scientist specializing in chemistry who does research connected with chemistry.

Chemistry: a branch of science that deals principally with the properties of substances, composition (structure of matter), the changes and the transformations they undergo, the energy that is released or absorbed during these processes and the natural laws that describe these changes. There are five main branches of chemistry: analytical chemistry, physical chemistry, biochemistry, organic chemistry, and inorganic chemistry. There are many subcategories, or branches, of chemistry, such as phytochemistry, pharmaceutical chemistry, nuclear chemistry, green chemistry, quantum chemistry.



Branches of chemistry

Chirality: a term which may be applied to any asymmetric object or molecule. The property of non-identity of an object with its mirror image. The handedness of an asymmetric molecule.

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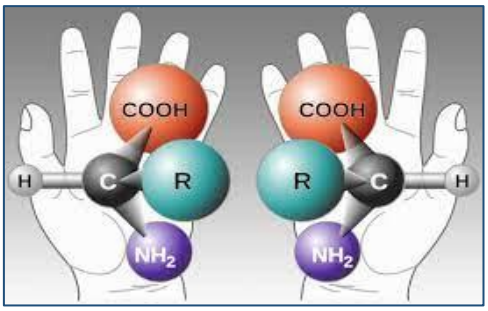
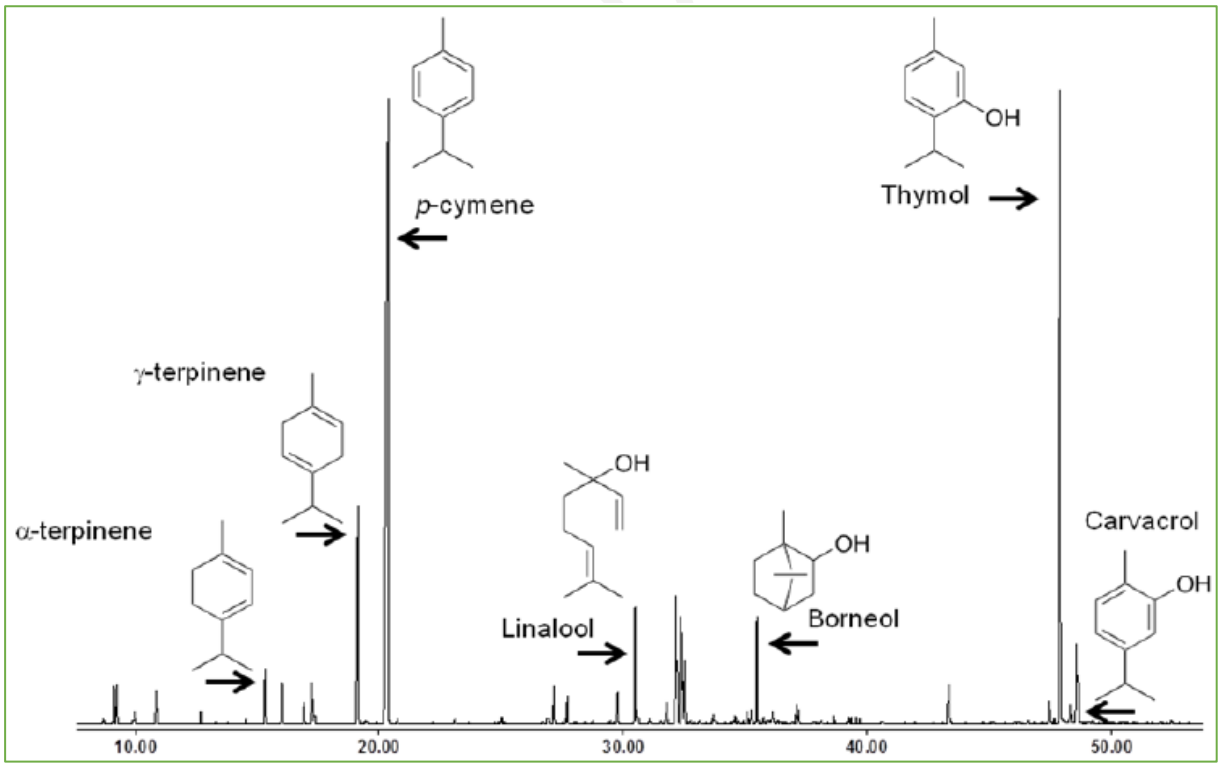


Chirality is a handedness of an asymmetric molecule

Chromatography: a series of related techniques for the separation of a mixture of compounds by their distribution between two phases. In gas-liquid chromatography the distribution is between a gaseous and a liquid phase. In column chromatography the distribution is between a liquid and a solid phase.

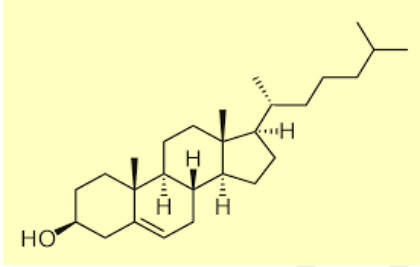
Chromatogram: the visual output of the chromatograph. In the case of an optimal separation, different peaks or patterns on the chromatogram correspond to different components of the separated mixture.



An example of chromatogram's *Thymus vulgaris* essential oil

Citral ($C_{10}H_{16}O$): a pale-yellow liquid that in commerce is a mixture of two isomeric forms, alpha and beta; insoluble in water, soluble in glycerin or benzyl benzoate; used in perfumery and as an intermediate to form other compounds.

Cholesterol ($C_{27}H_{46}O$): an organic compound with a unique structure with a hydrocarbon tail, a central sterol nucleus made of four hydrocarbon rings, and a hydroxyl group. Cholesterol is a structural component of cell membranes and serves as a building block for synthesizing various steroid hormones, vitamin D, and bile acids.



Cholesterol molecule formula

Colorant: something added to something else to cause a change in color. It can be dyes, pigments, biological pigments, inks, paint, colored chemicals.

Coconut oil: coconut oil, edible oil extracted from the dried meat of the coconut, the fruit of the coconut palm (*Cocos nucifera*). Coconut oil is a yellowish white solid or semiliquid that melts at 23°C.



Coconut oil

Combination: a term indicating the operation of a chemical process by which two or more individual substances or two or molecules of a single substance condense to form a new chemical compound.

Compound: a term used generally to indicate a definite combination of elements into a more complex structure (a molecule). The physical and chemical properties of a compound are

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different from the physical and chemical properties of its constituent elements; that is, it behaves as a completely different substance. Examples of compounds include water, penicillin, and sodium chloride (the chemical name for common table salt).

Coumarins (**2H-1-benzopyran-2-one):** are a class of heterocyclic, phenolic compounds with benzene and an *alpha*-pyrone ring. These compounds exhibit various bioactive activities, including anticoagulant, antimicrobial, and antioxidant properties.

Crystal: a homogenous solid body of definite geometrical form bounded by plane surfaces and its atoms are arranged in a highly ordered, it formed when certain liquid substances pass into the solid state.



An example of crystals

Crystallization: the process by which solids form, where the atoms or molecules are highly organized into a structure known as a crystal. Some ways by which crystals form are precipitating from a solution, freezing, or more rarely deposition directly from a gas.

D

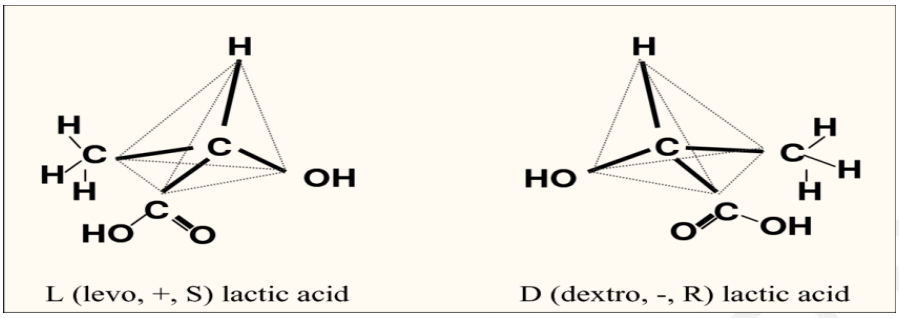
Decoction: an aqueous solution of the water-soluble constituents of a plant made by boiling the plant in water for some time and then straining off the solution.

Derivative: a substance that is made from another substance.

Density: the density of a substance is the relationship between the mass of the substance and how much space it takes up (volume). The mass of atoms, their size, and how they are arranged determine the density of a substance. Density is commonly expressed in units of grams per cubic centimeter. For example, the density of water is $1 g/cm^3$.

Dextro: A prefix used to designate dextrorotatory optical activity.

Dextrorotatory: any substance has the property of rotating the ray of polarized light to the right or clockwise and is labeled as ‹‹ "(+)" or "D"». The opposite is levorotary substance and is labeled as ‹‹"(−)" or "L"».



Lactic acid is chiral, consisting of two enantiomers

Dicotyledons: are a group of flowering plants whose seed typically has two embryonic leaves or cotyledons.

Dihydro: a prefix indicating combination with two atoms of hydrogen.

Dilute: not concentrated. A solution in which the solvent is in great excess. A relative term of no definite meaning unless qualified by a statement of the actual concentration.

Dihydroxy: a molecule containing two hydroxyl groups.

Displayed formula: a type of structural isomer that shows all the bonds between every atom in the compound.

Distillation: an experimental procedure used to separate a mixture of liquids. The liquids separate out due to their different boiling points. Ethanol can be separated from water by distillation since ethanol has a lower boiling point.

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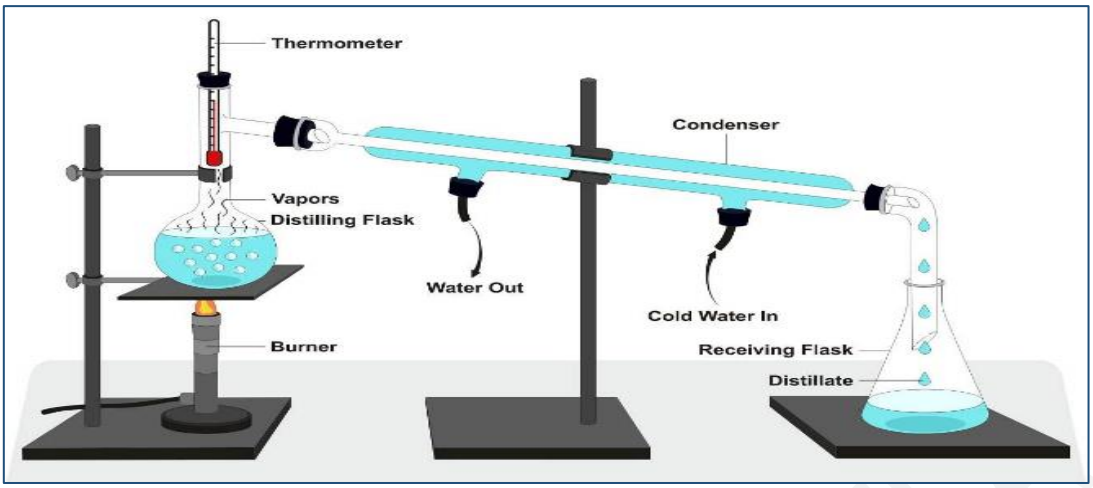


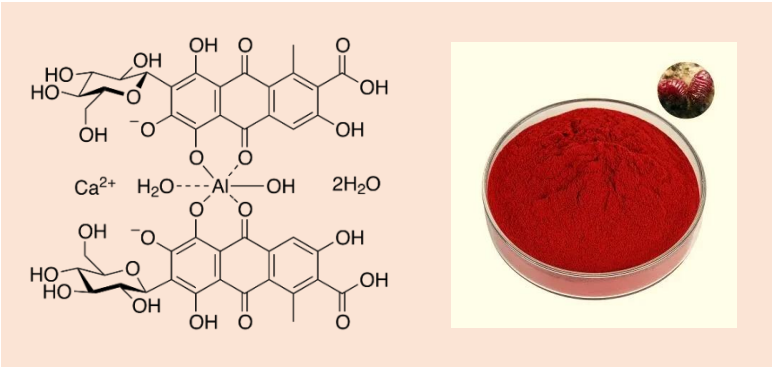
An example of distillation apparatus

Diuretic: a drug which increases the secretion of urine. It may act by stimulating the functional activity of the kidneys, by raising the osmotic pressure of the blood or by increasing blood pressure. Among the most diuretics compounds are digitalis and caffeine.

Drug: a drug is any substance presented for treating, curing, or preventing disease in human beings or in animals. A drug may also be used for making a medical diagnosis or for restoring, correcting, or modifying physiological functions.

Drug design: the creative process of discovering novel pharmaceuticals based on the understanding of a biological target is known as drug design.

Dyes: dyes may be organic or inorganic, natural or artificial. Examples of inorganic dyes are: Titanium dioxide and iron oxide. Natural dyes are derived from plants or animals. Artificial dyes are made in the laboratory. Carmine red is an example of a natural dye. It derives from carminic acid, extracted from the dry bodies of cochineal insect. Specific code names for the pigment include natural red E120. *Carmine* is also a general term for a particularly deep-red color.



Carmine deep-red color

E

Effective dose (ED): dose of a substance that causes a defined magnitude of response in a given system. Note that the "ED_{50}" is the median dose that causes 50% of the maximal response.

Half-maximal inhibitory concentration (IC_{50}): is the most widely used and informative measure of a drug's efficacy. It indicates how much drug is needed to inhibit a biological process by half, thus providing a measure of potency of an antagonist drug in pharmacological research.

Element: a substance which cannot be further subdivided by chemical methods. It is made up of atoms with the same atomic number; common examples are hydrogen, iron and gold.

Enantiomers: are two chemically identical molecular species which differ from each other as non-superposable mirror images. Molecular enantiomers, such as those of lactic acid, have identical chemical properties, and they are able to rotate the plane of polarization of plane-polarized light and the compounds with such activity is labelled as optical active.

Eluant: a liquid used to extract one material from another, as in chromatography.

Eluate: the solution that results from the elution process.

Elution: a term used in analytical and organic chemistry to describe the emergence of chemicals from the column of a chromatograph by means of a stream of liquid or gas.

Ephedrine ($C_{10}H_{15}NO$): a white, crystalline, water-soluble alkaloid present in several *Ephedra* species and also produced synthetically; it is used for its action on the bronchi, blood pressure, blood vessels, and central nervous system.

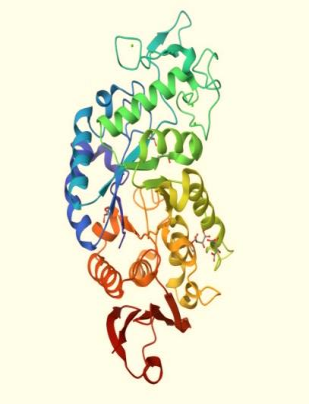
Ethanol (C_2H_5OH): a colorless liquid, miscible with water, boiling point 78.32°C; used as a reagent and solvent. Also known as ethyl alcohol.

Ether: one of a class of organic compounds characterized by the structural feature of an oxygen linking two hydrocarbon groups (such as R-O-R). It is a colorless liquid, slightly soluble in water; used as a reagent, intermediate, anesthetic, and solvent. Also known as ethyl ether.

Ethnopharmacology: the study of traditional medicinal practices and the pharmacological properties of plants used in these practices.

Ethyl acetate ($CH_3COOCH_2CH_3$): a colorless liquid has a characteristic sweet smell and is used in glues or nail polish removers. It is the ester of ethanol and acetic acid; it is manufactured on a large scale for use as a solvent.

Enzyme: a naturally occurring substance able to catalyze a chemical reaction. It is a numerous protein that are produced by living cells and catalyze specific biochemical reactions at body temperature. For example, *alpha* amylase is an enzyme that hydrolyses α bonds of large, α-linked polysaccharides.



3D structure of α-amylase

Eucalyptol ($C_{10}H_{18}O$): a colorless oil with a camphor like odor; boiling point is 174-177°C; used in pharmaceuticals, perfumery, and flavoring.

Essence: obtained from a drug, plant or the like through the process of distillation, maceration, absorption or pressing. Essences contain their characteristic properties in concentrated form. Concentrated essences are very strong extracts that can be twice to four times as strong as normal extracts. Imitation or synthetic essences are the chemically produced substances that aim to reproduce the taste and scent of the original ingredient.

Essential oils: an aromatic, volatile liquids obtained from plant material through steam distillation and named after the plant from which they are derived. Essential oils can be defined as either products or mixtures of fragrant substances or as mixtures of fragrant and odorless substances. These fragrant substances are chemically pure compounds that are volatile under normal conditions.

Extract: a material separated from liquid or solid mixture by a solvent.

Extraction: a method of separation in which a solid or solution is contacted with a liquid solvent (the two being essential mutually insoluble) to transfer one or more components into the solvent. Extraction, as the term is used pharmaceutically, involves the separation of medicinally active portions of plant or animal tissues from the inactive or inert components by using selective solvents in standard extraction procedures.

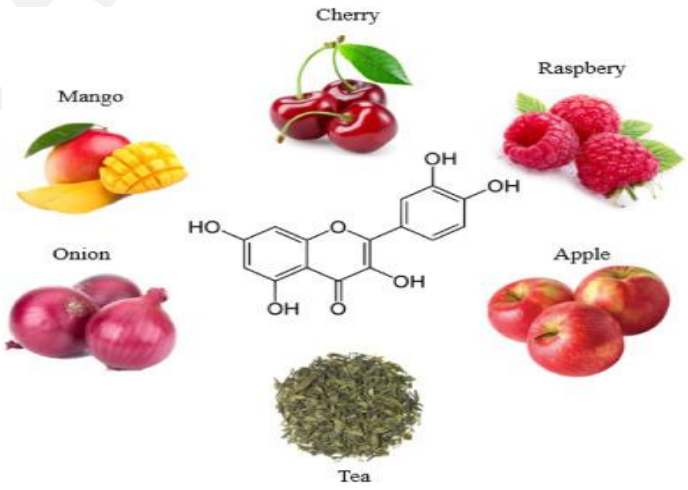


Extraction active compounds from plant

Free radicals: reactive chemical species (molecules or ions) that differ from other compounds in that they have unpaired electrons in their outer orbitals. They are capable of damaging cellular components, and accumulating evidence suggests they may contribute to various disease such as cancer.

Filtrate: a process used to separate solids from liquids or gases using a filter medium that allows the fluid to pass through but not the solid. The term "filtration" applies whether the filter is mechanical, biological, or physical.

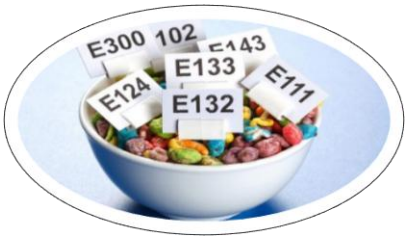
Flavonoids: a group of polyphenolic compounds that consist of two phenyl rings and a heterocyclic ring and are universally present in fruits, vegetables, grains, bark, roots, stems, flowers, It is believed that flavonoids have health-promoting properties due to antioxidant activities.



Quercetin is flavonoid

Flavorings: any ingredients that are used to enhance the flavor of medications. They usually are industry secrets. Flavorings may be natural (essential oils extracted from plants and fruit natural flavors) or artificial (aromatic alcohol, aldehydes, balms, phenols, terpenes, etc.).

Food additives: substances added to food to preserve flavor or enhance taste, appearance, or other sensory qualities. They are either derived from natural sources or are synthetic compounds and are divided into categories according to their intended purpose, including flavor enhancers, preservatives, thickeners, stabilizers, flavors, emulsifiers, humectants, colorants, and gelling agents, though some may serve multiple roles.



Types of food additives

Formulation: the particular mixture of base chemicals and additives required for a product. Water and oil-based components are frequently used in cosmetic formulations. Animal fats and vegetable oils are used to make the oil-based components, which are obtained naturally or synthetically.

Freeze: to solidify, especially at low temperature. Freezing is a phase transition in which a liquid turns into a solid when its temperature is lowered below its freezing point.

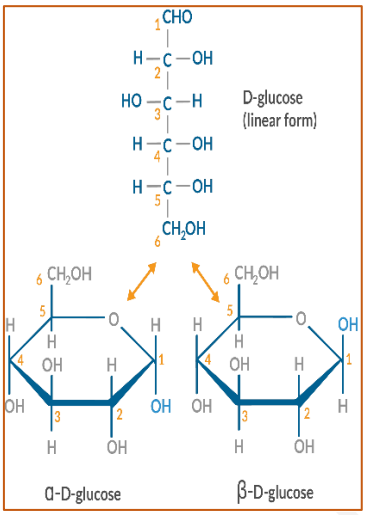
G

Gas chromatography: a separation technique involving passage of a gaseous moving phase through a column containing a fixed adsorbent phase; it is used principally as a quantitative analytical technique for volatile compounds.

Gel: a two-phase colloidal system consisting of a solid and a liquid in more solid form.

Gelatin: a complex protein extracted from animal cartilage and bones. It is soluble in water; it also sets to a jelly. Gelatin can enhance the flavor, texture, and nutritional value of certain foods, such as mousses, stews, and ice cream.

Glucose: a simple sugar (monosaccharide) and an important carbohydrate in biology. Cells use it as a source of energy and a metabolic intermediate. It has the molecular formula $C_6H_{12}O_6$. It is found in fruits and honey.



Glucose molecule formula

Gums: a class of amorphous transparent substances allied to the carbohydrates characterized by insolubility in alcohol and organic solvents. The real gums dissolve in water. Gum Arabic, cherry gum and plum gum are examples of this class.

H

Hard water: water that contains certain salts, such as those of calcium or magnesium, which form insoluble deposits in boilers and form precipitates with soap.

Heavy water (D_2O): a compound of hydrogen and oxygen containing a higher proportion of the hydrogen isotope deuterium than does naturally occurring water. Also known as deuterium oxide.

Heat: the amount of energy that is transferred from one system to its surroundings because of a temperature difference.

Hetero: a prefix meaning different; for example, a heterocyclic compound is one in which the ring is made of more than one kind of atom.

Heterocyclic compound: compound in which the ring structure is a combination of more than one kind of atom; for example, pyridine (C_5H_5N).

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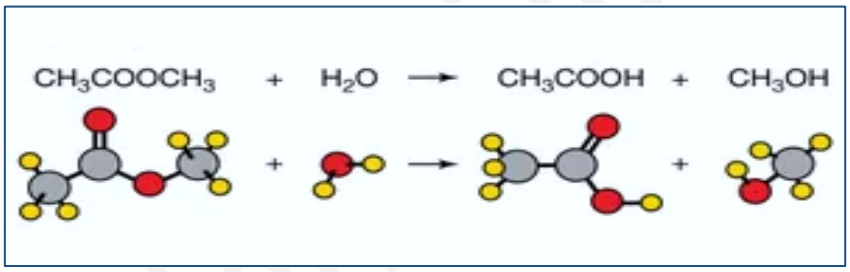
Heterogeneous phase: a mixture of phases such as liquid-vapor, or liquid-vapor-solid (e.g., when oil and water are combined, they do not mix evenly, but instead form two separate layers).

High performance liquid chromatography (HPLC): chromatographic technique that separates the components of a mixture by pumping a small quantity of it into small diameter tubes, and is used in phytochemistry, biochemistry and analytical chemistry to identify, quantify and purify the individual components of the mixture.

Hydrocarbons: compounds made up of carbon and hydrogen atoms only. Some examples of hydrocarbons are methane (CH_4) and ethene (C_2H_4).

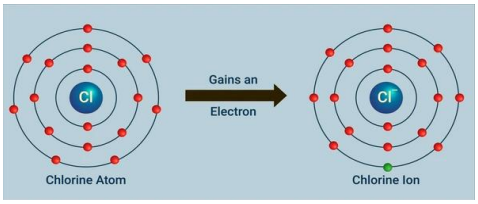
Hydrocinnamic acid ($C_6H_5CH_2CH_2COOH$): a compound whose crystals have a floral odor melt at 46°C; used in perfumes and flavoring.

Hydrolysis: decomposition or alteration of a chemical substance by water, often with the partition of the substance into two parts, such as in the hydrolysis of an ester to an acid and an alcohol.



Hydrolysis of an ester

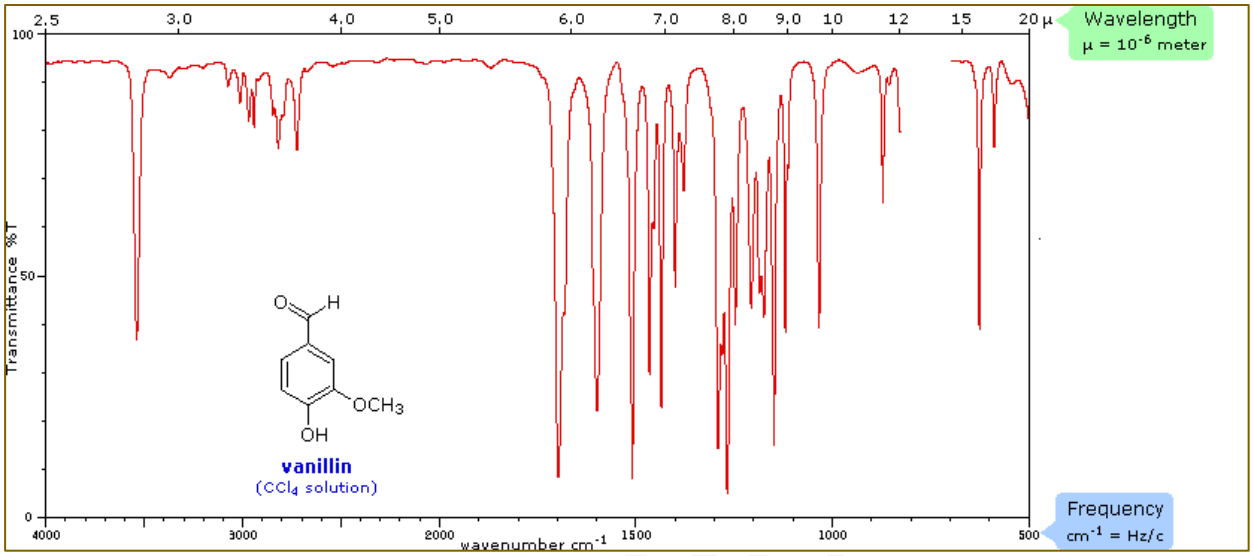
Ion: an atom or group of atoms that has lost or gained one or more electrons to become a charged species (e.g., H^+, K^+, Na^+, Cl^-, O^{-2}, etc.).



Chlorine atom and ion

Incubation: maintenance of chemical mixtures at specified temperatures for varying time periods to study chemical reactions, such as enzyme activity.

Infrared spectroscopy: the study of the absorption of infrared light by substances. Since this corresponds to vibrational (and some rotational) changes, infrared spectroscopy provides valuable information about the structure of a substance. Detailed correlation tables and spectrum exist relating infrared bands (absorbances) to functional groups.



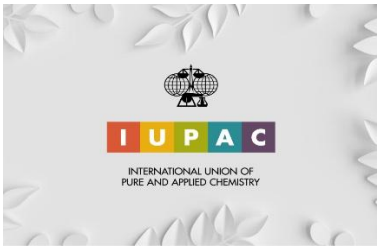
An IR spectrum of vanillin

Infusion: the aqueous solution of a soluble constituent of a substance as the result of the substance's steeping in the solvent for a period of time.

Inhibitor: a general term for any compound which will inhibit (slow down) a reaction. A substance which is capable of stopping or retarding a chemical reaction; to be technically useful, it must be effective in low concentration.

Isolation: separation of a pure chemical substance from a compound or mixture; as in distillation, precipitation, or absorption.

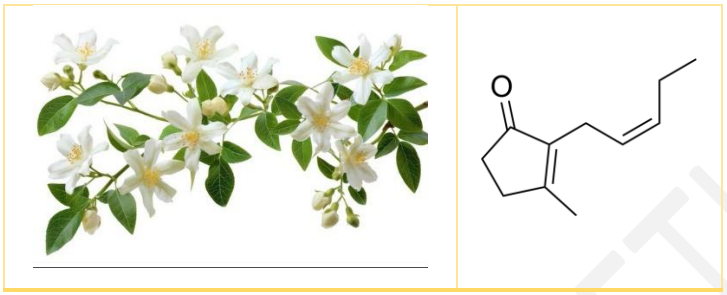
IUPAC (International Union of Pure and Applied Chemistry): an international scientific (nongovernmental) organization, recognized as the world authority on chemical nomenclature, terminology, standardized methods for measurement, atomic weights, and many other critically evaluated data. Abbreviated IUPAC.



International Union of Pure and Applied Chemistry

J

Jasmone ($C_{11}H_{16}O$): a liquid ketone found in jasmine oil and other essential oils from flower plants jasmine (*Jasminum officinale*).



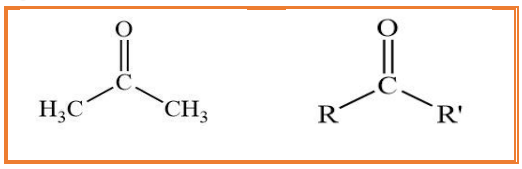
Jasmone isolated from *Jasminum officinale*

Juglone ($C_{10}H_6O_3$): a naphthoquinone derivative that occurs naturally in black walnuts and is toxic to plants.

Juniperic acid ($C_{16}H_{32}O_3$): a crystalline hydroxy acid that melts at 95°C, obtained from waxy exudations from conifers.

K

Ketone: one of a class of chemical compounds of the general formula RCOR, where R and R are alkyl, aryl, or heterocyclic radicals. ketone is used as solvents, and in general are important intermediates in the synthesis of organic compounds.



ketone formula

Kojic acid ($C_6H_6O_4$): a crystalline antibiotic with a melting point of 152–154°C; soluble in water, acetone, and alcohol; used in insecticides and as an antifungal and antimicrobial agent.

L

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Laboratory: a room or building equipped for scientific experiments, research, or teaching, or for the manufacture of drugs or chemicals.



Laboratory research

Lauraceae: the laurel family of flowering plants and order Laurales, comprising some 50 genera and more than 2,500 species of mostly evergreen shrubs and trees. The leaves of this family are usually leathery and evergreen with numerous essential oil cavities, which accounts for the aromatic nature of many species. Most of the species also have aromatic oil in the wood and bark. The most famous species belong to this family is *Laurus nobilis* L.



Laurus nobilis L.

Lauric acid ($CH_3(CH_2)_{10}COOH$): a fatty acid melting at 44°C, boiling at 225°C, colorless needles soluble in alcohol and ether, insoluble in water; found as the glyceride in vegetable fats, such as coconut and laurel oils; used for wetting agents, in cosmetics, soaps, resins, and insecticides, and as a chemical intermediate.

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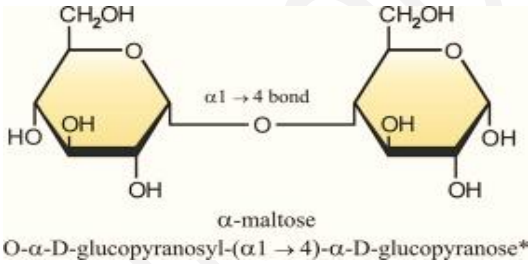
Lead acetate ($Pb(C_2H_3O_2)_2$*3H2O): poisonous, water-soluble white crystals decomposing at 280°C; used in hair dyes, medicines, and textile.

M

Maleic acid (HOOCCH-CHCOOH): a colorless, crystalline dibasic acid; soluble in water, acetone, and alcohol; melting point 130-131°C. It is a dicarboxylic acid that is made by all living organisms, contributes to the sour taste of fruits, and is used as a food additive.

Maltol ($C_6H_6O_3$): crystalline substance with a melting point of 161–162°C and a fragrant caramellike odor; used as a flavoring agent in bread and cakes.

Maltose: also known as malt sugar, is a disaccharide formed from two units of glucose joined with an α(1→4) bond. Maltose is the two-unit member of the amylose homologous series, the key structural motif of starch.



Structure of maltose

Mass spectrometry: a form of spectrometry in which, generally, high energy electrons are bombarded on to a sample and this generates charged fragments of the parent substance; these ions are then focused by electrostatic and magnetic fields to give a spectrum of the charged fragments.

Mechanism: a detailed description of the course of a chemical reaction as it proceeds from the reactants to the products, with as complete a characterization as possible of the reaction steps and intermediate species.

Melt: to change a solid to a liquid by the application of heat.

Menthol ($C_{10}H_{19}OH$): a chemical naturally found in peppermint and other mint plants, an alcohol-soluble, white crystalline compound; used in medicines and perfumes, and as a flavoring agent. The main form of menthol occurring in nature is (-)-menthol, which is assigned the (1*R*,2*S*,5*R*) configuration.

Measurements: provide information that is the basis of most of the hypotheses, theories, and laws that describe the behavior of matter and energy in both the macroscopic and microscopic domains of chemistry.

Minimal Lethal Dose: (LD_{50}) is the amount of an ingested substance that kills 50 % percent of a test sample. It is expressed in milligrams of substance per kilogram (mg/kg) of body weight.

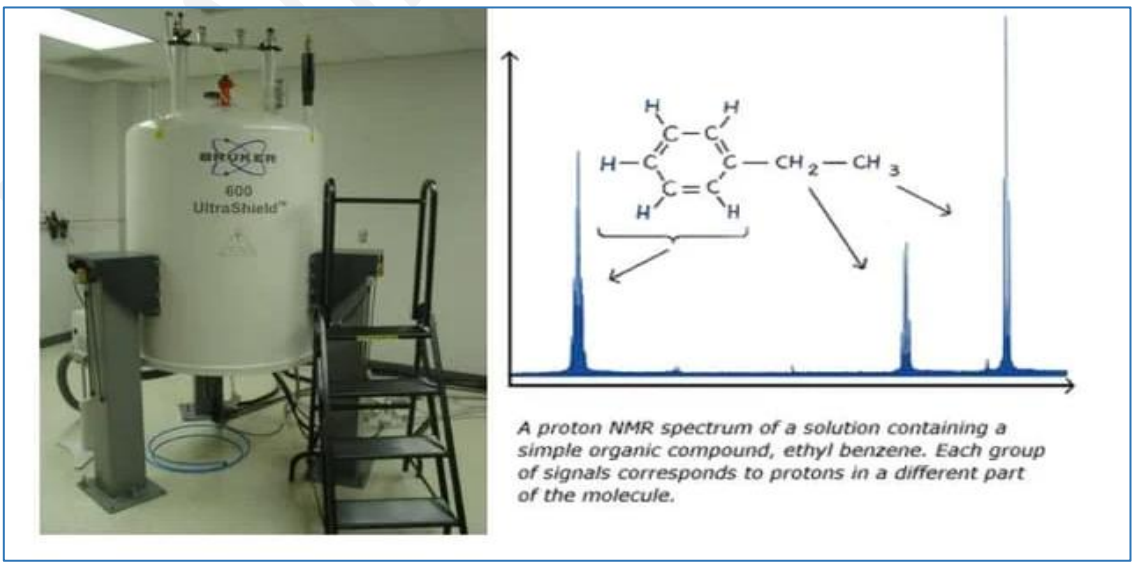
Molecular Formula: the total number of atoms of each element in the compound. A molecular formula uses chemical symbols and subscripts to indicate the exact numbers of different atoms in a molecule or compound. An empirical formula gives the simplest, whole-number ratio of atoms in a compound. A structural formula indicates the bonding arrangement of the atoms in the molecule.

N

Naringin: a crystalline bioflavonoid with a melting point of 171°C; soluble in acetone and alcohol; used as a food supplement.

Neutral: property of a solution which is neither acidic nor basic, having the same concentration of hydrogen ions as water.

Nuclear magnetic resonance spectrometer: a spectrometer in which nuclear magnetic resonance is used for the analysis of protons and nuclei and for the study of changes in chemical and physical quantities over wide frequency ranges.



NMR spectrometer beside NMR spectrum

Nuclear magnetic resonance (NMR) spectroscopy: a form of spectroscopy which depends on the absorption and emission of energy arising from changes in the spin states of the nucleus of an atom. It is a preeminent technique for determining the structure of organic compounds. Of all the spectroscopic methods, it is the only one for which a complete analysis and interpretation of the entire spectrum is normally expected. NMR is non-destructive, and with modern instruments good data may be obtained from samples weighing less than a milligram.

Olefin (C_nH_{2n}): a family of unsaturated, chemically active hydrocarbons with one carbon-carbon double bond; includes ethylene and propylene.

Oleic acid ($C_{17}H_{33}COOH$): yellowish, unsaturated fatty acid with lardlike aroma; soluble in organic solvents, slightly soluble in water; boils at 286°C; the main component of olive oils; used in soaps, ointments, and cosmetics. Also known as octadecenoic acid.

Oil: any nonpolar chemical substance that is composed primarily of hydrocarbons and is hydrophobic (does not mix with water) and lipophilic (mixes with other oils). Oils are usually flammable and surface active. Most oils are unsaturated lipids that are liquid at room temperature.

Organic compound: a compound that contains carbon (except carbon dioxide, carbon monoxide, and carbonates).

Organic solvents: a solvent is usually a liquid that dissolves a solid, liquid, or gaseous solute, resulting in a solution. Common uses for organic solvents are acetone, methyl acetate, ethyl acetate, hexane, petrol ether and ethanol.



Some organic solvents

Oxidation: a chemical process in which the proportion of electronegative substituents in a compound is increased, or the charge is made more positive, or the oxidation number is increased.

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𝒫

Paper chromatography: a procedure for analysis of complex chemical mixtures by the progressive absorption of the components of the unknown sample (in a solvent) on a special grade of paper.

Parabens: (methylparaben and propylparaben), used by the pharmaceutical and cosmetic industries since 1920. Parabens are large spectrum antimicrobial drugs, hydro soluble, insipid, colorless and odorless. With such characteristics they are broadly employed in the formulation of medications. Paraben's concentrations vary, but hardly exceed 1%.

Pharmaceutical chemistry: is concerned with the design (drug design) and synthesis of biologically active molecules. The aim is to gain new chemical molecules that could enable the discovery of new pharmaceuticals or optimize already known drug structures.

Pharmaceutical company: is defined as a company that invests in researching, producing, and marketing drugs/medicines for the treatment of diseases, relying on medical data and reports of patients for drug discovery. The biggest pharma companies in the world in 2024 is ranked by 2023 revenue for pharmaceutical sales only are Pfizer, Merck, Sanofi, AstraZeneca, and Novartis.

Pharmaceutical industry: refers to the segment of business devoted to the design, development, and manufacture of chemical products for use in the diagnosis and treatment of disease, disability, or other dysfunction, or to improve function. Pharmaceutical companies may be private or public

Pharmaceutical excipient: it is inactive constituent and a substance without therapeutic power, used to guarantee stability, physicochemical and organoleptic properties of pharmaceutical products.



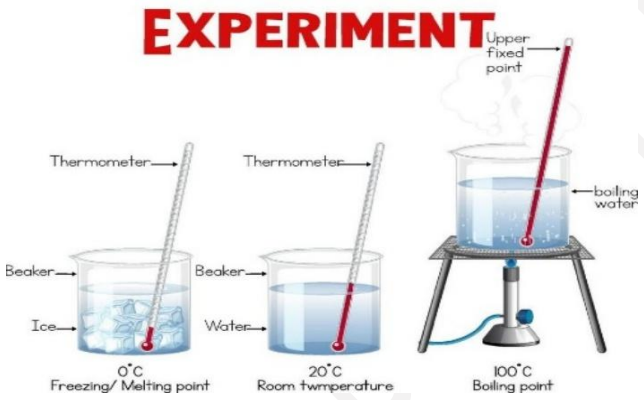
Binders are common types of excipients

Pharmacology: the science dealing with the nature and properties of drugs, particularly their actions.

Phase: the state of a compound (solid, liquid, or gas).

Phenolic compounds: are a group of metabolites derived from the secondary pathways of plants. Polyphenols comprise flavonoids, phenolic acids, tannins, lignans, and coumarins, compounds naturally found in fruits, vegetables, cereals, roots, and leaves among other plant products.

Physical properties: are characteristics that describe matter as it exists. Some of many physical characteristics of matter are shape, color, size, and temperature. An important physical property is the phase (or state) of matter. Melting point and boiling points are examples of physical properties of matter.



Some physical properties of matter

Phytochemistry: is the study of the chemicals produced by plants, particularly the secondary metabolites, synthesized as a measure for self-defense against insects, pests, pathogens, herbivores, ultraviolet exposure and environmental hazards. The proper understanding of phytochemical is essential for drug discovery and for the development of novel therapeutic agents against major diseases.



Phytochemistry is the study of phytochemicals

Pectin: is a soluble fiber (polysaccharide) found in fruits. It is used as a thickener in cooking and baking. It is also sometimes used to make medicine.

Perennial plant: having a life cycle lasting more than two years. Synonyms: constant, incessant, continual.

Pigments: pigment, any of a group of compounds that are intensely colored and are used to color other materials. In plants, the primary function of pigments is photosynthesis, which uses the green pigment chlorophyll and several colorful pigments that absorb as much light energy as possible.



Structure of chlorophyll

Polyprotic acids: compounds that have two or more acidic hydrogens and dissociate in steps manner (e.g., H_2SO_4, H_3PO4, $H_2C_2O_4$). In the case of a diprotic acid H_2A, the steps of dissociation as following:

$$H_2A(aq) + H_2O(l) \rightleftharpoons HA^-(aq) + H_3O^+(aq) \qquad pK_{a1}$$

$$HA^-(aq) + H_2O(l) \rightleftharpoons A^{2-}(aq) + H_3O^+(aq) \qquad pK_{a2}$$

Preservatives: A preservative is a substance or a chemical that is added to products such as food products, beverages, pharmaceutical drugs, paints, biological samples, cosmetics, wood, and many other products to prevent decomposition by microbial growth or by undesirable chemical changes.

Proximate analysis: the separation into and determination of the classes of constituents of a mixture, usually applied to biological products, as plants, in this process no attempt is made to determine the elementary composition of the various constituents. Indeed, proximate analysis

can be defined as a technique to measure the chemical properties of a compound based on four particular elements: moisture content, fixed carbon, volatile matter and ash content.

Q

Qualitative analysis: the process of determining the nature of various elements or simple compounds present in a mixture.

Quantitative analysis: the process of determining the quantity or the amount of any elements present in a given compound or of the constituents of a mixture.

Quinine: white powder or crystals, soluble in alcohol, ether, carbon disulfide, chloroform, and glycerol. It is an alkaloid derived from cinchona bark tree; a species known as *Cinchona officinalis* L. from the family Rubiaceae. It is used as an antimalarial drug.



Quinine isolated from cinchona tree

Quinone: yellow crystalline compound with irritating aroma; melts at 116°C; soluble in alcohol, alkalis, and ether; used to make dyes and hydroquinone.

R

Radical scavenger: one of a group of molecules like flavonoids that combines with free radicals in a chemical or biochemical system to render them less active chemically.

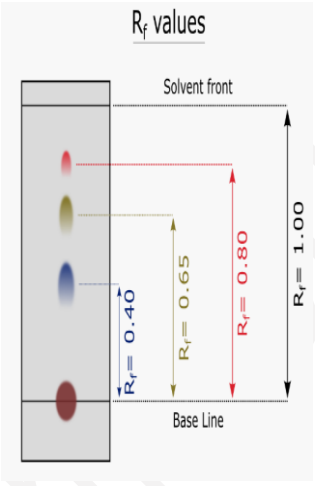
Reduction: chemical processes in which the proportion of more electronegative substituents is decreased, or the charge is made more negative, or the oxidation number is lowered.

Resin: any of a class of solid or semisolid organic products of natural or synthetic origin with no definite melting point, generally of high molecular weight; most resins are polymers.

Resorcinol: is an organic compound with the formula $C_6H_4(OH)_2$. It is one of three isomeric benzenediols, the 1,3-isomer (or meta-isomer) white, toxic crystals; soluble in water, alcohol, ether, and glycerol; melts at 111°C; used for resins, dyes.

Rutin: is a rutinoside that is quercetin with the hydroxy group at position C-3 substituted with glucose and rhamnose sugar groups. It is a disaccharide derivative, a tetrahydroxy flavone and a rutinoside. It has a role as anti-inflammatory and an antioxidant.

R_f value: in chromatography, a measurement based on the relative distance traveled by a sample of a substance in a specific procedure; under standard conditions it is a characteristic property of the substance.



R_f value in CCM

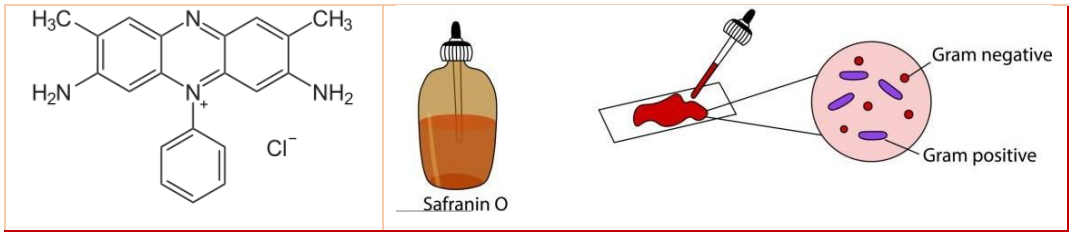
Rutaceae: family of flowering plants, composed of 160 genera and about 2,070 species. It includes woody shrubs and trees and is distributed throughout the world, especially in warm temperate and tropical regions. The family contains economically important fruits. Like Citrus species include the lemon (*Citrus limon*), sweet orange (*Citrus sinensis*), lime (*Citrus aurantifolia*).

S

Saccharin: a sweet-tasting, white powder, soluble in acetates, and alcohol; melts at 228°C; used as a sugar substitute for syrups, and in medicines, foods, and beverages.

Safranine: Any of a group of phenazine-based dyes; some are used as biological stains. An organic chloride salt having 3,7-diamino-2,8-dimethyl-5-phenylphenazin-5-ium as the counterion. It is commonly used for staining Gram-negative bacteria. Bacteria that retain the

initial crystal violet stain (purple) are said to be "gram-positive," whereas those that are decolorized and stain red (or safranin) are said to be "gram-negative".



Safranin stains Gram-negative bacteria

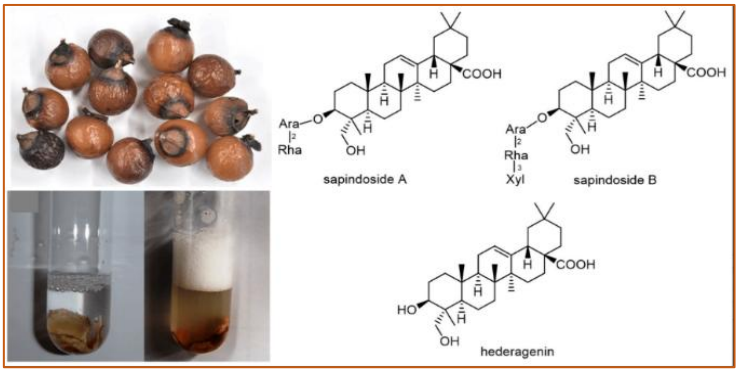
Santalol ($C_{15}H_{24}O$): is an organic compound that is classified as a sesquiterpene. It is a colorless liquid with a boiling point of 300°C; derived from sandalwood oil and used for perfumes.



Sandalwood oil

Saponification: the process of converting chemicals into soap; involves the alkaline hydrolysis of a fat or oil, or the neutralization of a fatty acid.

Saponin: any of numerous plant glycosides characterized by foaming in water. Plant saponins have the most surfactant properties of all the bioactive chemical compounds. When agitated with water, they form a soapy lather, hence their name “saponins”.



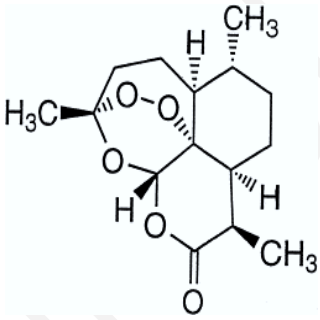
Saponins isolated from plant

Saturated: the term given to organic molecules which contain no multiple bonds.

Scopoletin (6-methoxy-7-hydroxycoumarin): a naturally occurring simple analogue of coumarin. Coumarins belong to the benzopyrone chemical family; which are widely distributed in the plant world, in seeds, fruits, flowers, roots, leaves and stems, with the largest concentrations generally found in fruits and flowers.

Secondary metabolites: are ubiquitous substances occurring naturally in plants and microorganisms. They are classified into three main groups terpenoids, phenolic compounds, and non-protein nitrogen compounds such as alkaloids.

Sesquiterpenes: are bitter substances and a class of terpenes that consist of three isoprene units and have the molecular formula $C_{15}H_{24}$. They often contain α, β-unsaturated-γ-lactone as a major structural feature. In recent studies, sesquiterpenes have been associated with anti-tumor, cytotoxic, and anti-microbial activities.



Artemisinin is a sesquiterpene lactone

Spectrophotometer: an instrument that measures the degree of absorption (or emission) of electromagnetic radiation by a substance.

Soxhlet extraction: is one of the modern extraction techniques in which the circulation of the same solvent occurs through the Soxhlet extraction system several times. It is a type of uninterrupted extraction technique; however, it can be also termed as a series of short maceration.

Dr. Ahmed USEILA



Soxhlet apparatus

Stearic acid ($C_{17}H_{35}COOH$): a saturated fatty acid with an 18-carbon chain. The IUPAC name is octadecanoic acid. It is a soft waxy solid.

Sugar: saccharose, cane or beet sugar. A generic term for class of carbohydrates characterized by solubility in water, a sweet taste and has crystallinity form.

Sugarcane: (*Saccharum officinarum*) plant of the family Poaceae, primarily cultivated for its juice from which sugar is processed. Most of the world's sugarcane is grown in subtropical and tropical areas.



Sugarcane (*Saccharum officinarum*)

Sweeteners: liquid medications are usually very unpleasant to the taste, and sometimes it is necessary to combine different sweeteners in the same product in order to overcome this inconvenience. The most used sweetener by the pharmaceutical industry is sucrose, its artificial surrogates (saccharin sodium, sodium cyclamate and aspartame) and sorbitol in fact they are dangerous and are forbidden to diabetic patients.

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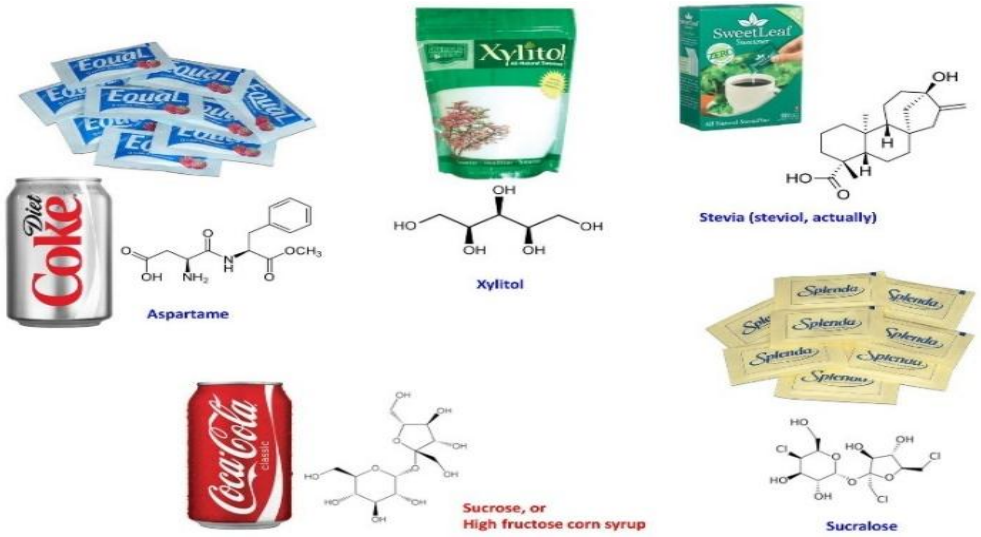


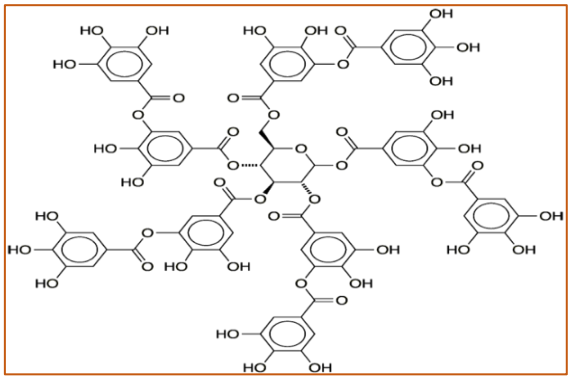
Sweeteners

J

Tannins: a yellowish or brownish bitter-tasting organic substance present in some galls, barks, and other plant tissues, consisting of derivatives of gallic acid such as tannic acid. The astringency from the tannins is what causes the dry and puckery feeling in the mouth following the consumption of unripened fruit or tea.

Tanning: the process of converting hides into leather. The agents used are tannins, metallic hydroxides and oils. The mechanism of the process is supposed to be an adsorption of the tanning agent on the surface of the fiber.

Tannic acid: a specific tannin that formally contains 10 galloyl (3,4,5-trihydroxyphenyl) units surrounding a glucose center. The best-known families of which their species contain tanning acid are Anacardiaceae and Fagaceae.



Structure of tannic acid

Dr Amen BOUSEFEL

Terpineol ($C_{10}H_{17}OH$): a combustible, colorless liquid, derived from pine oil, soluble in alcohol, slightly soluble in water, boils at 214-224°C; used in medicine, perfumes, soaps, and disinfectants, and as an antioxidant.

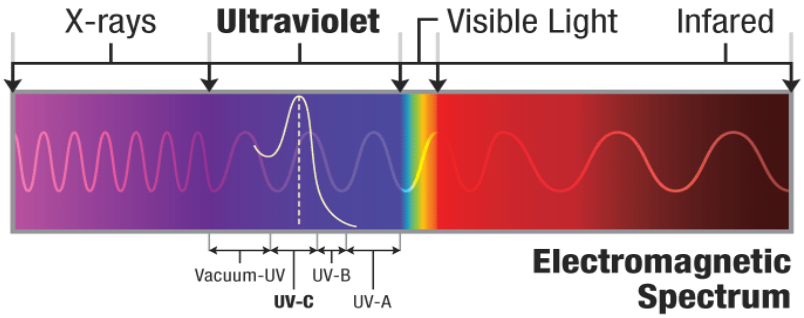
U

Ultimate analysis: the process of determining the elementary composition of carbon compounds.

Umbelliferae: also known as Apiaceae, in the order Apiales, comprising about 434 genera and nearly 3,780 species of plants distributed throughout a wide variety of habitats, principally in the north temperate regions of the world. A number of species are economically important as leaf and root vegetables, herbs and spices, and garden ornamentals such as: carrot, parsley and anise.

Umbelliferone: is a coumarin substituted by a hydroxy group ay position 7. It has a role as a fluorescent probe, a plant metabolite and a food component. It absorbs ultraviolet light strongly at several wavelengths. It is used in sunscreens and it has been reported to have antioxidant properties.

Ultraviolet light: (UV) radiation is a form of non-ionizing radiation found at the lower end of the electromagnetic spectrum between x-rays and visible light is classed as the range that occurs below the visible range (400–700 nm). It is broken down into four ranges, UV-A, UV-B, UV-C and vacuum UV.



UV radiation

UV/Vis spectroscopy: *Ultra*-violet visible spectroscopy is a spectroscopic method that is based on the interaction of a chemical species with light in the ultraviolet and visible ranges of the spectrum. Which is suitable for a large spectrum of organic compounds.

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V

Vanillin ($C_8H_8O_3$): a crystalline phenolic aldehyde that is extracted from vanilla beans or prepared synthetically and is used especially in flavoring and in perfumery.

Visible absorption spectrophotometry: Study of the spectra produced by the absorption of visible-light energy during the transformation of an electron from the ground state to an excited state as a function of the wavelength causing the transformation.

Vitamin: any of various organic substances that are essential in small quantities to the nutrition of most animals and some plants, act especially as coenzymes and precursors of coenzymes in the regulation of metabolic processes but do not provide energy or serve as building units, and are present in natural foodstuffs or sometimes produced within the body. Major health organizations list vitamins:

- Vitamin A (all-*trans*-retinols, all-*trans*-retinyl-esters, all-*trans*-*β*-carotene and other provitamin A carotenoids).
- Vitamin B_1 (thiamine), Vitamin B_2 (riboflavin), Vitamin B_3 (niacin), Vitamin B_5 (pantothenic acid), Vitamin B_6 (pyridoxine), Vitamin B_7 (biotin), Vitamin B_9 (folic acid and folates), Vitamin B_{12} (cobalamins).
- Vitamin C (ascorbic acid).
- Vitamin D (calciferols).
- Vitamin E (tocopherols).
- Vitamin K_1 (phylloquinones).
- Vitamin K_2 (menaquinones).
- Vitamin K_3 (menadiones).

W

Water (H_2O): is an inorganic compound. It is a transparent, tasteless, and odorless. It is the main constituent of Earth's hydrosphere and the fluids of all known living organisms (in which it acts as a solvent).

Waxes: liquid and solid mixtures of fatty acid esters. All plants appear to contain small amounts of waxes. They serve essential functions in plants, such as reducing water loss through transpiration and protecting plant surfaces from environmental stresses.

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Natural waxes

Weak acid: an acid that does not ionize greatly; for example, acetic acid or carbonic acid.

Xanthone (CO(C6H4)2O): White needle crystals that are found in some plant pigments; insoluble in water, soluble in alcohol, chloroform, and benzene; melts at 173°C, sublimes at 350°C; used as a dye intermediate, in perfumes and pharmaceuticals.

X-ray crystal spectrometer: an instrument designed to produce an *x*-ray spectrum and measure the wavelengths of its components, by diffracting *x*-rays from a crystal with known lattice spacing.

X-ray spectrometer: an instrument for producing the *x*-ray spectrum of a material and measuring the wavelengths of the various components.

X-ray spectrometry: a technique for quantitative analysis of the elemental composition of specimens. Irradiation of a sample by high-energy electrons, protons, or photons ionizes some of the atoms, which then emit characteristic *x*-rays whose wavelength depends on the atomic number of the element and whose intensity is related to the concentration of that element.

Y

Yield: in chemistry, yield, also known as reaction yield or chemical yield, refers to the amount of product obtained in a chemical reaction. The **actual yield** is the amount of product that is actually formed when the reaction is carried out in the laboratory. The **percent yield** is the ratio of the actual yield to the **theoretical yield**, expressed as a percentage:

$$\text{Percent Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\%$$

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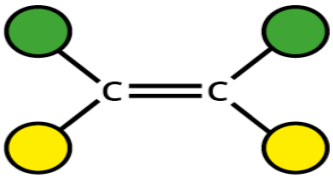
Z

Z configuration: in organic chemistry, the ***Z*** configuration denotes the arrangement around a double bond where the highest priority groups on each carbon are on the same side. If the highest priority groups for each carbon are on opposite sides of the molecule, we have the *E* isomer.



(Z) ISOMER

Z configuration

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Chapter 3: Lab equipment

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3. Lab equipment

3.1 Introduction

The introduction of laboratory tools is very important in starting a practicum. It helps in knowing the name of laboratory tools and their function in practicum. Not only that, the introduction of laboratory tools is also useful in avoiding work accidents and failed experiments in the laboratory.

The introduction of chemical laboratory tools is also expected to be able to increase students' insights about the function of chemical laboratory tools so that experiments will be conducted in practicum can run smoothly. Well, here are laboratory tools that are commonly used in chemical practicums in the laboratory (Tables below).

3.2 General laboratory consumables

Glassware	**Tools**
Beakers	Spatulas
Flasks	Scissors
Florence flask	Scoops
Volumetric Flasks	Rubber
Test tubes	Plastic
Tube racks	Washing Bottle
Containers	Clips
Reagent bottles	Clamps
Spray, dropping bottles	
Funnels	**Heating**
Buchner Funnel	Burners
Cylinders	Beaker tongs
Dishes	Tripod
	Wire gauze

LABORATORY APPARATUS
Balances
Spectrophotometers
Mechanical Shaker
Vacuum Pump
Water bath
Magnetic Stirrer With Hot Plate
Rotary Evaporator

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3.2.1 Glassware

Beaker

Beaker is useful as a reaction container. Actually, it made of *Pyrex* glass that serve to hold liquid or solid samples, to store, heat, and mix chemical compounds. They are available in a variety of sizes. Although they often possess volume markings, these are only rough estimates of the liquid volume; it is adequate for use that does not require high accuracy.



Burette

Burette known as glass burette is used for extremely accurate addition of liquid. By adjusting the stopcock, the amount of liquid that is released can be slowed to a drop every few seconds.



Claisen flask

The Claisen flask or Claisen distillation flask is a special type of distillation flask with a branched neck designed especially for vacuum distillation.



Erlenmeyer flask

Erlenmeyer flask known as a conical flask. It is used in applications where solutions must be mixed several times.



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Florence flask

Florence flask is also known as a boiling flask. It is used to hold liquids and can be easily swirled and heated.



Funnel

A **funnel** is designed to be used in a laboratory setting which can be made of plastic or glass; it used for pouring liquids or powder through a small opening and for holding the filter paper in filtration.



Graduated cylinder

Graduated cylinder is a primary measuring tool for the volume of a liquid. It has several markings up and down the length of the container with specific increments.



Pipettes

Pipettes are used for measuring an exact volume of liquid and placing it into another container.



Separatory funnel

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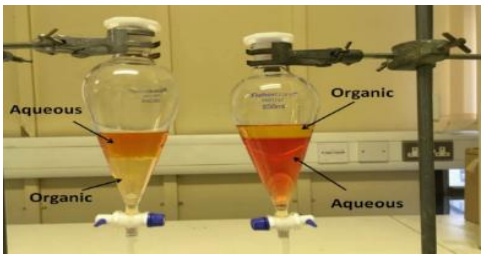
Separatory funnel is a glass funnel with a tap at the bottom used for two liquids that do not dissolve in each other.



Stirring rod

Stirring rod is made of glass and it is used to mix chemicals and liquids in laboratory experiments.



Test tube

Test tube is a glass tube with one end open and the other end closed. The closed end is rounded. It is used to hold small samples. It is used for qualitative assessment and comparison.



Volumetric Flasks



Volumetric flasks are used to measure precise volumes of liquid or to make precise dilutions. They are used to measure and store solutions with a high degree of accuracy (precise volumes). These flasks generally possess a marking near the top that indicates the level at which the volume of the liquid is equal to the volume written on the outside of the flask.

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Watch glass

Watch glass is a circular concave piece of glass used in chemistry as a surface to evaporate a liquid, to hold solids while being weighed, for heating a small amount of substance, and as a cover for a beaker.



3.2.2 Tools

Crucible

Crucible a is a container of porcelain used in the melting or calcination of materials or reaction mixtures at high temperatures.





Crucible tongs

Crucible tongs is used to transfer a hot crucible inside/atop the curve at the end of the tongs. It can also be used to transfer other hot things by pinching them with tongs



Clamp

Clamp is used to hold round laboratory glassware, such as a beaker, and flasks, etc. This type of clamp is made from stainless steel.



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Eye dropper



per or simply dropper, is a device used to transfer small quantities of liquids.

Filtration Paper

Filtration Paper is mainly adapted to a filter funnel, to separate mixtures of insoluble solids into liquids.



Iron ring

Iron ring sometimes referred to as an iron support ring, is used in chemistry laboratory to stabilize flasks mounted to a ring stand and support them over the work area.



Iron stand

Iron stand a vertical metal rod with a heavy base to which iron rings and clamps can be fastened. It is used to hold experiments and other lab equipment, using rings or clamps.



Mortar and pestle

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Mortar and pestle are a set of two simple tools used to prepare ingredients or substances by crushing and grinding them into a fine paste or powder in the kitchen, laboratory, and .



Magnetic stirrer bars

Magnetic stirrer bars known also as spin bar, is a small white oblong teflon-covered magnet. These bars have only one purpose: to stir solutions.



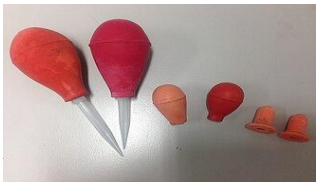
Reagent bottles

Reagent bottles are used to hold liquid chemicals.



Rubber bulbs

Rubber bulbs are used in chemistry laboratories, by placing them on top of a glass or plastic tube. It serves as a vacuum source for filling reagents through a pipette or Pasteur pipette and also help control the flow of liquid from the dropping bottle.



Spatula

Spatula is a hand-held laboratory tool used for transferring and manipulating small quantities of solid or semi-solid materials, such as powders, crystals, or gels. It consists of a flat, narrow blade, usually made of metal or plastic, attached to a handle.

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Spot plate

Spot plate also called a reaction plate is a laboratory tool made either from ceramics.



Stirrer bar retriever

Stirrer bar retriever contains a strong magnet to remove a stir bar from all glass and plastic containers used in the laboratory.



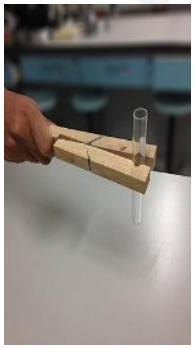
Test tube brush

Test tube brush: is used to clean test tubes. They are developed to be able to reach all corners of the glassware.



Test tube holder

Test tube holder is used to hold test tube in place when the tube is hot or should not be touched. It is used to hold test tubes upright during experiments.



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Test tube rack

Test tube rack a wire, wood or plastic grid that can hold a number of test tubes.



Wash bottle

Wash bottle is a squeeze bottle with a nozzle, used to rinse various pieces of laboratory glassware, such as test tubes and round bottom flasks.



3.2.3 Heating equipment

Bunsen Burner

Bunsen Burner is a mechanical apparatus that is connected to a flammable gas source. it produces a single open gas flame, and is used for heating, sterilization, and combustion.



Hot Plates

Hot Plates can also be used as sources of heat when an open flame is not desirable. The primary function of a laboratory hot plate is to heat substances in containers such as beakers or flasks. The heated substances are then utilized for various applications, such as chemical synthesis and sample preparation.

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Tripod

Tripod known as tripod for Bunsen burner a metal stand with three legs and no base. Used as a stand for flat-bottomed flasks and glass beakers during heating of small experiments.



Wire gauze

Wire gauze a wire gauze on a ring supports beakers to be heated by Bunsen burners. The gauze is placed on the tripod stand between the Bunsen burner and the glassware to support the beakers, flasks, or other glassware during heating.



3.2.4 Apparatus

Analytical balance

Analytical balance or electronic balances have replaced most mechanical balances due to their greater accuracy and ease of operation. They are easier to use because they usually have a digital readout, and weighing dishes can be tared to read zero mass before using. Most balances used for preparation of solutions have a sensitivity of +/- 0.01 g, but electronic analytical balances can be sensitive to +/- 0.1 mg or less. Electronic balances require routine maintenance and recalibration.



Autoclave

An **autoclave** is a crucial piece of equipment that uses steam under pressure to kill harmful bacteria, viruses, fungi, and spores on items that are placed inside a pressure vessel. The items are heated to an appropriate sterilization temperature for a given amount of time.



Centrifuge

A **centrifuge** is a piece of laboratory equipment that separates gas or liquid of minute density difference or same density through spinning the sample around a specific axis. It is a motor-driven device that provides a high spinning speed to the samples.



Desiccator

Desiccator is a closed vessel that contains a desiccant (a drying agent) in its base. Desiccants include silica gel and anhydrous calcium chloride. It is a device used to control the humidity of the air.



Distilling apparatus

A **distilling apparatus** is a piece of laboratory equipment that is used to separate mixtures of two liquids with different boiling points. It refers to a wide range of equipment used for

various distillation techniques in chemistry, including the distillation flask, distillation column, condenser, and collecting flask(s). The use of a distillation apparatus is the most commonly used method for extracting essential oils.



Fume Hoods

Fume Hoods also known as a fume cabinet, is a form of ventilation equipment used in laboratories to reduce exposure to poisonous or dangerous fumes, gases, dust, and vapors. Besides it is useful for conducting chemical processes.



Koffler Hot Bench

Koffler hot bench is an apparatus provides a simple accurate way of determining the melting point of organic compounds.



Mechanical shaker

Mechanical shaker it is a piece of laboratory equipment used to mix, blend, or agitate substances in a bottle or flask by shaking them.



pH meter

A **pH meter** is an instrument used to measure hydrogen ion activity in solutions - in other words, this instrument measures acidity/alkalinity of a solution. The degree of hydrogen ion activity is ultimately expressed as pH level, which generally ranges from 1 to 14.



Rotary evaporator

Rotary evaporator also called as “rotavap” is a device used in labs for the efficient and gentle removal of solvents from samples by evaporation.



Vortex mixers

Vortex mixers are laboratory equipment used to mix small volumes of liquids, typically in tubes or microplates. The mixer works by creating a vortex, or circular motion or movement, in the sample. The vortex allows for efficient mixing, dissolving, or suspending of particles in the liquid.



Water bath

Water bath a water bath is laboratory equipment made from a container filled with heated water. It is used to incubate samples in water at a constant temperature over a long period of time. All water baths have a digital or an analogue interface to allow users to set a desired temperature. Utilizations include warming of reagents or melting of substrates. It is also used to enable certain chemical reactions to occur at high temperature.



Water distiller

A **water distiller** is a machine that purifies water by removing more than 99.9% of contaminants, including chemicals, heavy metals, microorganisms and sediment. While

design may vary, a typical water distiller consists of a boiling chamber, a cooling system and a separate storage tank



Chapter 4: Scientific paper

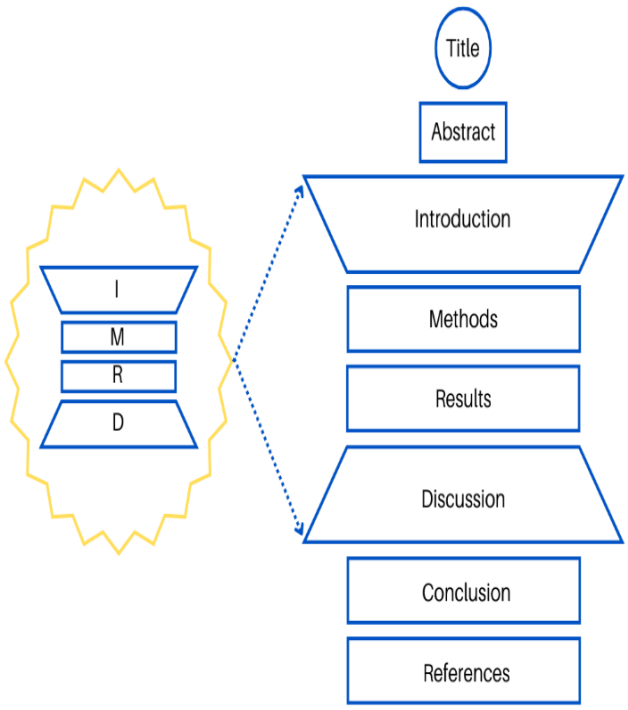
Dr. Ahlem BOUSETLA

4. Scientific paper

4.1 Introduction

Given the explosion of information and knowledge in the field of chemistry, adapting primary literature as part of active-learning seems to be more effective in improving scientific literacy among science undergraduates than the pure transmission of content knowledge using traditional textbooks. In addition, students also will have to read research articles as part of undertaking laboratory research projects in higher undergraduate courses. This has been beneficial for preparing them for postgraduate, though traditionally only students in later years of their undergraduate classes get to work with scientific articles.

Scientists and researchers communicate their research results one to another through scientific articles or papers. These articles are generally published in scientific journals or presented in conferences. To make the communication efficient and effective, the articles must be presented coherently and logically. They must be highly readable, clear, accurate, and concise. This can be realized through the use of the format commonly used in scientific articles., known as AIMRaD (Abstract, Introduction, Methodology, Result, Conclusion, and Reference.



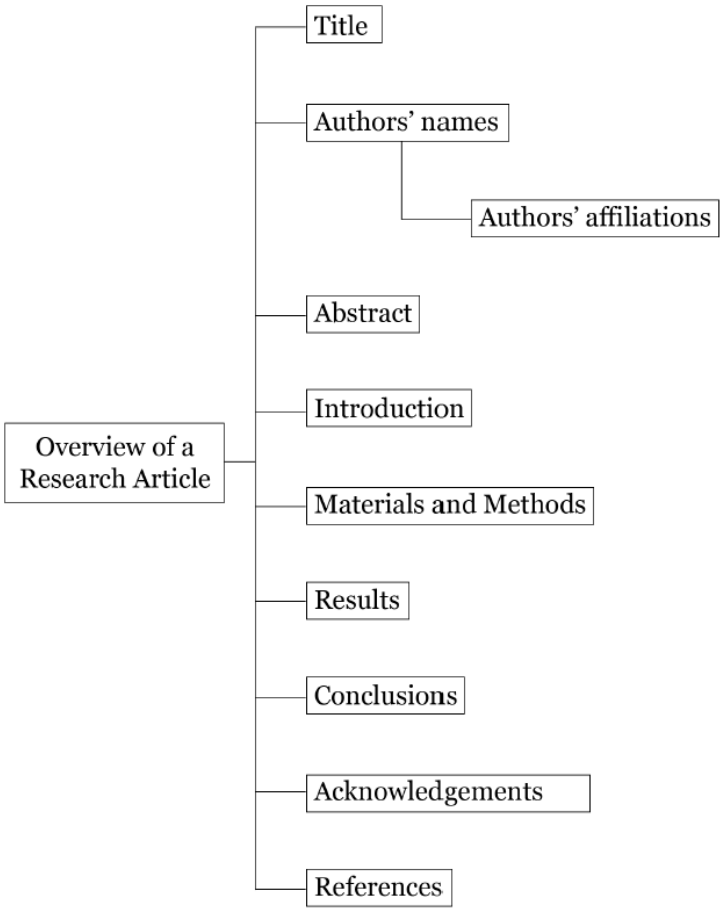
AIMRaD structure

When researchers read an article or scientific paper, they would have examined the details of the various aspects of the paper. They must understand the strategy of the research, the interpretation of the results and the conclusions stated by the authors.

The prime objective of reading an article critically is to learn to form your opinion of the authors' data presented in the article by going through each section and systematically evaluating what has been presented by applying certain processes, models, questions, and theories that result in enhanced clarity and comprehension.

4.2 The anatomy of a typical scientific paper

If you look briefly through an scientific paper, you would normally find that the title is at the top of the first page, followed by the names of the authors with their affiliations.



The Anatomy of a Typical Scientific paper

The title normally gives a good description of what the research work is about.

Usually, the model organism used in the study is stated, together with the key idea in the paper. The authors listed are the researchers who had contributed to the paper in one way or

another, such as conducting the experiments, designing the study, analyzing the data or writing the content. The order of the names normally reflects the extent of contribution of the authors to the research paper

Example 1:



The first page of an article looks like

The title:

The title normally gives a good description of what the research work is about. Usually, the model organism used in the study is stated, together with the key idea in the article.

The authors:

The authors listed are the researchers who had contributed to the article in one way or another, such as conducting the experiments, designing the study, analyzing the data or writing up the article. In the field of scientific research, there are very clear guidelines about authorship. Therefore, a paper can have several authors. The order of the names normally reflects the extent of contribution of the authors to the research paper.

- The "**first author**" is a coveted position because of its increased visibility. This author is the first name readers will see, and because of various citation rules, publications are usually referred to by the name of the first author only. In-text or bibliographic referencing rules, for example, often reduce all other named authors to "*et al*."
- The **last author** position is traditionally reserved for the supervisor or principal investigator. As such, this person receives much of the credit when the research goes well and the flak when things go wrong. The last author may also be the corresponding author;
- The **corresponding author** is the person who is the primary contact for journal editors (the first author could, however, fill this role as well, especially if they contributed most to the work).

Key tasks of corresponding author:

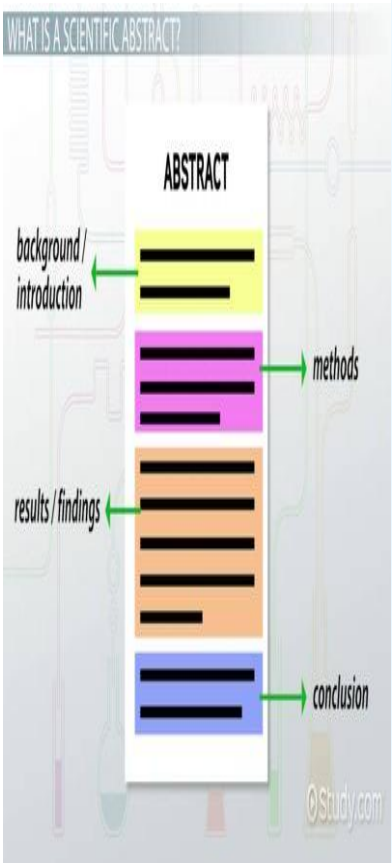
- Obtaining the journal guidelines and ensuring the requirements are met.
- Producing the first draft of the manuscript.
- Coordinating the feedback from co-authors.
- Ensuring all authors are in agreement before the final version is submitted.
- Coordinating the signing of the copyright agreement.

The authors' affiliations:

The authors' affiliations are an indication of where the authors are working or where the research work described in the article was performed?

In research paper, the authors could be from different institutions. This is quite common for collaborative work where authors working at different institutions within or outside the country collect their resources or and collaborate their efforts and expertise to solve a common research question.

Example 2:



ABSTRACT: Diabetes is a group of metabolic disorders characterized by elevated blood sugar levels, leading to many undesirable health consequences. There are many herbal formulations, traditionally used by the Northeast Indian population for disease management. These formulations require scientific validations to optimize their efficacy and increase their popularity. In this study, we attempt to scientifically validate a polyherbal formulation traditionally used for the management of diabetes through preliminary phytochemicals investigation, characterization of potential phytochemicals using Fourier transform infrared (FT-IR) spectroscopy, high-resolution liquid chromatography mass spectrometry (HR-LC/MS) analysis, and *in silico* characterization of physiochemical, drug-likeness, and pharmacokinetic properties of identified phytochemical compounds. Qualitative phytochemical screening of various extracts of the formulation confirmed the presence of alkaloids, phenols and tannins, flavonoids, fats, and oils. Phytochemical quantification of the various extracts showed that the highest total phenolic content is present in the ethanolic extract (35.61 ± 0.15 mg GAE/g), while the highest total flavonoid content is present in the chloroform extract (76.33 ± 2.96 mg QE/g) of the formulation. FT-IR spectroscopic analysis revealed various characteristic band values with various functional groups in the formulation extract such as amines, alcohol, fluoro compounds, phenol, alkane, alkene, and conjugated acid groups. HR-LC/MS analyses identified nearly 51 compounds including 9 small peptides and 42 potential phytochemical compounds. *In silico* SwissADME analysis of identified compounds revealed 25 potential compounds following Lipinski's rule and showing drug-like characteristics, and out of them, 16 compounds exhibited good oral bioavailability, as revealed in the bioavailability radar. The overall study showed that the presented polyherbal formulation is enriched with bio-active phytochemical compounds with good pharmaceutical values.

The abstract:

The abstract is a small section, is about 150 to 200 words in general. This is a summary of the key issue that the authors set out to study and includes the strategy taken in the study to tackle the research questions. The main findings obtained would also be presented. The Abstract further includes a statement or two about the significance of the data or conclusions from the study.

The keywords:

The Keywords need to be descriptive and capture the most important aspects of the paper. It is about three to five words, phrases, or acronyms.

Example 3:

Phytochemical screening and determination of phenolics and flavonoids in *Dillenia pentagyna* using UV–vis and FTIR spectroscopy

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Flavonoids
Antioxidant property

ABSTRACT

Here, we report an ultrasonic-assisted extraction (UAE) of phytochemicals from bark, leaves, sepals, fruits, and seeds of *Dillenia pentagyna* (Roxb) using different organic solvents such as chloroform, ethanol, and n-hexane. The preliminary phytochemical screening results showed that the ethanolic extract is enriched with phenolics, flavonoids, tannin, saponin, alkaloid, and terpenoids. The profiling of phytochemicals is carried out employing UV–Vis and Fourier-transform infrared (FTIR) spectroscopy analyses. The higher amount of phenolic compounds obtained in the ethanolic extract of bark and leaves as compared to other parts of the plant. Consequently, a higher amount of total flavonoid compounds unveiled in the bark of targeted species. The ethanolic extract of bark and leaves showed good free radical scavenging activity using DPPH with inhibition percentage of 90.58 ± 1.89% and 76.46 ± 1.58%, respectively, in comparison to standard ascorbic acid at 10 μg/mL. Moreover, the half-maximal inhibitory concentration (IC_{50}) value of bark and leaves are 5.64 and 6.54 μg/mL, respectively, in comparison to standard ascorbic acid. With the best of our knowledge, it is the first report pertaining to characterization and quantification of phenols and flavonoids as well as the investigation of the medicinal property in *D. pentagyna*.

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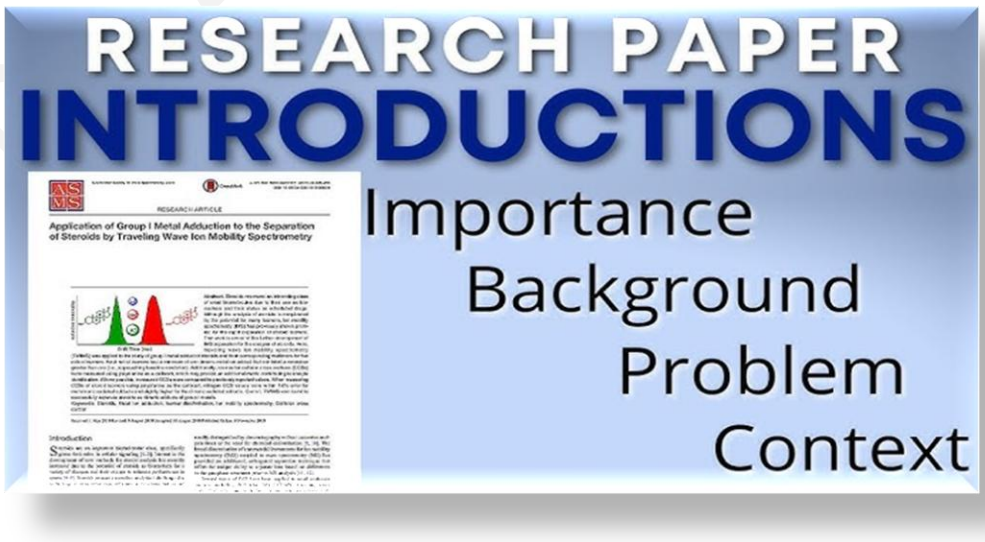
Introduction:

The introduction is a section within which the authors will provide essential background information surrounding the research subject matter of interest. This is in order to establish the basic hypothesis for the research work. At the end of the Introduction, the authors would include a statement on the hypothesis they aim to test and some predictions of the possible outcome of their study.

The *Introduction* section clarifies the motivation for the work presented and prepares readers for the structure of the paper.



Example 4:

1. Introduction

There are about 300,000 plant species whose phytochemicals with diverse structures and properties are elucidated [1]. These phytochemicals are divided into two major categories, firstly primary metabolites such as carbohydrates, lipids, proteins; and secondly, secondary metabolites like alkaloids, terpenoids, and phenolic compounds. The primary metabolites are responsible for the growth and development of plants; whereas secondary metabolites play an important role in defense mechanisms against the environmental pollutants, insects, and other foreign threats to the plant [2]. Among, these phenolic compounds and flavonoids are considered to be a very important class of biomolecules having a significant medicinal property for the human being. The basic structure of phenolic compounds (gallic acid, caffeic acid, ferulic acid, protocatechuic acid, and coumaric acid) consists of a phenolic (C_6H_5OH) ring, the carboxylic acid (-COOH) and hydroxyl groups (-OH). Moreover, flavonoids are polyphenols that contain at least two phenolic rings and further categorized into different sub-class such as flavonols, flavonones, flavones, flavanolols, flavan-3-o1s, and isoflavones [3–5]. The antioxidant activity of phenolic compounds and flavonoids is directly proportional to the presence of the hydroxyl (-OH) group in the sample. Further, the positions of hydroxyl groups also affect the ability of free radical scavenging activity [6,7]. The phenolic compounds have already been shown many pharmacological activities such as antimicrobial, antioxidants, anticancer, and antidiabetic [8–10].

Nowadays, the entry of toxic substances through food and drinking water generates free radicals which induce several diseases in the human body. It is due to the free radicals of reactive oxygen species attack on fatty acids, DNA, proteins, lipids, and initiate a rapid destructive chain reaction to damage the cell membranes [11]. The phenolic compounds and flavonoids play a significant role in preventing the damage caused by free radicals [12,13]. Thus, the characterization and determination of phytochemicals such as phenolic compounds and flavonoids in plant samples are essential to know the mechanism of these compounds against various biological activities. Here, different plant parts of *Dillenia pentagyna* (Roxb.) is chosen for the extraction and determination of bioactive components, and free radical scavenging activity of phenolic compounds and flavonoids is investigated.

* Corresponding author.
E-mail address: kshrivas@gmail.com (K. Shrivas).

In general, the introduction has to answer the fundamental question:

why has the research/study been undertaken?

The introduction should contextualize the study by indicating what and why has already been done locally and globally.

Consequently, the other key questions we should try to answer in the introduction are as follows:

- What is the problem ?
- Are there any existing and appropriate solutions?
- What is its main limitation?
- What is a researcher aimed at to solve the problem?

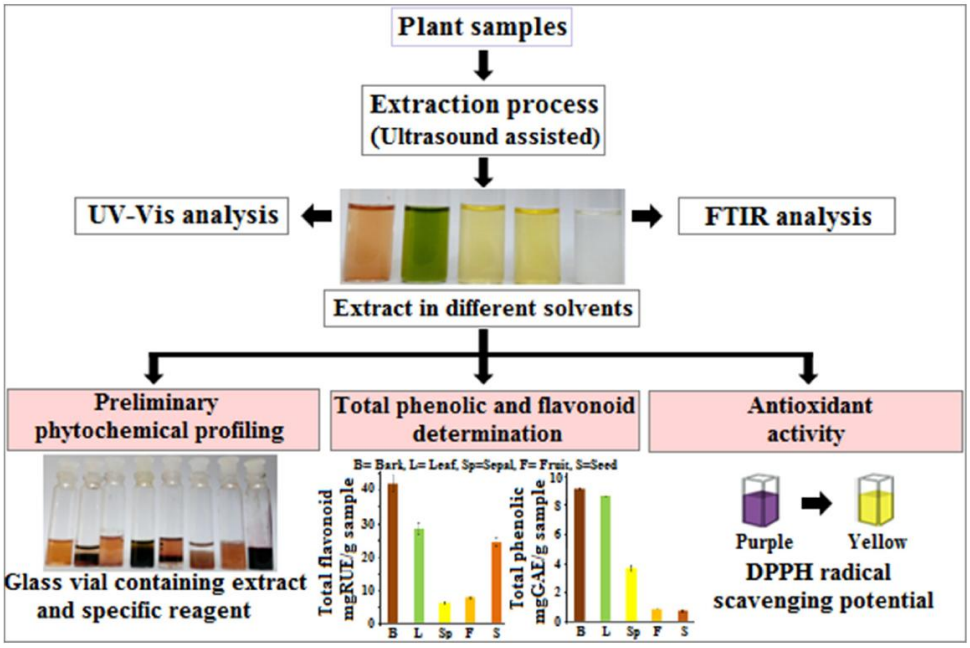
The Materials and Methods:

The materials and methods section is typically following the introduction is an indispensable part of an article. In this section, what materials were used and how experiments were conducted in the research would be provided in a fair number of details.

The objective of the "M and M" section is to make available details of the experiments that would enable other researchers to repeat the experiments if needed. This could be for the

purpose of verifying what the authors had reported as well as for other researchers needing the same or similar protocols for their own research.

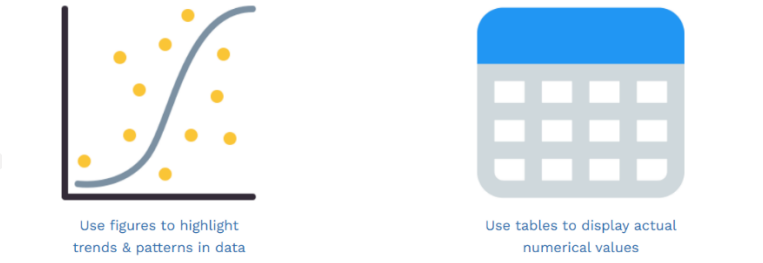
Example 5:



Scheme 1. The extraction of phytochemicals, screening using chemical reagents, UV–Vis and FTIR analyses, total phenolic and flavonoid and their antioxidant activities.

The Results and Discussion:

These sections **present** and **discuss** the research results, respectively. They are often usefully combined into one section. The finding that the authors have obtained in their experiments would be presented in the form of figures and tables.



The results section will be text descriptions of the outcome from the experiments conducted in laboratory or in the research field.

The results that the authors have obtained in their experiments would be presented in the form of figures, tables. It is an appropriate method to summarize large amounts of data for a more concise and accurate information.

The implications of the data would be elaborated in a discussion section. Here the authors try to provide an analysis of the results in context of the existing knowledge. They would attempt to explain how their outcome had explained or provided answers to their hypothesis.

Example 6:

Table 2
Effect of solvents on percentage of yield of crude extract from different parts of *D. pentagyna*.

D. pentagyna	Percentage (%) yield of crude extract in different solvents		
	Ethanol	Chloroform	n-Hexane
Bark	8.44 ± 0.45	4.23 ± 0.26	2.25 ± 0.21
Leaves	5.58 ± 0.13	2.29 ± 0.17	2.21 ± 0.22
Sepals	2.19 ± 0.19	1.86 ± 0.18	0.72 ± 0.2
Fruit	3.62 ± 0.38	3.21 ± 0.08	0.98 ± 0.12
Seeds	1.6 ± 0.28	0.89 ± 0.03	0.52 ± 0.08

± Standard deviation for triplicate results.

to extract the most of the polar substance from different plant samples. Thus, ethanol was used as a solvent for the extraction of phytochemicals from different parts of the plant.

3.2. Screening of phytochemicals from different plant samples using chromophoric reagents

The extract of bark, leaves, sepals, fruits, and seeds with different solvent was subjected for preliminary phytochemical screening to identify the presence of alkaloids, flavonoids, phenolic acids, terpenoids, tannins, saponins, and carbohydrates in the plant samples. The results are shown in Fig. 1(A) to (O) and Table 3. Ethanol, chloroform and hexane extract of bark, leaves, sepals, fruits, and seeds were taken separately in a 5-mL glass vial and treated with particular reagent described in

Table 3
Preliminary phytochemical screening for ethanol, chloroform and n-hexane extract of bark, leaves, sepals, fruits and seeds.

Phytochemicals	Bark	Leaves	Sepals	Fruits	Seeds
Ethanol extract					
Alkaloids	+	−	−	−	+
Flavonoid	+	+	+	+	+
Phenolic	+	+	+	+	+
Terpenoids	+	+	+	+	+
Tannins	+	+	+	+	+
Saponins	+	+	−	+	+
Carbohydrates	+	+	+	+	+
Chloroform extract					
Alkaloids	+	−	−	−	+
Flavonoid	−	+	−	−	−
Phenolic	+	−	−	−	+
Terpenoids	+	+	−	−	+
Tannins	+	−	−	−	+
Saponins	+	−	−	+	+
Carbohydrates	+	+	+	+	+
n-Hexane extract					
Alkaloids	−	−	−	−	+
Flavonoid	−	+	−	+	−
Phenolic	−	+	+	+	+
Terpenoids	−	+	+	+	−
Tannins	−	+	+	+	+
Saponins	−	−	−	−	−
Carbohydrates	+	+	+	+	+

+ indicates detected, − indicates not detected.

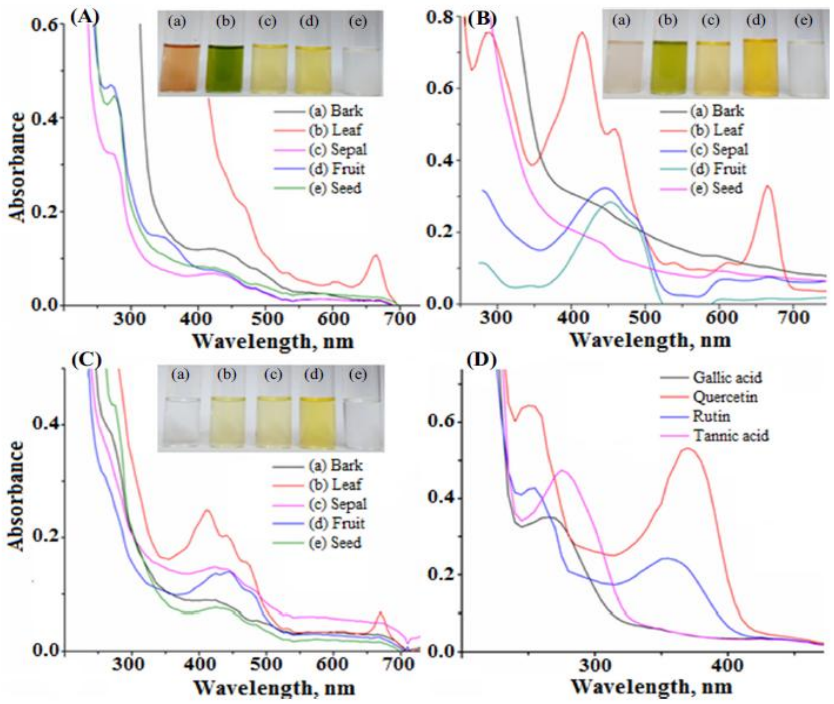


Fig. 2. UV–Vis spectra of different extracts of bark, leaves, sepals, fruits and seeds of *D. pentagyna* in ethanol extract (A), chloroform extract (B), n-hexane extract and (C). Fig. (D) is the UV–Vis spectra of standard compound such gallic acid, quercetin, rutin, and tannic acid.

The conclusion:

summarizes key findings and their interpretations, discusses if the research questions were answered, and mentions the limitations of the study, as well as recommendations for future research.

Example 7:

Conclusions

The plant-based bioactive compounds having pharmacological activity are a promising and precious alternate. Many scientists and researchers have fascinated to discover new pharmacologically active phytoconstituents from plant samples, mainly to advance the treatment and curing of a patient's life after healing. In this study, we report that the UAE is more efficient for the extraction of phytochemicals from different parts of *D. pentagyna*. The bark and leave extracts have potential to reduce damages and diseases caused by reactive free radicals, in a more helpful way alike to that of the standard ascorbic acid. To the best of our knowledge, this study on quantification of phenolic and flavonoid contents is the first report on *D. pentagyna*. The ethanol extracts of bark and leaves exhibited the potent antioxidants property by inhibiting the branching chain reaction of reactive free radicals. Hence, it is inferred that the ethanol extracts of bark and leaves of *D. pentagyna* with a higher amount of phytoconstituents like phenolic compounds and flavonoids and with good antioxidant activities are the most excellent candidates for the formation of a cost-effective anti-inflammatory drug with not as much of side effects.

Acknowledgement:

in this part further information such as the names of scientists or colleagues who provided reagents, materials and technical assistance or comments on the article would typically also be provided here. In this section the authors thank people who contributed with the supply of the needed materials. Thank people who contributed technically but maybe not intellectually (would not be authors).

Example 8:

Acknowledgements

We would like to thank the Science and Engineering Research Board (SERB), India for awarding Kamlesh Shrivas as an Extra Mural Research Project (File No: EMR/2016/005813). Financial assistance from Department of Science and Technogy, India, DST-FIST [No.-SR/FST/CSI-259/2014I] and University Grant Commisson, India UGC-SAP [No.-F-540/7/DRS-II/ 2016 (SAP-I)] are also gratefully acknowledged. National Center for Natural Resources is also acknowledged for providing lab facility [DST-IRHPA grant [IR/SO/LU/0008/2011(SERB)]. The authors thank the Council of Scientific and Industrial Research (CSIR) New Delhi for providing Tarun Kumar Patle as a Junior Research Fellowship (Fill no. 09/266/(0081)/2018-EMR-I).

References:

The last section in an article is the section, which is essentially a list of articles cited by the authors (also known as a bibliography) in the article to support their work or are relevant to the study (more on this later).

Example 9:

References

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4.3 The main characteristics of a scientific paper

- They are usually published in a periodical called a journal whose purpose is to publish this kind of work. In academic publishing, a scientific journal is a periodical publication designed to advance science by editing and publishing new research findings to the scientific community. These journals serve as a platform for researchers, and scientists to share their latest discoveries, insights, and methodologies across many scientific disciplines.
- They are peer reviewed, namely, papers are written by experts and are reviewed by several other experts in the field who verify and check the quality of the writing and the accuracy of the analysis and conclusions drawn by the authors.
- They are citable and include citations. Actually, citation is a reference to the source of any information used in research. This means that the author can refer to a previously cited research paper with confidence, while the reader can easily look up that reference at any time in the future. Apart from this, all cited works are listed in a reference section at the end of the paper.

4.4 The different types of research paper

Research papers play a critical role in academia, allowing scholars to explore and contribute to existing knowledge in their respective fields. However, not all research papers are the same. There are different types of research papers, each of which serves a specific purpose and requires different methods and writing styles. Indeed, Scientific research is usually reported in peer reviewed journals or as conference proceedings. For the beginner the journal literature is the best choice.

Primary Research Articles

Known also as (original research articles) Research articles report the results of research activity or findings. The author explains why and how the research was done and what the results mean. Published in peer reviewed or referred publications (journals). Research articles are primary sources.

Communications and Letters

Concise reports of recent, significant research findings. Authors want to publish before someone else publishes similar findings. The focus is on rapid communication and broad dissemination. Communications are published in peer reviewed journals. Communications and letters are primary sources.

Review Articles

Review articles attempt to summarize and synthesize prior research. These articles can provide useful background about the major developments, important contributors, gaps in research, and current debates on a particular topic and may suggest future directions for research. Review articles are a great way to identify key articles and provide lots of references or citations. They are published in peer reviewed journals. Review articles are considered secondary sources because the author did not conduct the research.

Conference Proceedings or Proceedings

Describe research presented at a conference. Conference proceedings may be long papers or limited to an abstract. These publications may or may not be peer reviewed.

Pre-Print or Post-Print

A pre-print is the original version of a manuscript prior to peer review and formatting.

A post-print is the final version of the manuscript submitted for publication.

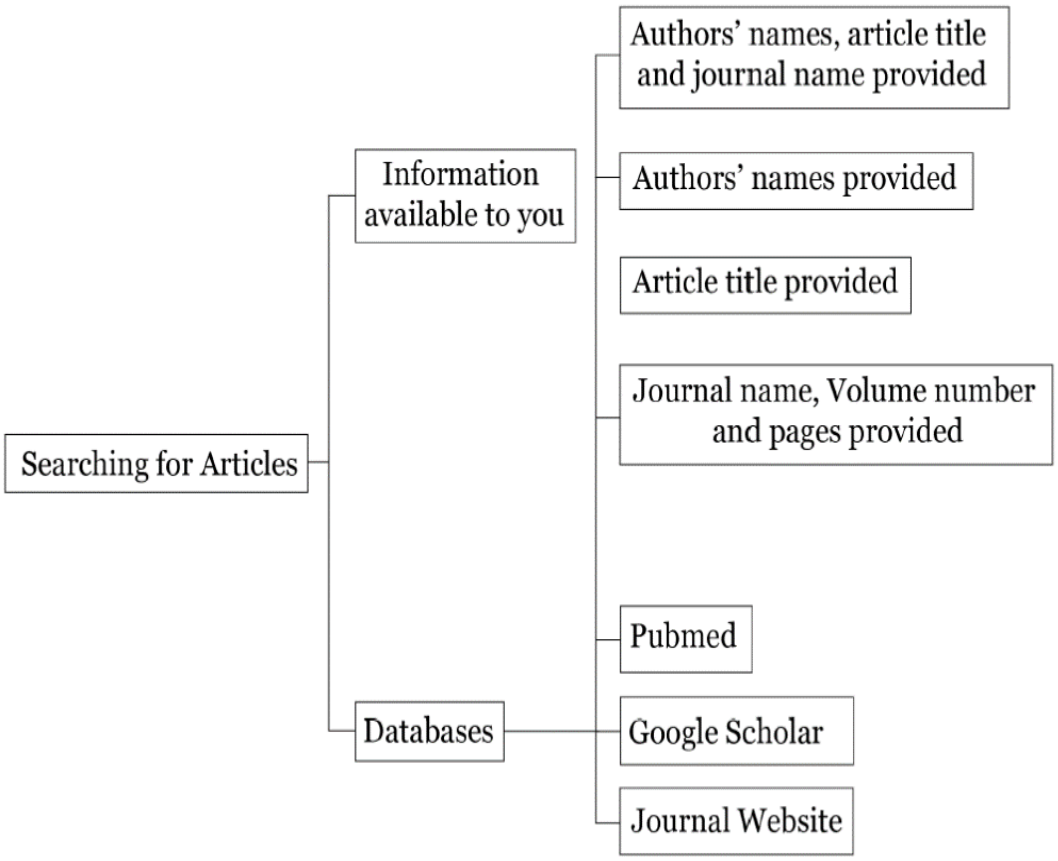
Published version/PDF is the version of record with full formatting and copyediting.

4.5 How to search for a paper?

One of the initial steps to reading a research article is to find and retrieve the full article. In certain cases, your lecturer could provide you the article in its entirety.

In other instances, you might only be provided the title and names of the authors of the article. You then have to look up the articles and download them at the appropriate journal or library websites. It is good to learn more about which search engines or databases are used routinely for finding and retrieving articles of interest.

When presented with the task of looking up articles, you have several key search engines to use to retrieve the articles of interest.



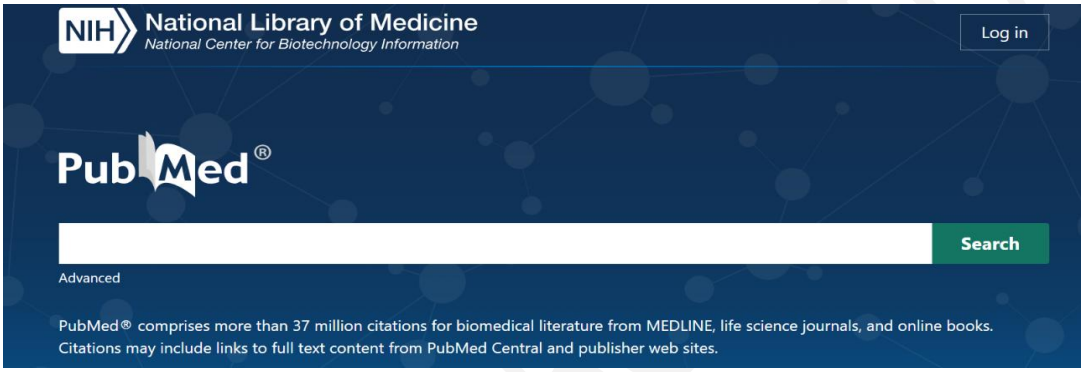
Information needed to search for articles using specific databases

In such instances, the article information provided to you could be the authors' names or titles of articles.

Pubmed

For Life Science and Biomedical articles, one key search engine is called:

The "**Pubmed**" hosted at the NCBI website (www.ncbi.nlm.nih.gov/pubmed). It is an example of a public online bibliographic database accessible to anyone with an Internet connection. This is a very powerful database that is maintained by the U.S. National Library of Medicine at the National Institutes of Health. The nature of the Pubmed is such that it not only serves as a bibliographic database for published works, but it is also a repository of the articles depending on the access that journals provide. A subscription in order that the full article can be downloaded. If the library at your university subscribes to the specific journal in question, then you could easily download the article by going through your library service; most university libraries will allow matriculated students to access journals through the specific library links.

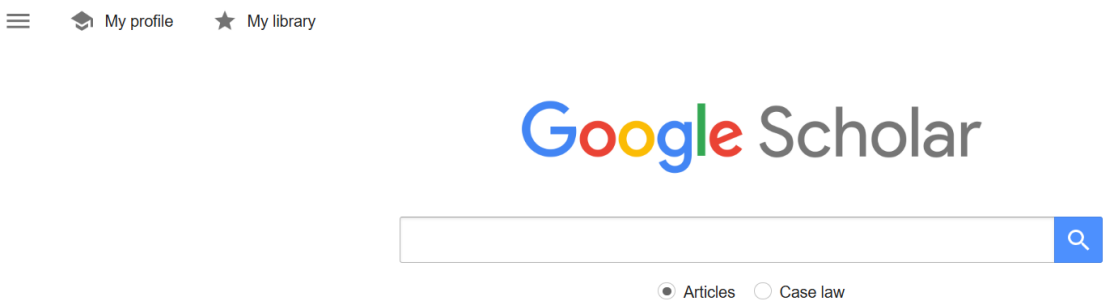


Google Scholar

You can also use Google Scholar (http://scholar.google.com).

Google Scholar is a freely accessible web search engine that indexes the full text or metadata of scholarly literature across an array of publishing formats and disciplines.

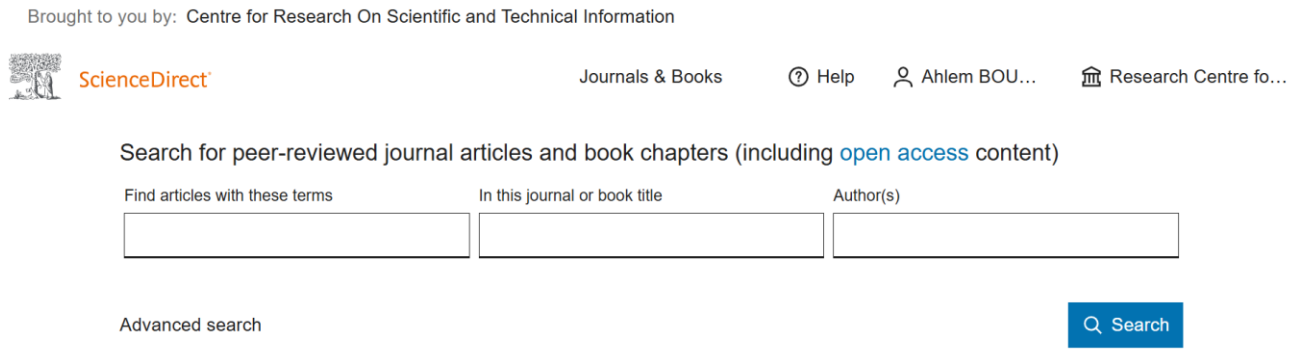
Google Scholar conduct searches by keyword, author and article title. There is also an advanced search with more options and allow researcher to access to electronic copy for the article or scientific paper.



Science Direct

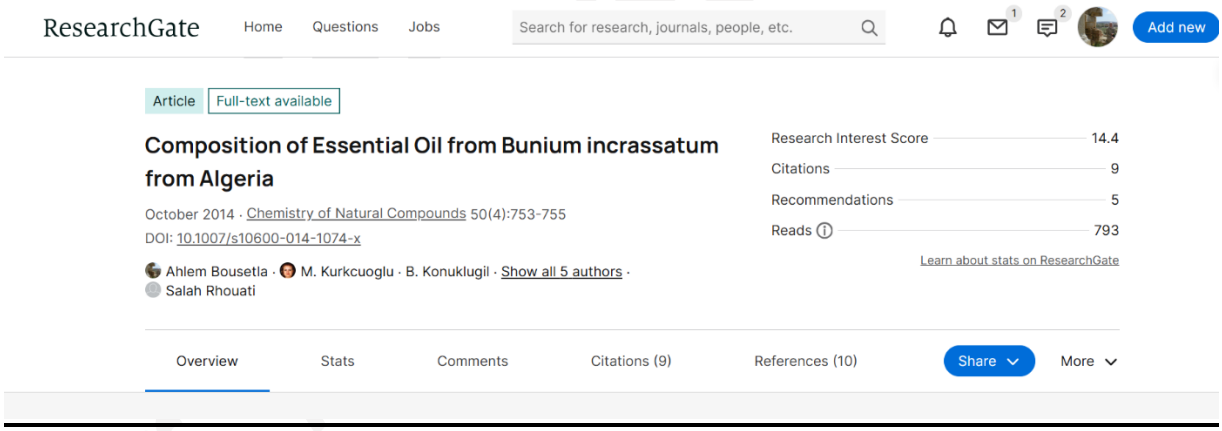
ScienceDirect is a searchable web-based bibliographic database, which provides access to full texts of scientific and medical publications of the Dutch publisher Elsevier as well of several small academic publishers.

You can search in Science Direct or Web of Science or (subscription required-usually accessible through your university library) to search for articles.



ResearchGate

ResearchGate is a European commercial social networking site for scientists and researchers to share papers, ask and answer questions, and find collaborators.



Sndl

SNDL gives an access to a rich and varied range of national and international electronic documentation, covering all areas of education and scientific research.

International documentation (acquired *via* subscriptions)

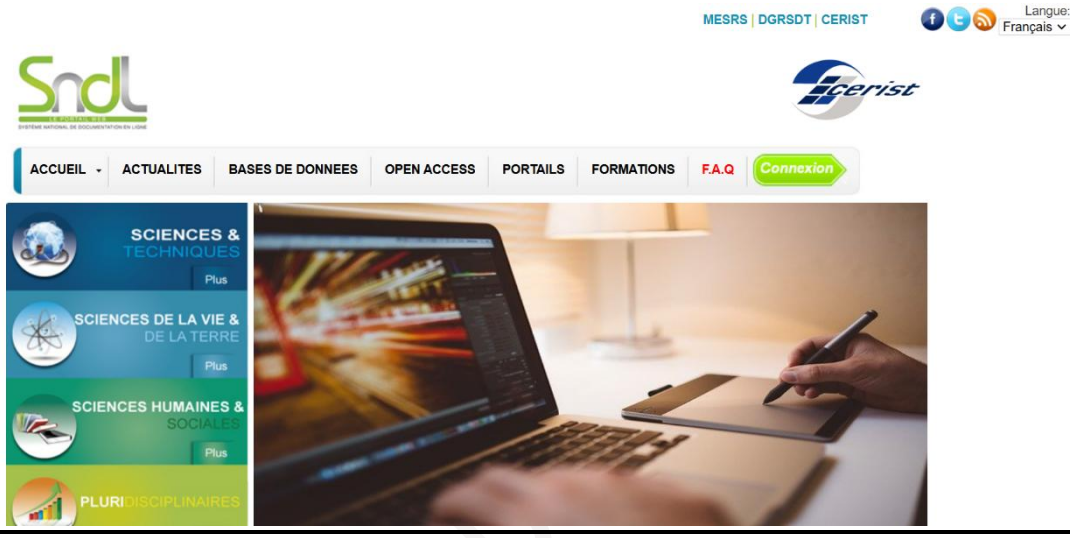
In terms of access, this documentation is divided into two categories:

The first category is accessible without restriction to all students, and permanent researchers on university campuses and research centers.

The second category, on the other hand, is dedicated to the research aspect, and is open to teachers-researchers, permanent researchers, post-graduate students (Doctorants and Magisters), engineering students at the end of their studies and Master2 students.

Access to this second category of documentation is unrestricted, but requires an individual account. The procedure for obtaining an account is straightforward and is handled by:

The head of the central library, for teacher-researchers not yet affiliated to a research laboratory, Masters 2 students and final-year engineering students.



4.6 Reading a research paper

Scientific papers are the heart of the science community. It is essential to learn how to read a paper quickly but insightfully.

When you read a research paper, your goal is to understand the scientific contributions the authors are making. This is not an easy task.1 It may require going over the paper several times. Expect to spend **several hours** to read a paper. The key idea is that you should read the paper in up to three passes, instead of starting at the beginning and plowing your way to the end. Each pass accomplishes specific goals and builds upon the previous pass:

The first pass gives you a general idea about the paper.

The second pass lets you grasp the paper's content, but not its details.

The third pass helps you understand the paper in depth.

4.7 Why reading a research paper is important?

It is worth mentioning that scientific contributions can take on many forms. Some papers offer new ideas; others implement ideas, and show how they work; others bring previous ideas

together and unite them under a novel framework. Knowing other work in the area can help you to determine which sort of contribution a paper is actually making. Reading research papers on different scientific topics gives you a deeper appreciation of the work of peers, helps build wider perspectives, allows you to see things clearly in your topics.

4.8 Several points students could bear in mind as they read research papers for the first time

- What was the current state of knowledge in the field that the research work was described in the article?

This information will be found in the **Introduction** section of the paper.

- What was the idea tested in the article?

This information will be found **at the end of the Introduction section** of the paper.

- What were the key techniques used in the experiments described?

This information will be found in the **Materials and Methods** section of the paper.

- What were the data obtained in the study?

This information will be found in the **Results** section of the paper.

- What were the conclusions drawn by the authors from their data?

This information will be found in the **Discussion** section of the scientific paper.



Dr. Abdou BOUSETLA

Conclusion

Dr. Ahlem BOUSETLA

Conclusion

English for Science is a course designed to help “Master II” students in “Pharmaceutical Chemistry” to acquire the vocabulary and syntax most commonly used in laboratory of chemistry and improve their understanding of research by reading a scientific paper on their subject. Once their vocabulary is large enough to understand the appropriate materials, they will find it easy to write an assay, dissertation or thesis in English.

Dr. Ahlem BOUSETLA

Appendix tables

Dr. Ahlem BOUSETLA

Table1 : Multiples and Sub-multiples

Multiplier	Exponent Form	Prefix	SI Symbol
1 000 000 000 000	10^{12}	tera	T
1 000 000 000	10^{9}	giga	G
1 000 000	10^{6}	mega	M
1 000	10^{3}	kilo	k
100	10^{2}	hecto	h
10	10^{1}	deca	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	µ
0.000 000 001	10^{-9}	nano	n
0.000 000 000 001	10^{-12}	pico	p
0.000 000 000 000 001	10^{-15}	femto	f
0.000 000 000 000 000 001	10^{-18}	atto	a

Dr. Ahlem BOUGHIA

Table 2: Examples of common functional groups in organic chemistry

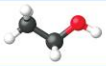
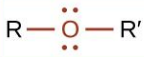
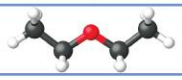
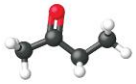
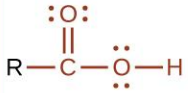
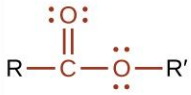
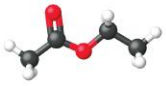
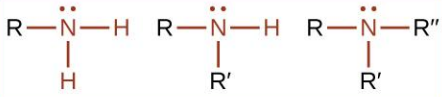
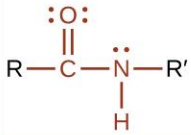
Compound Name	Structure of Compound and Functional Group (red)	Example	
		Formula	Name
alkene		C_2H_4 	ethene
alkyne		C_2H_2 	ethyne
alcohol		CH_3CH_2OH 	ethanol
ether		$(C_2H_5)_2O$ 	diethyl ether
aldehyde		CH_3CHO 	ethanal
ketone		$CH_3COCH_2CH_3$ 	methyl ethyl ketone
carboxylic acid		CH_3COOH 	acetic acid
ester		$CH_3CO_2CH_2CH_3$ 	ethyl acetate
amine		$C_2H_5NH_2$ 	ethylamine
amide		CH_3CONH_2 	acetamide

Table 3: Some characteristic absorption frequencies in IR spectroscopy

Bond Type	Frequency (cm^{-1})
C–H alkanes	2950 – 2850
C–H alkenes	3080 – 3020
C–H aldehyde	~2900
C–H alkyne	~3300
Alkyne triple bond	2250 – 2100 (s)
Alkene double bond	1680 – 1620 (s)
Carbonyl, ketone	1725 – 1700 (s)
Carbonyl, aldehyde	1740 – 1720 (s)
Carbonyl, ester	1750 – 1730 (s)
Carbonyl, acid	1725 – 1700 (s)
Carbonyl, amide	1690 – 1650 (s)
O–H, alcohols	3600 – 3200 (s,b)
O–H, acids	3000 – 2500 (b)
C–O, alcohols, esters, ethers	1300 – 1000
s: strong	**b: broad**

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Table 4: pKa Values of Common acids

Acid	formula	pKa
Acetic	CH_3COOH	4.76
Formic	HCOOH	3.75
Hydrofluoric	HF	3.20
Phosphoric	H_3PO_4	2.16
Trifluoro-acetic	CF_3COOH	0.52
Nitric	HNO_3	-1.4
Sulphuric	H_2SO_4	-2
Hydrochloric	HCl	-7
Perchloric	$HClO_4$	-10

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Links:

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https://www.britannica.com/science/hydrolysis

https://pubchem.ncbi.nlm.nih.gov/compound/Quinine

https://www.thgeyerlab.com/uploads/tx_news/ThGeyer_Catalogue_2014_UK_web.pdf

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https://www.merriam-webster.com/dictionary/chemistry

https://fr.scribd.com/document/605049282/CHAPTER-1-SCIENTIFIC-ARTICLE

https://www.youtube.com/watch?v=Xxm_beTs2LU&t=2s

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https://www.researchgate.net/publication/327729566_Knowledge_And_Science

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