Dr. Fadare's part

CHM 405

Pharmaceutical Industry: They deal with pharmaceutics.

Pharmaceutics

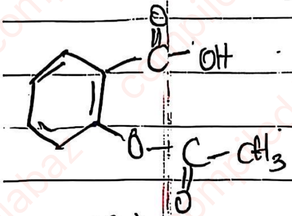
① Drug molecules (API) → Active Pharmaceutical Ingredient

② Excipients: The most important excipient for tablet is Starch. The starch functions as a binder for the drug molecule, it make the drug hard.

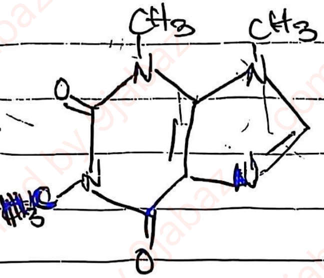
nything to be used in the pharmaceutical industry must be 99.9% pure, very pure.

The Starch used in the pharmaceutical industry is Corn starch

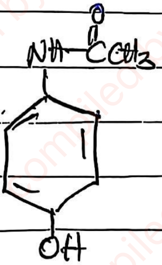
API



aspirin



Caffeine



Paracetamol molecule

amin C – Ascorbic acid

olypropylene is resistant to chemical attacks.

Solutions
(i) intravenous → drip
(ii) Saline, ionic
(iii) Therapeutics

fat soluble

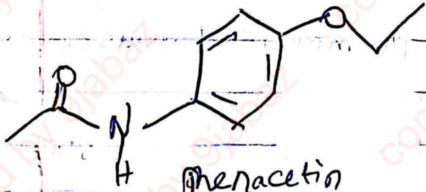
④ Injection ⑤ Emulsion ⑥ stabilizers e.g Tocopherol, ascorbic acid

⑦ Vaccines ⑧ Antibodies

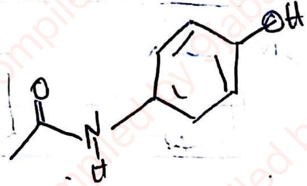
water soluble

Assignment

Get more list of Pharmaceutics

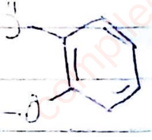


phenacetin

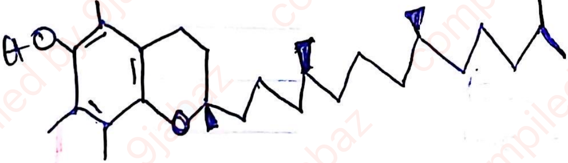


Paracetamol

Tylenol

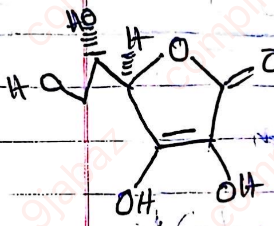


Tocopherol structure



*It can behave like an anti oxidant

oxidant helps to preserve the shelf life of a molecule



ascorbic acid

$\downarrow [O]$

$R^{\bullet} \quad {}^{\bullet}H \longrightarrow RH$

$RO^{\bullet} \quad {}^{\bullet}H \longrightarrow ROH$

Chemist do;
(i) organic synthesis
(ii) process chemistry
(iii) Chemical-eng
(iv) Industrial chemistry

Difference between API VS Tablet

e.g Paracetamol API is the drug molecule
paracetamol tablet is the drug molecule + excipients + stabilizers

Chemistry do:
Analysis (i) purity level (ii) Quality control

API

① Non steroidal Anti inflammatory agents (NSAIDs)
② Antimicrobial agents
③ Antimalarials
④ Anti depressants   Research

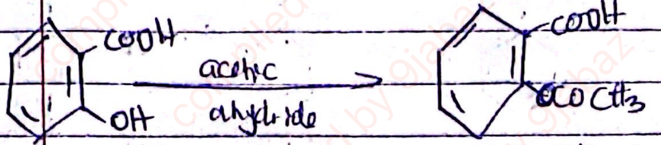
* Research & Development (R&D): Drug Design and Development R

- Organic Synthesis
- Pharmacology
- Biochemistry
- Microbiology

NSAIDs

(i) Aspirin
(ii) Paracetamol
(iii) Ibuprofen
(iv) Naproxen
(v) Diclofenac
(vi) Indomethacin

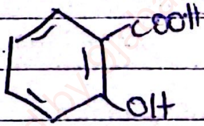
Aspirin Preparation



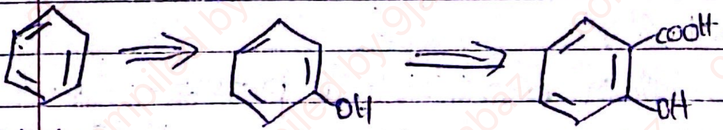
Salicylic acid

Acetyl salicyclic acid
(aspirin)

Starting Material



① salicylic acid. What is the source??

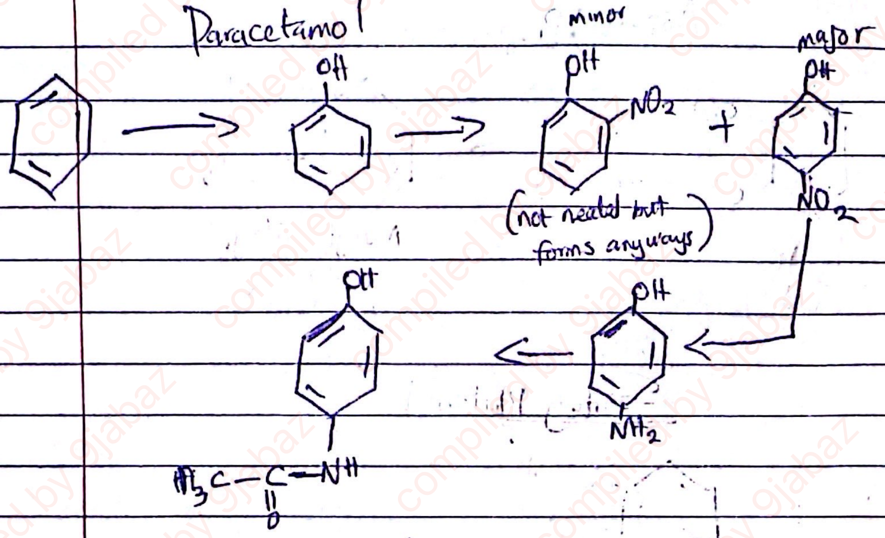


Petrochemica

petro chemical

② Detemine If it will be economical to produce
Natural or synthetic means
③ salicyclic acid throgn petro chemical
① Condition
⑪ Chemical reaction
⑩ Equipment

Paracetamol



para acetaminophenol

What is the industrial production of paracetamol, write all steps.

⊛ In the industry, describe all the process and conditions ④ for the production of paracetamol API

Down process

13/11/2025

tea → conc $\xrightarrow{\text{column chromatography}}$ isolated white powder

$\downarrow$ ~~product~~

melting point → UV → mass spectroscopy $\xrightarrow{\text{elemental analysis}}$ Formular

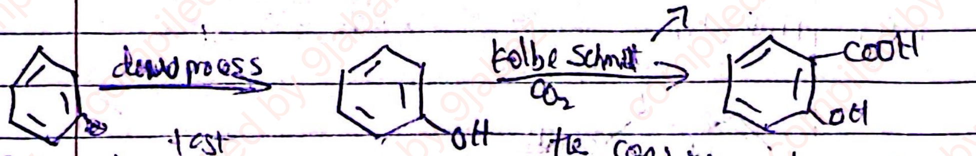
$\downarrow$ NMR

Structure

Synthesis

The pharmaceutical company is a petrol halide industry. Salicyclic acid can be ~~start~~ gotten starting with benzene (from petrochemicals)

conditions; H_2SO_4 catalyst



Explain down process and ~~how to get~~ the conditions to get a good yield.

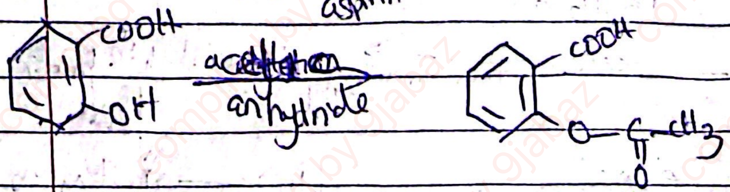
Condition

(i) catalyst (ii) temperature (iii) pressure (iv) solvent

If the temperature is 105°–150°C it favours the ortho product but if the temperature is 220°–250°C it produces the para product

side effect started showing up e.g ulcer due to the phenolic OH, then it was esterified by acetylation

* Salicyclic acid is the precursor to asprin.

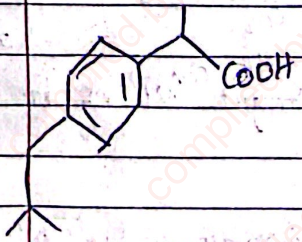


Meanwhile, asprin still causes ulcer but not as much as salicyclic acid. Therefore other drugs have been made to resemble ~~asprin~~ Salicylic e.g paracetamol.

(i)

It has been made to have the therapitic feature of Salicyclic acid and not cause ulcer, which has been successful.

(ii) Ibuprofen



Precursor molecule is the one that we can do a slight modification to get our target molecule.

Precursor ——→ Target molecule

↓ breakdown in biological system

Metabolite

Industrial Processes for making API

① The reaction(s): Feasibility is considered
② Reagents : Source, affordability is considered
③ Condition ; affordability, infrastructure is considered.

consideration

Assignment & test

- Kinds of reactors in industry.

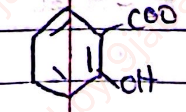
④ Work-up
(i) filtration
(ii) recrystallization
(iii) Purification (chromatography) ⇒ Find out what type of chromatography
(iv) Analysis ⟶ What do you consider in analysis??

test.

test
What are the considerations

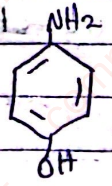
14/11/25

Aspirin



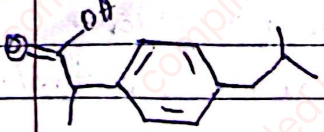
Precursor molecule

Paracetamol



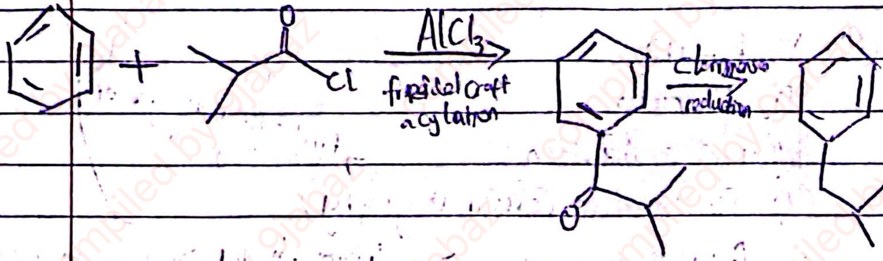
precursor molecule

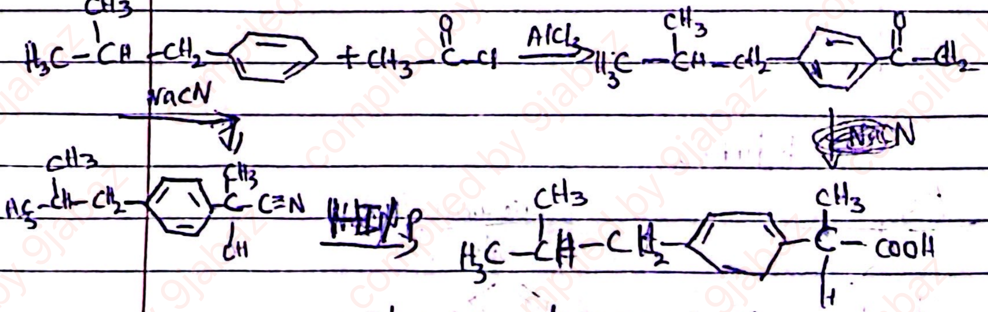
Ibuprofen



Ibuprofen

We can start with benzene





* Why grignard reagent not used?

Atom economy is a measure of mass efficiency of a Chemical reaction, Specifically the proportion of reactant atoms that are incorporated into the desired products

Boots synthesis step; it is 40% atom efficient

① Friedle acylation of isobutyl benzene with acetyl chloride
② Darzens reaction with ethyl chloroacetate to form epoxy ester
③ Hydrolysis and decarboxylation to form an aldhyde
④ Condensation with hydroxyamine to form an aldoxime
⑤ Dehydration of the aldoxime using acetic anhydride to yield to nitrile
(6.) Acid-catalyzed hydrolysis of the nitrile to the final carboxylic acid (Ibuprofen)

Dr. Lawal's part

Cement is a binder, before content can bind it must react with ~~w~~ water

Operations for producing cement

raw material ⟶ rotary kiln $\xrightarrow{\text{clinker}}$ grinder

The major raw material for cement is limestone

$CaCO_3 \longrightarrow CaO + CO_2$

Others are silica, alumina

Process involved

① Quarrying : where it is crushed

② Raw material preparation; (Dry and wet process)

③ ~~Drying process~~ Clinkering

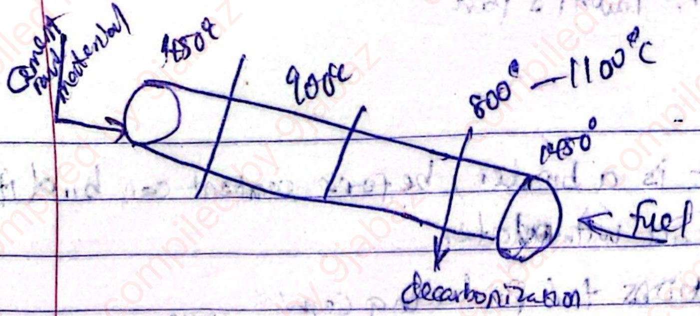
The rotary kiln is divided into four

① Drying zone with temp. °F about 450°C

(ii) Calcination zone : with temp about 900°C that is where the reaction $CaCO_3 \longrightarrow CaO + CO_2$ take place

(iii) Clinkering zone : This where the main reaction takes place with temp of 1250°– 1450°C

Compounds like tricalcium silicate (C_3S), dicalcium silicate (C_3S), tricalcium aluminate (C_3A)



Zone 1 — decarbonation, above 900°C

$$CaCO_3 \xrightarrow{heat} CaO + CO_2$$

calcination

Zone 2, temp. 1100 → 1300°C

$$CaO + SiO_2 \rightarrow 2CaO\,SiO_2$$

Zone 3, sintering stage → breaking into fine particle

$$2CaO.SiO_2 + CaO \rightarrow 3CaO\,SiO_2$$

$$3CaO\,Al_2O_3 + CaO + FeO_3 \rightarrow 4CaO\,Al_2O_3\,Fe_2O_3$$

Assigment

① Mention ~~cod~~ 8 physical and chemical Analysis carried out on cement and discuss their importance.

② Discuss the importance of cyberspace, internet of Thing (IoT) and machine learning (ML) in Cement production

CEMENT

Cement is one of the most fundamental materials in modern construction and civil engineering. It serves as binding component in concret, mortars and grouts.

Cement is defined as a binder, a substance capable of setting, hardening and adhering to other materials to bind them together.

The most widely used category is hydraulic cement, which sets and hardens through chemical reactions with water and remains stable even when exposed to moisture.

Portland Cement is the most common hydraulic cement that forms the basis of the vast majority of concrete structures globally.

Manufacture of Cement (Portland Cement)

It involves a highly controlled sequence of operation

The manufacturing process involved include; raw material extraction, preparation, burning in the rotary kiln to produce clinker and grinding the clinker with gypsum to regulate setting time.

raw material extraction ⟶ preparation ⟶ burning in the rotary kiln to produce clinker ⟶ grinding of clinker with gypsum to regulate setting time.

There are two main approaches
(i) the dry process (ii) the wet process

Raw Materials

The main raw material for cement manufacture is limestone ($CaCO_3$), which serves as the major source of lime (CaO).

Other essential components – silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3) commonly supplied through clay, shale, laterite and other minerals. The proportions of these oxides determine the chemical makeup of the finished cement and strongly influence the performance characteristics.

(1) Quarrying

Limestone and clay are extracted from quarries using drilling, Blas or mechanical excavation. The raw materials are transported to the cement plant, where they are crushed into small fragments. This early stage aims to ensure consistency in raw feed composition

(2) Raw material Preparation

To produce high quality cement, it is crucial to maintain a uniform mixture of the required mineral oxides. This stage involves proportioning, blending and grinding

The Dry process

In the dry process, the crushed limestone and clay are dried if necessary and then crushed and then ground into a fine powder, with particles less than 20Mm in size, ensuring efficient reaction and heat transfer in the kiln.

The Wet process

In wet process, the materials are mixed with water in a wash mill to form slurry. The clay is pulverized in the presence of water, producing a mixture that is homogenized, screened and corrected chemically if needed. While the wet method offers more superior raw meal. It consumed ~~a lot of~~ more energy due to evaporation of water during clinkering.

Therefore modern plants have shifted to the dry process, which is more energy efficient and environmentally sustainable

⑧. Clinkering

The raw meal (dry powder or slurry) is feed into the rotatary kiln where drying, heating, calcination and clinkering a high temperature reaction stage yielding nodules known as clinker

Rotary kiln

60m long steel cylinder

The raw materials passes through:

(i) Drying zone: Remove moisture

(ii) Calcination zone: (~900°C): $CaCO_3$ decomposes to $CaO + CO_2$.

(iii) Clinkering zone (1250 – 1450°)

Reactions

Zone 1: 0–35mins, 800–1100°C.

Decarbonation; Formation of $3CaO \cdot Al_2O_3$ above 900°C; Melting of fluxing compounds, Al_2O_3 and Fe_2O_3

$$CaCO_3 \xrightarrow{heat} CaO + CO_2$$

Zone 2: 35–40min, 1100–1300°c

Exothermic reactions and formation of secondary silicate phases.

$$2CaO + SiO_2 \longrightarrow 2CaO \cdot SiO_2$$

Zone 3: 40–50mins 1300–1450–1300°c

Sintering and reaction within the melt to form ternary silicates and tetra calcium aluminoferrate

$$2CaO \cdot SiO_2 + CaO \xrightarrow{heat+time} 3CaO \cdot SiO_2$$

$$3CaO \cdot Al_2O_3 + CaO + Fe_2O_3 \xrightarrow{heat+time} 4CaO \cdot Al_2O_3 \cdot Fe_2O_3$$

Zone 4: 50–60min, 1300 – 1000°c

Cooling and crystallization of various mineral phase formed in kiln

④ Cement milling

Clinker nodules, typically 3–15mm in diameter are mixed with about 3-5% gypsum (calcium sulfate dihydrates) and ground into a fine powder using ball mills or vertical roller mills. The smoothness of cement particles affects the strength development and rate of hydration.

Gypsum is essential for controlling the setting time, without it, C_3A would hydrate almost immediately

Chemical composition of Portland Cement

The four major clinker compounds; C_3S, C_2S, C_3A, C_4AF are resposible for strength development, heat evolution, durability and other characteristics

Other minor constituents, e.g MgO, alkalis, (Na_2O, K_2O) and sulfates influence performance, particularly durability and setting behaviour.

C_3S	Tricalcium silicate Ca_3SiO_5	Early strength, rapid hydration
C_2S	dicalcium silicate Ca_2SiO_4	Long term strength
C_3A	tricalcium Aluminate $Ca_3Al_2O_6$	Very fast reaction, high heat
C_4AF	tetracalcium Alumino ferrite $Ca_4Al_2Fe_2O_{10}$	Reduces clinkering temperature, contributes to colour.

Hydration of Cement

Hydration is the process ~~by~~ which cement react with water to form hardened products. Each compounds hydrates at a differ rate and contributes uniquely to strength development

Upon contact with water, cement particles dissolve, releasing ion such as Ca^{2+}, OH^-, SiO_4^{4-} and $Al(OH)_4^-$. These ions then recombine to form hydration products;

(i.) Calcium silicate hydrate
(ii.) Calcium hydroxide
(iii.) Ettringite and monosulphate phases

Hydration Characteristics of Cement Constituent

① C_3S – hydrates rapidly and is largely responsible for initial set and early strength within first 7 days, cements rich in C_3S develop high early compressive strength, commonly used in high-early-strength application

② C_3A – hydrates the fastest and releases large amount of heat. To prevent flash setting, gypsum is added to the cen to regulate the reaction and allow usable working time

③ C_2S – hydrates slowly and contributes primarily to streng gain beyond one week, enhancing long term performan

④ C_4AF – hydrates moderately rapidly but contributes little to strength. Its presence, however lowers the required kiln temperature for clinkering, making production more efficient

Paper

Lignin are high molecular weight biopolymer

Importance of Removing Lignin

(i) To make white and bright paper
(ii) To ~~increase~~ improve paper strength
(iii) To enhance chemical stability and longeity
(iv) To improve processibility

A wood with high cellulose fiber

② Pulping to improve impurity.
Steps involved in pulping
1. Preparation of raw material: The wood is first debarked, then chop it into tiny particles
2. Seperation of fibre: chips are kept in large pressure cooker and digested with steam at a specific temperature

③ Bleaching proces

* rat and cockroaches eat paper Sometimes because it is rich in Cellulose

* Paper making procedure

(I.) Pulping procedure
(II) Refining procedure
(III) Dilution process to form a thin fibre
(IV) formation of fibres on a thin screen
(V) Pressurization to enhance materials density
(VI) Drying to eliminate the density of material
(VII) Finishing procedure

Pulping

Different type;

(I) Mechanical pulp: grindstones is embedded with silicon carbide or aluminium oxide (why?) and are used to grind small wood logs to make ston pulp. They are used for products that require less strength such as newsprint

(II) Thermomechanical pulp: produced by processing woo chips using heat. The lignin is not removed.

(iii) Chemi-Thermomechanical pulp: Thee goal is to make fibros easier to refine

(iv) Chemical pulp: The lignin chemical compound is removed with chemical pulp. Kraft process is the dominant chemical pulping method

~~Sulfite process~~

Sulfite

Assignment

(i) Explain the term textile
(ii) Mention and explain general properties of fibre
(iii) Breifly discuss the following types of fibre
(a) Natural fibre
(b) Synthetic fibre
(c)

* Structure of lignin, cellulose and naming them
\+ Types of lignin that should be removed in pulping

FOOD PROCESSING TECHNOLOGY

Explain the term food technolog

Basic composition of food

examples;

1. Macronutrient: Structure of protein, what is peptide → define
2. Micronutrient

(a) Vitamins: types; water soluble and fat soluble

Give 5 examples

Vitamin A — Ascorbic acid

types of vitamins and functions-

* Deficiencies in micronutrient

Physical & Chemical Composition of food

Chemical ppt: reactivity, flavour

* how to determine the expiry date of food.

Food Preservation

* Traditional method Modern methods

Modern (i) pasteurization - heat → rapidly cool

(ii) freezing

(iii) Bogging

(iv) Vacuum packing

Preservative can considered to be carcinogenic

* Shelf life
* Sensory evaluation and quality control
* Food processing technology

27/11/26

Polymer

Polyol – any compound that has 2-OH group

* Natural polymers
* Synthetic polymers

Types of Polymerization

Polymerization is the process of reacting small molecules together to form three dimensional network or polymer chain

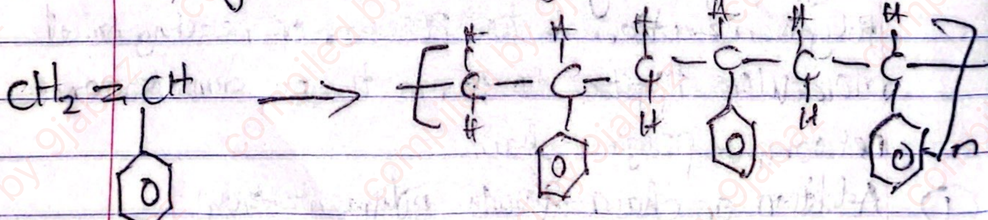
① Addition or chain-growth polymerization
② Condensation or step growth polymerization

for no.1, unsaturated monomers are converted to polymers of high molecular weight

Examples of Monomer and their Polymer

Monomers	Polymer	Repeat units
1. ethylene $CH_2=CH_2$	Polyethylene	$[CH_2-CH_2]_n$
2. polypylene $CH_2=\overset{CH_2}{\underset{\vert}{CH}}$	polypropylene	$[CH_2-\overset{CH_2}{CH}]_n$
Other monomers are styrene		
③ styrene $CH_2=\underset{C_6H_5}{CH}$	polysterene	$[CH_2-\overset{C_6H_5}{\underset{H}{C}}]_n$

Polymerization of Styrene



sterene

polystenene

Mechanisms

① Free radical chain polymerization steps;

(i) initiation of the active monone

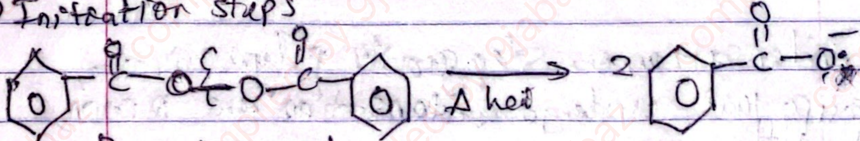
(ii) Propagation or growth of the active chain by sequential addition of monomer

(iii) Termination of the active chain to give the final product.

Examples of initiators, benzoic peroxide, acetyl peroxide, hydrogen peroxide

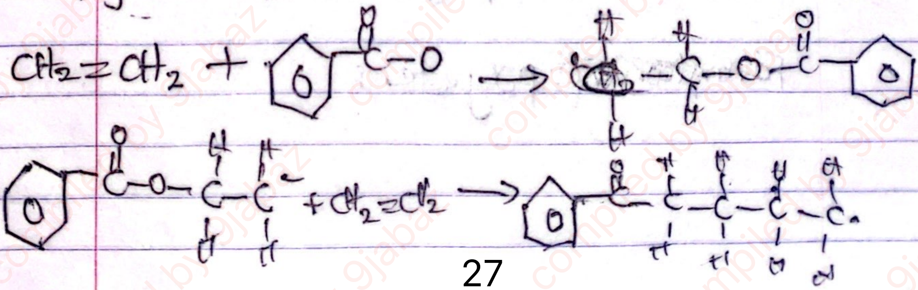
Examples of .

① Initiation steps

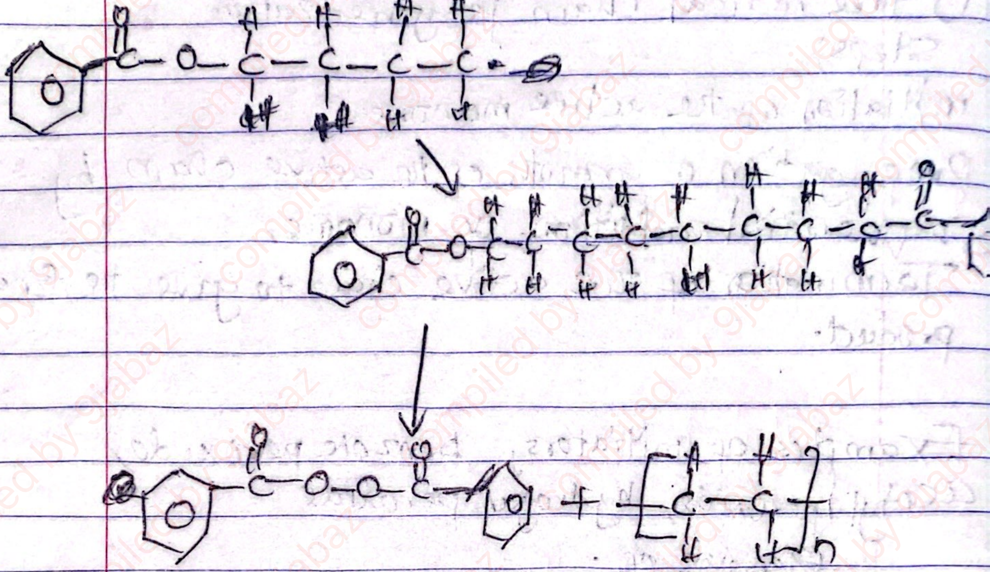


Benzoyl peroxide

(2) Propagation step



Termination step



② Condensation or step growth polymerization

Groups that undergo condensation are $RCOOH$, OH, NH_2, NCO

Examples of condensation polymers; polyesters, polyethers, Polyurethanes, phenolic, expoxy resin etc.

Formation of polyesters

Formation of polyester

$HO-CH_3-CH_2-OH + HOOC-(CH_2)_4-COOH$

$HO-[CH_2-CH_2-OOC-(CH_2)_4-COO]-H + H_2O$

CEMENT: MANUFACTURE AND CHEMICAL COMPOSITION

Introduction

Cement is one of the most fundamental materials in modern construction and civil engineering, serving as the binding component in concrete, mortars, and grouts. In its broadest sense, a cement is defined as a binder a substance capable of setting, hardening, and adhering to other materials to bind them together. While many natural and synthetic materials exhibit cementing properties, the most widely used category is hydraulic cement, which sets and hardens through chemical reactions with water and remains stable even when exposed to moisture. **Portland cement** is the most common hydraulic cement that forms the basis of the vast majority of concrete structures globally.

Manufacture of Cement (Portland cement)

Modern Portland cement production involves a highly controlled sequence of operations. The manufacturing process involved include raw material extraction, preparation, burning in a rotary kiln to produce clinker, and grinding the clinker with gypsum to regulate setting time. Two main approaches—the dry process and the wet process—are used depending on the raw materials and technological preferences. The steps involved in the manufacturing of cement are presented in Figure 1.

Raw Materials

The main raw material for cement manufacture is **limestone ($CaCO_3$)**, which serves as the major source of lime (CaO). Other essential components include **silica (SiO_2)**, **alumina (Al_2O_3)**, and **iron oxide (Fe_2O_3)**, commonly supplied through clay, shale, laterite, or other minerals. The proportions of these oxides determine the chemical makeup of the finished cement and strongly influence its performance characteristics.

1. Quarrying

Limestone and clay are extracted from quarries using drilling, blasting, or mechanical excavation. The raw materials are transported to the cement plant, where they are crushed into smaller fragments. This early stage aims to ensure consistency in raw feed composition, as natural deposits often vary in mineral content.

2. Raw Material Preparation

To produce high-quality cement, it is crucial to maintain a uniform mixture of the required mineral oxides. This stage involves proportioning, blending, and grinding.

The Dry Process

In the dry process, the crushed limestone and clay are dried if necessary and then crushed or ground into a fine powder. Mineral adjustments are made to correct chemical deficiencies. The raw meal is ideally composed of particles less than 90 μm in size, ensuring efficient reaction and heat transfer in the kiln.

The Wet Process

In the wet process—historically used where clay contained high moisture—the materials are mixed with water in a wash mill to form a slurry. The clay is pulverized in the presence of water, producing a fluid mixture that is homogenized, screened, and corrected chemically if needed. While the wet process offers superior raw meal homogeneity, it consumes significantly more energy due to the need to evaporate water during clinkering. For this reason, most modern plants have shifted to the dry process, which is more energy-efficient and environmentally sustainable (Gartner & Sui, 2018).

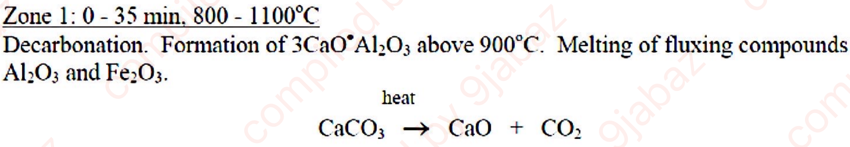
3. Clinkering

The prepared raw meal (dry powder or slurry) is fed into a **rotary kiln**, where it undergoes drying, heating, calcination, and **clinkering** a high-temperature reaction stage yielding nodules known as clinker.

The Rotary Kiln

A rotary kiln is typically a 60-meter-long steel cylinder mounted on roller bearings and inclined at about 1 in 30 as shown in Figure 2. Pulverized coal or alternative fuels are injected into the lower end of the kiln, where their combustion provides temperatures up to 1450°C. As the kiln rotates, raw materials pass through successive thermal zones:

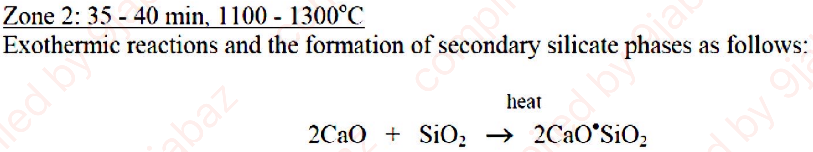
1. **Drying zone:** Removes moisture.
2. **Calcination zone (~900°C):** $CaCO_3$ decomposes to $CaO + CO_2$.
3. **Clinkering zone (1250–1450°C):** Complex reactions form cement compounds such as Tricalcium silicate (C_3S), Dicalcium silicate (C_2S), Tricalcium aluminate (C_3A), Tetracalcium aluminoferrite (C_4AF). The formation of these compounds determines early and long-term strength characteristics. The clinker exits the kiln red-hot and is rapidly cooled to stabilize the mineral phases.



Zone 1: 0 - 35 min, 800 - 1100°C

Decarbonation. Formation of $3CaO^{\bullet}Al_2O_3$ above 900°C. Melting of fluxing compounds Al_2O_3 and Fe_2O_3.

$$CaCO_3 \xrightarrow{\text{heat}} CaO + CO_2$$



Zone 2: 35 - 40 min, 1100 - 1300°C

Exothermic reactions and the formation of secondary silicate phases as follows:

$$2CaO + SiO_2 \xrightarrow{\text{heat}} 2CaO^{\bullet}SiO_2$$

Zone 3: 40 - 50 min, 1300 - 1450 - 1300°C

Sintering and reaction within the melt to form ternary silicates and tetracalcium alumino-ferrates:

$$2CaO^{\bullet}SiO_2 + CaO \xrightarrow{\text{heat + time}} 3CaO^{\bullet}SiO_2$$

$$3CaO^{\bullet}Al_2O_3 + CaO + Fe_2O_3 \xrightarrow{\text{heat + time}} 4CaO^{\bullet}Al_2O_3^{\bullet}Fe_2O_3$$

Zone 4: 50 - 60 min, 1300 - 1000°C

Cooling and crystallisation of the various mineral phases formed in the kiln.

4. Cement Milling

Clinker nodules, typically 3–15 mm in diameter, are mixed with about 3–5% gypsum (calcium sulfate dihydrate) and ground into a fine powder using ball mills or vertical roller mills. The smoothness of cement particles affects the strength development and rate of hydration. Gypsum is essential for controlling the setting time; without it, C_3A would hydrate almost instantaneously.

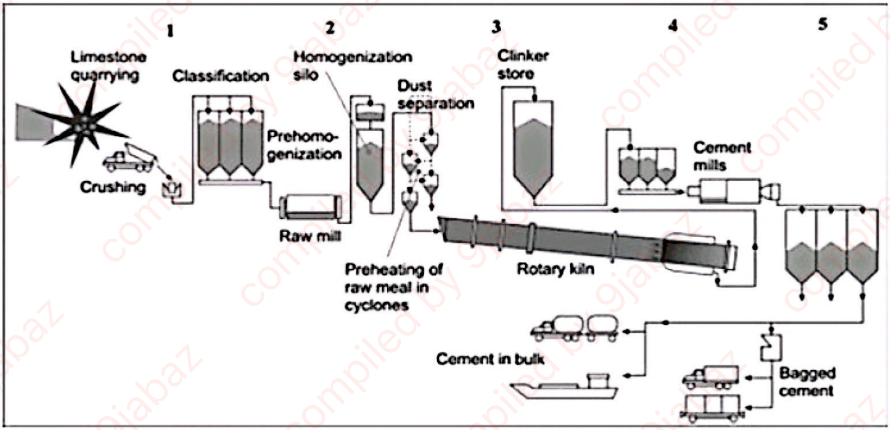


Figure 1. Schematic diagram for the manufacturing of cement

Figure 2. Image of a rotary kiln

Chemical Composition of Portland Cement

Cement's properties depend largely on its chemical composition. The four major clinker compounds: C_3S, C_2S, C_3A, and C_4AF, are responsible for strength development, heat evolution, durability, and other characteristics as presented in Table 1. Other minor constituents such as magnesium oxide (MgO), alkalis (Na_2O, K_2O), and sulfates also influence performance, particularly durability and setting behavior.

Table 1. Chemical composition of Portland cement

S/n	Compound	Chemical Formula	Abbreviation	Function
1.	Tricalcium silicate	Ca_3SiO_5	C_3S	Early strength, rapid hydration
2.	Dicalcium silicate	Ca_2SiO_4	C_2S	Long-term strength
3.	Tricalcium aluminate	$Ca_3Al_2O_6$	C_3A	Very fast reaction; high heat
4.	Tetracalcium aluminoferrite	$Ca_4Al_2Fe_2O_{10}$	C_4AF	Reduces clinkering temperature, contributes to color

Hydration of Cement

Hydration is the process by which cement reacts with water to form hardened products. Each compound hydrates at a different rate and contributes uniquely to strength development. Upon contact with water, cement particles dissolve, releasing ions such as Ca^{2+}, OH^-, SiO_4^{4-}, and $Al(OH)_4^-$. These ions then recombine to form hydration products including the following:

i. **Calcium silicate hydrate (C–S–H)**: The main binding phase
ii. **Calcium hydroxide (CH)**
iii. **Ettringite and monosulfate phases**

Hydration Characteristics of Cement Constituents

1. **Tricalcium Silicate (C_3S) -** C_3S hydrates rapidly and is largely responsible for initial set and early strength within the first 7 days. Cements rich in C_3S develop high early compressive strength and are commonly used in high-early-strength applications.
2. **Tricalcium Aluminate (C_3A) -** C_3A hydrates the fastest and releases a large amount of heat. To prevent flash setting, gypsum is added to the cement to regulate the reaction and allow usable working time.
3. **Dicalcium Silicate (C_2S) -** C_2S hydrates slowly and contributes primarily to **strength gain beyond one week**, enhancing long-term performance.
4. **Tetracalcium Aluminoferrite (C_4AF) -** Hydrates moderately rapidly but contributes little to strength. Its presence, however, lowers the required kiln temperature for clinkering, making production more energy efficient.

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PULP AND PAPER MAKING PROCESS

Pulp and paper are made from cellulosic fibres and other plant materials. Some synthetic materials may be used to impart special qualities to the finished product [Figure 1]. Paper is made from wood fibres, but rags, flax, cotton linters, and sugar cane residues are also used in some papers. Used paper is also recycled, and after purifying and sometimes deinking, it is often blended with virgin fibres and reformed again into paper. Products such as cellulose acetate, rayon, cellulose esters made from cellulose can be used for packaging films. The pulping process is aimed at removing lignin without losing fibre strength, thereby freeing the fibres and removing impurities that cause discoloration and possible future disintegration of the paper. Hemicellulose plays an important role in fiber-to-fiber bonding in papermaking. It is similar to cellulose in composition and function. Several extractives such as waxes, oleoresins are contained in wood but they do not contribute to its strength properties; these too are removed during the pulping process.

The fiber extracted from any plant can be used for paper. However, the strength and quality of fiber, and other factors complicate the pulping process. In general, the softwoods (e.g., pines, firs, and spruces) yield long and strong fibers that contribute strength to paper and they are used for boxes and packaging.

Hardwoods produce a weaker paper as they contain shorter fibers. Softwoods are smoother, transparent, and better suited for printing. Softwoods and hardwoods are used for paper-making and are sometimes mixed to provide both strength and print ability to the finished product.

Steps involved in pulp

1. Preparation of raw Material

Wood that has been received at a pulp mill can be in different forms. It depends on the pulping process and the origin of the raw material. It may be received as bolts (short logs) of round-wood with the bark still attached, as chips about the size of a half-dollar that may have been produced from sawmill from debarked round wood elsewhere.

If round wood is used, it is first debarked, usually by tumbling in large steel drums where wash water may be applied. Those debarked wood bolts are then chipped in a chipper if the pulping process calls for chemical digestion. Chips are then screened for size, cleaned, and temporarily stored for further processing.

2. Separation of Fibre

In the fibre separation stage, the chips are kept into a large pressure cooker (digester), into which is added the appropriate chemicals in kraft chemical pulping.

The chips are then digested with steam at specific temperatures to separate the fibers and partially dissolve the lignin and other extractives. After the digestion process, the cooked pulp is discharged into a pressure vessel. Here the steam and volatile materials are tubed off. After that, this cooked pulp is returned to the chemical recovery cycle. Fibre separation in mechanical pulping is less dramatic. Debarked logs are forced against rotating stone grinding wheels in the stone ground-wood procedure. Refiner pulp and thermo-mechanical pulp are produced by chips. These chips are ground by passing them through rapidly rotating in both processes.

In the second stage after refining, the pulp is screened, cleaned, and most of the process water is removed in preparation for paper making.

Figure 1, Schematic diagram for pulp and paper making process

3. Bleaching Process

Raw pulp contains an appreciable amount of lignin and other discoloration, it must be bleached to produce light colored or white papers preferred for many products. The fibers are further delignified by solubilizing additional lignin from the cellulose through chlorination and oxidation. These include chlorine dioxide, chlorine gas, sodium hypochlorite, hydrogen perioxide, and oxygen. Sodium Hydroxide, a strong alkali is used to extract the dissolved lignin from fibers surface. The bleaching agents and the sequence in which they are used depend on a number of factors, such as the relative cost of the bleaching chemicals, type and condition of the pulp.

Mechanical pulp bleaching varies from chemical pulp bleaching. Bleaching of mechanical pulp is designed to minimize the removal of the lignin that would reduce fiber yields.

Chemicals used for bleaching mechanical pulps selectively destroy coloring impurities but leave the lignin and cellulosic materials intact; these include sodium bisulfite, calcium or sodium hypochlorite, and hydrogen or sodium peroxide.

Papermaking Procedure

Paper is made through the following processes:

1) Pulping procedure will be done to separate and clean the fibres
2) Refining procedure will be followed after pulping processes
3) Dilution process to form a thin fibre mixture
4) Formation of fibres on a thin screened
5) Pressurization to enhance the materials density
6) Drying to eliminate the density of materials
7) Finishing procedure to provide a suitable surface for usage

Bleached or unbleached pulp may be further refined to cut the fibers and roughen the surface of the fibers to enhance formation and bonding of the fibers as they enter the paper machine. Water is added to the pulp slurry to make a thin mixture normally containing less than 1 percent fiber. The dilute slurry is then cleaned in cyclone cleaners and screened in centrifugal screens before being fed into the 'wet end' of the paper-forming machine. The dilute stock passes through a head-box that distributes the fiber slurry uniformly over the width of the paper sheet to be formed.

1. Pulping

Different method of pulping

i. Mechanical pulp

Manufactured grindstones with embedded silicon carbide or aluminum oxide can be used to grind small wood logs called "bolts" to make stone pulp. If the wood is steamed prior to grinding it is known as pressure ground wood pulp. Most modern mills use chips rather than logs and ridged metal discs called refiner plates instead of grindstones. If the chips are just ground up with the plates, the pulp is called refiner mechanical pulp and if the chips are steamed while being refined the pulp is called thermomechanic pulp. Steam treatment significantly reduces the total energy needed to make the pulp and decreases the damage (cutting) to fibres. Mechanical pulps are used for products that require less strength, such as newsprint and paperboards.

ii. Thermomechanical pulp

Thermomechanical pulp is pulp produced by processing wood chips using heat (thus "thermo-") and a mechanical refining movement (thus "-mechanical"). It is a two-stage process where the logs are first stripped of their bark and converted into small chips. These chips have a moisture content of around 25–30 percent. A mechanical force is applied to the wood chips in a crushing or grinding action which generates heat and water vapour and softens the lignin thus separating the individual fibres. The pulp is then screened and cleaned, any clumps of fibre are reprocessed. This process gives a high yield of fibre from the timber (around 95 percent) and as the lignin has not been removed, the fibres are hard and rigid.

iii. Chemi-thermomechanical pulp

Wood chips can be pre-treated with sodium carbonate, sodium hydroxide, sodium sulphate and other chemicals prior to refining with equipment similar to a mechanical mill. The conditions of the chemical treatment are much less vigorous (lower temperature, shorter time, less extreme pH) than in a chemical pulping process since the goal is to make the fibers easier to refine, not to remove lignin as in a fully chemical process. Pulps made using these hybrid processes are known as chemi-thermomechanical pulps (CTMP).

iv. Chemical pulp

Chemical pulp is produced by combining wood chips and chemicals in large vessels called digesters. There, heat and chemicals break down lignin, which binds cellulose fibres together, without seriously degrading the cellulose fibres. Chemical pulp is used for materials that need to be stronger or combined with mechanical pulps to give a product different characteristics. The kraft process is the dominant chemical pulping method, with the sulfite process second. Historically soda pulping was the first successful chemical pulping method.

Sulfite process

This produces wood pulp that is almost pure cellulose fibers by treating wood chips with solutions of sulfite and bisulfite ions. These chemicals cleave the bonds between the cellulose and lignin components of the lignocellulose [Figure 2]. A variety of sulfite/bisulfite salts are used, including sodium (Na^+), calcium (Ca^{2+}), potassium (K^+), magnesium (Mg^{2+}), and ammonium (NH^{4+}). The lignin is converted to lignosulfonates, which are soluble and can be separated from the cellulose fibers. For the production of cellulose, the sulfite process competes with the Kraft process, which produces stronger fibers and is less environmentally costly.

Sulphate process

The kraft process (also known as kraft pulping or sulfate process) is a process for conversion of wood into wood pulp, which consists of almost pure cellulose fibers, the main component of paper. The kraft process entails treatment of wood chips with a hot mixture of water, sodium hydroxide (NaOH), and sodium sulfide (Na_2S), known as white liquor that breaks the bonds that link lignin, hemicellulose, and cellulose. The technology entails several steps, both mechanical and chemical. It is the dominant method for producing paper. In some situations, the process has been controversial because kraft plants can release odorous products and in some situations produce substantial liquid wastes.

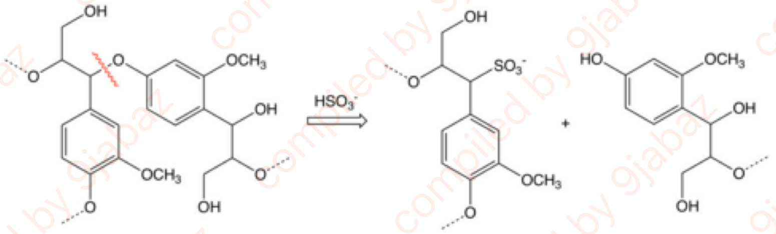

Figure 2. Sulfite process – bonds cleavage between the cellulose and lignin components of the lignocellulose.

Soda pulping

Soda pulping is a chemical process for making wood pulp with sodium hydroxide as the cooking chemical. In the *Soda-AQ process,* anthraquinone (AQ) may be used as a pulping additive to decrease the carbohydrate degradation. The soda process gives pulp with lower tear strength than other chemical pulping processes (sulfite process and kraft process), but has still limited use for easy pulped materials like straw and some hardwoods.

FOOD TECHNOLOGY AND PROCESSING

Abstract

The book chapter titled "Food Technology and Processing" offers a comprehensive overview of the multidisciplinary field that encompasses the scientific concepts and innovative techniques employed in the transformation of raw agricultural materials into safe, nutritious, and appealing food products for consumption. It delves into the realms of scientific principles and innovations of food technology, elucidating its role in product development, safety measures, sensory evaluation, and quality control. These encompass methodologies such as thermal treatments, cold storage, and the judicious incorporation of additives, all aimed at sustaining flavor, quality, and safety. Simultaneously, the chapter explores food processing as a series of transformative steps: from the thorough cleansing and sorting of raw materials to the precision of cooking, mechanical manipulation, and eventual packaging, that collectively shape raw ingredients into a wide array of consumer-ready foods. Together, the domains of food technology and processing synergize to cater to contemporary demands for palatability, nutritional value, safety, and sustainability. This chapter presents a holistic view of their collaborative role, addressing challenges and capitalizing on opportunities within the dynamic landscape of the ever-evolving global food industry. In essence, it highlights the intricate balance between science, innovation, and the culinary arts in delivering the foods that nourish and delight us.

Keywords: Food technology, processing, quality, safety, sustainability

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I. INTRODUCTION

Throughout human history, the basic principles of food processing were born out of necessity. Early societies dried, smoked, or fermented food to extend its shelf life and ensure a continuous supply during lean periods. Techniques like salting, pickling, and sun-drying were employed to prevent spoilage and make food more palatable. The Industrial Revolution marked a significant turning point in food processing. The advent of machinery enabled large-scale production, making processed foods more accessible to a wider population. Canning technology, developed in the early 19th century, revolutionized food preservation by sealing food in airtight containers. This innovation significantly prolonged shelf life, making it possible to transport food over long distances without spoilage.

As scientific knowledge advanced, so did the understanding of the chemical and biological processes behind food spoilage and preservation. The late 19th and early 20th centuries saw the emergence of refrigeration and freezing methods, which further expanded the range of available preserved foods. Pasteurization, named after Louis Pasteur, became a staple process to destroy harmful microorganisms while retaining the flavor and nutritional value of foods like milk and juice. The mid-20th century witnessed the rise of convenience foods and the application of more sophisticated technologies. Microwaves, freeze-drying, and advanced packaging techniques became integral to the food processing industry. As consumer preferences evolved, a demand for healthier and minimally processed foods led to the development of techniques such as high-pressure processing and minimal heat treatment, which preserved the freshness and nutritional quality of foods.

Today, food technology and processing encompass an extensive range of methods and techniques. From genetic modification and nanotechnology to 3D printing and sustainable packaging, the field continues to evolve to meet the demands of a growing global population while addressing concerns about safety, nutrition, and environmental impact. These advancements have not only improved food safety and accessibility but have also shaped the modern culinary landscape, offering a diverse array of choices to consumers worldwide.

1. **Evolution and Significance:** The evolution and significance of food technology and processing encapsulate a transformative journey that has redefined how we produce, consume, and think about food. This evolution mirrors the progress of human civilization and addresses critical global challenges. Food technology and processing have evolved from rudimentary preservation methods in ancient times, driven by the need to sustain food supplies. Innovations like drying, salting, and fermenting paved the way for more advanced techniques.

    During the Industrial Revolution, breakthroughs like canning, pasteurization, and refrigeration revolutionized food preservation, distribution, and safety. This era laid the foundation for the mass production of safe and accessible food. In today's complex landscape, food technology plays a pivotal role in addressing pressing issues. It optimizes agricultural practices, minimizes waste, and enhances food safety. It's a driving force behind functional foods tailored to health needs, and it aligns with sustainable practices to ensure a better future for both people and the planet.

The significance of food technology and processing extends beyond sustenance. It shapes culture, economy, and health. Innovations in processing have led to diverse and convenient food choices, catering to modern lifestyles. Food technology's role in nutritional fortification addresses dietary deficiencies and health concerns. Ultimately, this evolution underscores our ability to harness scientific knowledge and technological advancements to meet the ever-changing demands of a global population. The journey of food technology and processing is a testament to human ingenuity, ensuring safe, nutritious, and enjoyable food for all while promoting sustainable practices for a better world.

2. **Role in Addressing Global Food Challenges:** The role of food technology and processing in addressing global food challenges is pivotal, offering innovative solutions to complex issues that impact food security, nutrition, sustainability, and safety on a global scale.

   - **Enhancing Food Security:** Food technology enables the preservation, processing, and distribution of surplus harvests, reducing post-harvest losses and ensuring a steady food supply. Techniques like canning, drying, and freezing extend shelf life, reducing food wastage and increasing availability.

   - **Improving Nutritional Value:** Food processing techniques such as fortification and enrichment enhance the nutritional content of foods. Micronutrients, vitamins, and minerals are added to staple foods to address malnutrition and nutrient deficiencies, especially in vulnerable populations.

   - **Sustainable Resource Utilization:** Food technology promotes sustainable use of resources by developing efficient processing methods that minimize water consumption, energy use, and waste generation. It also supports the utilization of byproducts and reduces the environmental impact of food production.

   - **Food Safety Assurance:** Advanced processing techniques like pasteurization, high-pressure processing, and irradiation contribute to food safety by eliminating harmful microorganisms. These technologies minimize the risk of foodborne illnesses, safeguarding public health.

   - **Meeting Dietary Preferences:** Food technology caters to diverse dietary preferences and needs by producing allergen-free, gluten-free, vegetarian, and vegan products. This variety accommodates cultural, religious, and health-related dietary choices.

   - **Reducing Environmental Impact:** Food processing technologies facilitate the production of plant-based and alternative protein sources, reducing the environmental strain caused by traditional livestock farming. This supports sustainable agricultural practices and lowers greenhouse gas emissions.

   - **Global Food Distribution:** Processing enables the creation of convenient and ready-to-eat foods that are easy to transport and distribute globally. This aids in providing emergency relief and addressing food shortages in disaster-stricken areas.

- **Innovation in Food Products:** Food technology fosters innovation in creating novel, nutritious, and functional foods. From superfoods to functional beverages, these innovations cater to evolving consumer demands for health, convenience, and unique flavor experiences.

The role of food technology and processing in addressing global food challenges is multi-faceted and transformative. By harnessing scientific advancements and technological innovations, it offers comprehensive solutions that contribute to food security, nutrition, sustainability, and safety, ultimately improving the lives of people around the world.

3. **Interplay between Science, Technology, and Culinary Arts:** The interplay between science, technology, and culinary arts represents a dynamic collaboration that shapes the field of food technology and processing. These three pillars work in harmony to transform raw ingredients into the wide array of safe, nutritious, and appealing foods we enjoy today.

- **Science:** At the core of this interplay lies scientific understanding. Scientists study the chemical, physical, and biological properties of ingredients to unravel their behaviors during processing. For instance, understanding how enzymes work in fruits helps in designing preservation methods that retain their freshness.

- **Technology:** Technological advancements provide the tools and techniques necessary to manipulate ingredients and transform them into diverse food products. Innovations like pasteurization, high-pressure processing, and molecular gastronomy have expanded the possibilities of food creation.

- **Culinary Arts:** The culinary arts bring creativity and sensory expertise to the table. Chefs and culinary experts combine scientific knowledge with artistic flair to create dishes that not only satisfy taste buds but also engage all the senses. They understand how flavors interact, textures complement each other, and presentation impacts perception.

The synergy of these three components is evident throughout the entire food processing chain. From designing efficient production lines to enhancing nutritional content while maintaining taste, the interplay ensures that science-backed innovations are harmoniously integrated with culinary expertise to produce food products that meet the highest standards of safety, quality, and delight.

II. BASIC COMPOSITION OF FOOD

Food is a central part of our lives, providing nourishment, pleasure, and sustenance. Beyond its delicious flavors and enticing aromas, food is a complex mixture of various components that play a crucial role in our overall health and well-being. In this topic, we will delve into the basic composition of food, examining both macro and micronutrients, exploring the chemical and physical properties of food components, and understanding how the composition of food influences it's processing and quality.

Understanding Macro and Micronutrients: Macro and micronutrients are the foundational elements within our diets that contribute to the intricate web of human nutrition. These nutrients are vital for sustaining life, promoting growth, and ensuring the smooth functioning of numerous bodily processes.

1. **Macronutrients:** Macronutrients are the essential nutrients that make up the bulk of our daily caloric intake. They provide the energy needed for bodily functions and physical activity. The three primary macronutrients are**:**

   - **Carbohydrates:** Carbohydrates are the body's primary energy source. They include sugars, starches, and dietary fiber. Simple carbohydrates, like glucose and fructose, are quickly absorbed and provide rapid energy. Complex carbohydrates, found in foods like whole grains, provide sustained energy. Dietary fiber, a type of carbohydrate, aids digestion and offers various health benefits.

   - **Proteins:** Proteins are crucial for growth, repair, and maintenance of tissues. They are made up of amino acids, which serve as the building blocks for enzymes, hormones, and muscle tissue. Complete proteins, found in animal products, contain all essential amino acids. Incomplete proteins, found in plant-based foods, may lack some amino acids but can be combined to create complete protein sources.

   - **Fats:** Fats are a concentrated source of energy and play essential roles in the body. They are vital for the absorption of fat-soluble vitamins (A, D, E, and K), provide insulation and protection for organs, and are involved in various metabolic processes. Fats include saturated fats (often solid at room temperature), unsaturated fats (liquid at room temperature), and trans fats (often found in processed foods and best avoided).

2. **Micronutrients:** Micronutrients are essential nutrients required by the body in smaller quantities compared to macronutrients (carbohydrates, proteins, and fats). Despite being needed in smaller amounts, micronutrients play crucial roles in various physiological processes and are essential for overall health. Micronutrients are divided into two main categories**:**

   - **Vitamins:** Vitamins are organic compounds that play essential roles in various bodily functions, including metabolism, immune function, and maintaining healthy skin, eyes, and bones. They are further categorized into water-soluble vitamins (B-complex vitamins and vitamin C) and fat-soluble vitamins (vitamins A, D, E, and K). Each vitamin has specific functions and food sources.

   - **Minerals:** Minerals are inorganic elements that are essential for a wide range of bodily functions. They include minerals such as calcium, magnesium, potassium, sodium, phosphorus, iron, zinc, and others. These minerals are crucial for bone health, nerve function, muscle contraction, fluid balance, and oxygen transport in the blood, among other functions.

   Micronutrients are primarily obtained through a balanced diet that includes a variety of fruits, vegetables, whole grains, lean proteins, and dairy products. Deficiencies in micronutrients can lead to a range of health problems, such as vitamin deficiencies (e.g., scurvy due to vitamin C deficiency) or mineral deficiencies (e.g., osteoporosis due to calcium deficiency). Conversely, excessive intake of certain micronutrients can also have adverse health effects.

Maintaining a balanced and varied diet that provides an adequate supply of macro and micro nutrients is essential for overall health and well-being. In some cases, dietary supplements may be recommended to address specific micronutrient deficiencies or meet increased nutritional needs.

3. **Chemical and Physical Properties of Food Components:** The chemical and physical properties of food components form the intricate tapestry that defines the nature of foods we consume. Each component, whether it's carbohydrates, proteins, fats, vitamins, or minerals, possesses unique characteristics that contribute to the overall sensory experience and nutritional value of the final product. The chemical properties encompass elements like reactivity, acidity, and flavor compounds. For instance, the Maillard reaction between proteins and sugars during cooking creates flavors and aromas in baked goods. Similarly, understanding how acids influence the gelling of pectin in fruit preserves helps in achieving the desired texture. On the other hand, physical properties include aspects like solubility, viscosity, and elasticity. The physical behavior of proteins, for example, affects the texture of foods like bread and cheese. Fats determine mouthfeel and can influence the perception of creaminess in dairy products. Both these sets of properties intersect and interact during various stages of food processing. From the way starches thicken a sauce to how proteins denature during cooking, these properties define the intricate dance that occurs when ingredients transform into the delectable foods.

4. **Impact of Composition on Processing and Quality:** The intricate relationship between food composition, processing methods, and final product quality is a critical consideration in the realm of food technology. The unique blend of carbohydrates, proteins, fats, vitamins, minerals, and water within each ingredient sets the stage for a cascade of transformations during processing. For instance, the sugar content of fruits can influence the viscosity of jams and jellies during cooking. The protein content of meat determines how it changes in texture and flavor when exposed to heat. The presence of fats can impact the mouthfeel and preservation of baked goods. Moreover, the water content within ingredients plays a pivotal role. It affects the stability of emulsions in dressings and may lead to textural changes in bread and pastries during freezing. The addition of various additives, such as stabilizers or preservatives, can further alter the processing behavior and quality of foods.

III.FOOD PRESERVATION

The principles of food preservation encompass a range of techniques and strategies aimed at extending the shelf life of food, ensuring its safety, and maintaining its nutritional quality.

1. **Traditional and Modern Preservation Methods:** Traditional preservation methods are those that have been used for centuries or even millennia to prevent food from spoiling or

becoming unsafe for consumption. Some examples of traditional preservation methods are**:**

- **Drying:** This method involves removing the moisture from food by exposing it to sun, air, or artificial heat. Drying prevents the growth of microorganisms and enzymes that cause spoilage. Dried foods can last for a long time and are easy to store and transport. However, drying can also reduce the nutritional value, flavor, color, and texture of food.

- **Salting:** This method involves adding salt to food to create an environment that is unfavorable for microbial growth. Salting can also enhance the flavor and texture of food, as well as prevent oxidation. Salting is commonly used for preserving meat, fish, cheese, and vegetables. However, salting can also increase the sodium intake of consumers, which may have negative effects on health.

- **Smoking:** This method involves exposing food to smoke from burning wood or other materials. Smoking can impart a distinctive flavor and aroma to food, as well as inhibit microbial growth and oxidation. Smoking is often used for preserving meat, fish, cheese, and spices. However, smoking can also produce harmful substances such as polycyclic aromatic hydrocarbons (PAHs) and nitrosamines, which may increase the risk of cancer.

- **Pickling:** This method involves preserving vegetables, fruits, and meat in vinegar, lemon juice, or oil. Spices, salt, and sugar are added to the mix to give the pickles their distinct flavour. Pickles can be made with a wide variety of ingredients, such as mangoes, lime, gooseberries, carrots, and onions.

- **Fermenting:** This method involves preserving food by allowing it to sit in a solution of salt or sugar water. The bacteria in the solution break down the sugars in the food, creating lactic acid, which acts as a natural preservative. Fermentation is commonly used to preserve dairy products, such as yogurt and buttermilk, as well as vegetables, such as pickles and sauerkraut.

- **Curing:** This method involves preserving meat by adding salt, sugar, nitrites, or nitrates to it. Curing can also enhance the flavour and colour of meat, as well as prevent the growth of harmful bacteria. Curing is often used for preserving ham, bacon, salami, and sausages.

2. **Modern Preservation Methods:** Modern preservation methods are those that use advanced technology and science to prevent food from spoiling or becoming unsafe for consumption. Some examples of modern preservation methods are**:**

   - **Pasteurization:** This method involves heating liquid food, such as milk or juice, to a high temperature for a short time and then cooling it rapidly. Pasteurization kills most of the harmful microorganisms and extends the shelf life of the food. Pasteurization was invented by Louis Pasteur in the 19th century.

- **Freezing:** This method involves lowering the temperature of food to below 0°C (32°F) to stop microbial growth and enzyme activity. Freezing can preserve the nutritional value, flavor, color, and texture of food for a long time. Freezing is suitable for preserving almost any type of food. However, freezing requires electricity and freezer space, and may cause freezer burn or ice crystals if not done properly.

- **Drying:** This method involves removing the moisture from food by exposing it to hot air or other sources of heat. Drying can reduce the weight and volume of food and make it resistant to microbial spoilage. Drying is suitable for preserving fruits, vegetables, meat, fish, and grains. However, drying can also reduce the nutritional value, flavor, color, and texture of food.

- **Vacuum Packing:** This method involves sealing food in an air-tight plastic bag or container and removing the air from it. Vacuum packing prevents oxygen from reaching the food and inhibits microbial growth and oxidation. Vacuum packing can extend the shelf life of food and retain its quality. Vacuum packing is often used for preserving meat, cheese, nuts, and dried fruits.

- **Irradiation:** This method involves exposing food to ionizing radiation such as gamma rays or X-rays. Irradiation can kill microorganisms and insects, delay ripening, prevent sprouting, and extend shelf life. Irradiation is suitable for preserving fruits, vegetables, meat, fish, eggs, and spices. However, irradiation may also alter the chemical composition, flavor, color, and texture of food.

- **Biopreservation:** This method involves adding beneficial microorganisms or their metabolites to food to inhibit the growth of spoilage microorganisms. Biopreservation can enhance the safety, quality, and shelf life of food. Biopreservation is commonly used for preserving dairy products, such as yogurt and cheese, as well as meat products, such as salami and ham.

- **Hurdle Technology:** This method involves combining two or more preservation methods to create multiple barriers or hurdles for microbial growth. Hurdle technology can improve the safety, quality, and shelf life of food while minimizing the adverse effects of each individual method. Hurdle technology is often used for preserving ready-to-eat meals, such as soups and salads.

- **Modified Atmosphere Packaging (MAP):** This method involves replacing the air in a package with a gas mixture that is optimal for preserving the food. MAP can slow down the respiration rate of fresh produce, inhibit microbial growth and oxidation, and maintain the color and flavor of food. MAP is widely used for preserving fruits, vegetables, meat, fish, bakery products, and cheese.

- **High-Pressure Processing (HPP):** This method involves applying high pressure (up to 600 MPa) to food in a sealed container for a few minutes. HPP can inactivate microorganisms, enzymes, and toxins, and preserve the freshness, flavor, color, and texture of food. HPP is suitable for preserving liquid or semi-solid foods, such as juices, sauces, soups, meats, and seafood.

- **Pulsed Electric Field (PEF):** This method involves applying short pulses of high voltage (up to 80 kV/cm) to food placed between two electrodes. PEF can damage the cell membranes of microorganisms and enzymes, and extend the shelf life of food. PEF is suitable for preserving liquid or semi-solid foods, such as milk, juice, eggs, and mashed potatoes.

- **Ultraviolet (UV) Light:** This method involves exposing food to UV light of a specific wavelength (254 nm) for a short time. UV light can kill or inactivate microorganisms and enzymes, and prevent spoilage and discoloration of food. UV light is suitable for preserving solid or liquid foods, such as fruits, vegetables, meat, fish, milk, and water.

3. **Microbial Safety:** Microbial safety refers to the prevention or reduction of microbial growth and contamination in food. Microorganisms, such as bacteria, fungi, yeast, and viruses, can cause food spoilage and foodborne illnesses. Some methods of food preservation that can enhance microbial safety are**:**

    - **Heating:** This method involves applying heat to food to kill or inactivate microorganisms and enzymes. Heating can be done by boiling, pasteurizing, sterilizing, canning, or baking.

    - **Acidifying:** This method involves lowering the pH of food to create an acidic environment that inhibits microbial growth. Acidifying can be done by adding vinegar, lemon juice, or other acids, or by fermenting food with lactic acid bacteria.

    - **Reducing Water Activity:** This method involves removing or binding water from food to reduce the availability of water for microbial growth. Reducing water activity can be done by drying, salting, sugaring, or adding humectants.

    - **Adding Preservatives:** This method involves adding natural or synthetic substances to food to prevent or delay microbial growth and spoilage. Preservatives can be antimicrobial agents, antioxidants, chelating agents, or pH regulators.

    - **Irradiating:** This method involves exposing food to ionizing radiation, such as gamma rays or X-rays, to kill or inactivate microorganisms and insects. Irradiating can also delay ripening, prevent sprouting, and extend shelf life.

4. **Shelf Life Extension:** Shelf life extension refers to the prolongation of the period of time that food can be stored without losing its quality and safety. Shelf life extension depends on the type of food, the initial microbial load, the storage conditions, and the packaging system. Some methods of food preservation that can extend shelf life are**:**

    - **Preservatives:** One common method for extending the shelf life of food products is the use of preservatives. These are chemical substances added to foods to inhibit the growth of bacteria, molds, and yeasts. For example, sodium benzoate and sorbic acid are preservatives used in many processed foods. These substances help prevent spoilage and maintain the freshness of products.

- **Packaging:** Packaging plays a critical role in preserving the quality and safety of products. Airtight and moisture-resistant packaging can prevent the entry of oxygen, which can cause oxidation and spoilage. It can also prevent moisture from entering, which is essential for products susceptible to moisture-related deterioration. Additionally, some packaging materials have oxygen-absorbing or desiccant properties to further enhance shelf life.

- **Temperature Control:** Controlling temperature is vital for extending shelf life. Many products are stored at specific temperature ranges to slow down the growth of microorganisms and enzymatic reactions that lead to spoilage. Refrigeration and freezing are commonly used to preserve perishable items like meat, dairy, and certain fruits and vegetables.

- **Dehydration:** Removing moisture from food products through dehydration methods like drying or freeze-drying can significantly extend shelf life. Microorganisms require water to grow, and by reducing moisture content, the environment becomes less conducive to their proliferation. Examples include dried fruits, jerky, and powdered milk.

- **Canning:** Canning is a process that involves sealing food in airtight containers and then heat-processing them to destroy harmful microorganisms. This method is often used for products like canned vegetables, fruits, and soups, allowing them to remain safe and shelf-stable for extended periods.

- **High-Pressure Processing (HPP):** HPP is a non-thermal preservation method that uses high pressure to inactivate bacteria, viruses, and enzymes while retaining the sensory and nutritional qualities of the food. It is used for products such as juices, meats, and seafood.

- **Modified Atmosphere Packaging (MAP):** MAP involves altering the composition of gases within a food package to slow down spoilage and microbial growth. By replacing oxygen with gases like nitrogen and carbon dioxide, the shelf life of products such as fresh produce, meats, and bakery items can be extended.

- **Antioxidants:** Antioxidants are substances that inhibit the oxidation of fats and oils, which can lead to rancidity. They are often added to products like snack foods, cooking oils, and processed meats to prolong shelf life.

- **Water Activity Control:** Controlling water activity (aw) is crucial for preserving many foods. By reducing the available water in a product, microorganisms cannot thrive. This is achieved by adding salt, sugar, or other ingredients that bind water. Microbial Testing and

- **Quality Control:** Regular testing and quality control measures are implemented to monitor and ensure the safety and quality of products throughout their shelf life.

Shelf life extension involves a combination of preservation methods, packaging techniques, and quality control measures to prolong the safe consumption and quality of various products. These methods are essential not only for reducing food waste but also for ensuring that consumers can enjoy safe and appealing food items.

5. **Nutrient Retention:** Nutrient retention refers to the preservation or enhancement of the nutritional value of food during processing and storage. Nutrient retention is a fundamental consideration in food preparation and preservation, as it directly impacts the nutritional quality of the foods we consume. Nutrients, such as vitamins, minerals, proteins, carbohydrates, and fats, are essential for human health and well-being. The methods we choose for processing and cooking food can either help preserve or deplete its essential nutrients. For instance, gentle cooking techniques like steaming or microwaving are preferred to boiling when aiming to retain water-soluble vitamins, while grilling and roasting can help maintain the nutritional integrity of meat and fish. Temperature and time control are pivotal factors, as prolonged exposure to high heat can lead to significant nutrient losses. By being mindful of these factors and incorporating nutrient-preserving methods into our cooking practices, it can be ensured that the food is not only delicious but also nutritionally beneficial.

IV. SENSORY EVALUATION AND QUALITY CONTROL

Sensory evaluation and quality control are indispensable aspects of the food industry. They play a pivotal role in ensuring that the foods we consume are not only safe but also meet the highest standards of taste, texture, aroma, and appearance.

1. **Sensory Evaluation:** Sensory evaluation methods are systematic approaches used to assess the sensory attributes of food products, including their taste, aroma, texture, appearance, and overall quality. These methods are essential in ensuring that food products meet consumer expectations and maintain consistent quality. Here are some common sensory evaluation methods**:**

   - **Sensory Panels:** Trained sensory panels consist of individuals who are experts in evaluating food attributes. These panelists undergo rigorous training to develop their sensory acumen. They use various techniques, such as descriptive analysis, to provide detailed sensory profiles of food products.

   - **Consumer Panels:** Consumer panels consist of typical consumers who evaluate food products. These panels provide insights into how the general public perceives the sensory attributes of a product. Consumer testing methods can include preference testing, hedonic scales, and acceptance testing.

   - **Difference Testing:** These tests determine whether there is a perceptible difference between two or more samples. Methods like the Triangle Test and Duo-Trio Test are used to identify distinguishable sensory differences between products.

   - **Descriptive Analysis:** Trained panelists use standardized terminology to describe specific sensory attributes, such as sweetness, saltiness, bitterness, and aroma intensity. Quantitative data are collected, allowing for precise sensory profiles.

- **Hedonic Scaling:** Panelists or consumers rate their overall liking or preference for a product using a scale, often ranging from "dislike extremely" to "like extremely." This method provides a general assessment of product acceptability.

- **Ranking Tests:** Panelists or consumers rank products based on specific sensory attributes or overall quality. These tests reveal the relative ranking of products in terms of sensory characteristics.

- **Temporal Methods:** Temporal methods assess how sensory attributes change over time. Examples include time-intensity testing and dynamic sensory profiling, which track attribute perception from the moment a product is tasted until it dissipates.

- **Check-All-That-Apply (CATA):** Panelists or consumers select specific sensory terms from a list that best describe their perceptions of a product. CATA analysis helps identify the key sensory characteristics of a product.

- **Affective Testing:** This method assesses emotional responses to food products. Panelists or consumers provide feedback on how a product makes them feel, linking emotions to sensory attributes.

6. **Quality Control:** Quality control is the process of ensuring that a product meets the established standards and specifications for its sensory attributes. Quality control measures are implemented to monitor and maintain the consistency and uniformity of a product throughout its production, storage, distribution, and consumption. Quality control measures can involve both instrumental and sensory methods. Instrumental methods are objective and precise measurements of physical or chemical properties of a product using specialized equipment. A proactive and preventive approach that places a strong emphasis on monitoring and control is HACCP.

7. **HACCP (Hazard Analysis and Critical Control Points):** HACCP is a systematic, science-based approach to food safety that identifies, evaluates, and controls hazards throughout the food production process. It's a preventive system that aims to ensure the safety of food products by proactively managing potential risks. Steps of HACCP includes**:**

   - **Hazard Analysis:** The first step involves identifying potential biological, chemical, or physical hazards that could occur at various stages of food production. Hazards might include pathogens, allergens, chemical contaminants, or foreign objects.

   - **Critical Control Points (CCPs):** After identifying hazards, the next step is to pinpoint critical control points in the production process where control measures can be applied to prevent, eliminate, or reduce these hazards to acceptable levels. CCPs are specific points in the process where control is essential.

   - **Establishing Critical Limits:** For each CCP, critical limits are set. These are measurable criteria that define the acceptable range of control for each hazard. Critical limits serve as boundaries to ensure the hazard is effectively managed.

- **Monitoring:** Regular monitoring of CCPs is essential to verify that the process remains under control and that critical limits are met. Monitoring can involve physical measurements, visual inspections, or testing procedures.

- **Corrective Actions:** If monitoring reveals that a CCP is not under control or that critical limits are exceeded, corrective actions must be taken. These actions include identifying the cause of the deviation, addressing it, and ensuring that the product is safe.

- **Verification:** Verification involves confirming that the HACCP system is working effectively. This can include periodic reassessment of hazards, reviewing monitoring records, and conducting third-party audits.

- **Record-Keeping:** Detailed records are maintained throughout the HACCP process. These records document hazard analysis, critical control points, critical limits, monitoring results, corrective actions, and verification procedures.

- **Documentation and Training:** Comprehensive documentation of the HACCP plan is essential, along with training for personnel involved in its implementation. This ensures that everyone understands their roles and responsibilities in maintaining food safety.

HACCP is widely recognized and implemented in the food industry to prevent foodborne illnesses and ensure the safety of food products. It is a proactive and preventive approach that places a strong emphasis on monitoring and control, making it an effective system for minimizing food safety risks. HACCP plans are tailored to specific food production processes, and they are continually reviewed and updated to address emerging hazards and maintain food safety standards.

V. FOOD PROCESSING TECHNOLOGIES

Food processing technology encompasses a wide range of methods and techniques used to transform raw agricultural materials into safe, convenient, and marketable food products. This multidisciplinary field integrates science, engineering, and culinary arts to ensure the quality, safety, and sustainability of food production.

1. **Thermal Processing in Food Technology:** Thermal processing is a fundamental aspect of food technology, utilizing heat to alter the properties of food products, enhance safety, and extend shelf life. Several key thermal processing methods are commonly employed**:**

   - **Cooking:** Cooking is a broad term encompassing various methods such as boiling, frying, grilling, roasting, and steaming. It uses heat to make food more palatable, eliminate pathogens, and enhance flavors and textures. For example, grilling a steak not only cooks it to a safe temperature but also imparts a desirable charred flavor.

   - **Blanching:** Blanching involves briefly immersing food items, usually vegetables, in boiling water or steam, followed by rapid cooling. This process is primarily used to deactivate enzymes that can cause food deterioration, such as browning or loss of nutrients. It also helps preserve color and texture before freezing.

- **Baking:** Baking is a dry-heat cooking method primarily used for bread, cakes, pastries, and other baked goods. It involves exposing food to controlled temperatures in an oven. Baking provides products with desirable textures, flavors, and aromas due to the Maillard reaction and caramelization.

Each of these thermal processing methods serves unique purposes in food preparation and preservation, contributing to both the safety and sensory quality of food products. Understanding the principles and techniques of thermal processing is essential for food technologists to create safe and appealing foods for consumers.

2. **Non-Thermal Processing in Food Technology:** Non-thermal processing methods in food technology are innovative techniques that do not rely primarily on heat for food preservation and processing. These methods are increasingly important because they can maintain the sensory and nutritional qualities of food products while ensuring safety. Here are two notable non-thermal processing methods**:**

- **High-Pressure Processing (HPP):** HPP involves subjecting packaged food products to extremely high pressures, typically between 100 to 800 megapascals (MPa). This pressure disrupts the cellular structure of microorganisms, enzymes, and pathogens, effectively sterilizing the food. Unlike traditional thermal processing, HPP preserves the fresh-like qualities of foods, including taste, texture, and nutritional content. It is used for products like fruit juices, guacamole, deli meats, and seafood.

- **Pulsed Electric Fields (PEF):** PEF is a non-thermal technique that exposes food to short bursts of high-voltage electrical pulses. These pulses create tiny holes in the cell membranes of microorganisms, leading to their inactivation and, ultimately, food preservation. PEF is used for liquid and semi-liquid products, such as fruit juices, dairy products, and liquid eggs. Like HPP, it preserves the sensory attributes and nutrients of food.

Non-thermal processing methods are gaining popularity due to their ability to extend the shelf life of products while retaining their quality. They are particularly valuable for the growing demand for minimally processed and fresh-like foods, meeting consumer expectations for both safety and sensory appeal. Food technologists continually explore and develop new non-thermal processing techniques to enhance the quality and safety of food products.Effect of non-thermal processing on food quality**:**

VI. ROLE OF FOOD TECHNOLOGY IN ADDRESSING MALNUTRITION

Food technology plays a pivotal role in the global battle against malnutrition, a multifaceted challenge that encompasses both undernutrition and overnutrition. Food technologists and scientists are at the forefront of innovative approaches to enhance the nutritional quality, accessibility, and affordability of food products. One significant strategy is fortification, where staple foods like rice, wheat, and salt are enriched with essential micronutrients such as iron, folic acid, and iodine. This ensures that even in regions with limited dietary diversity, individuals receive critical nutrients. Moreover, food technologists develop therapeutic foods, like ready-to-use therapeutic foods (RUTFs), designed to treat specific malnutrition conditions. These nutrient-dense formulations are vital for addressing severe acute malnutrition.

Exploring alternative ingredients is another avenue, with food technologists investigating the incorporation of insect proteins, algae, and plant-based proteins into food products, enhancing their nutritional profiles while promoting sustainability. Biofortification, involving the breeding of crops with naturally elevated nutrient levels, has also gained prominence. Biofortified crops like vitamin A-rich sweet potatoes or iron-fortified beans are making substantial impacts in regions where these staples are prevalent. Food processing techniques, such as high-pressure processing and minimal processing, are harnessed to retain the nutritional content of foods, ensuring essential vitamins and minerals are not lost during production. Moreover, food technology addresses the accessibility and affordability aspects of malnutrition by developing cost-effective processing methods and packaging solutions. Food technology serves as a formidable ally in the global fight against malnutrition. It empowers us to fortify foods, create targeted nutritional interventions, explore sustainable alternatives, and improve the overall quality and accessibility of nourishing foods, thereby making substantial contributions to global efforts to combat malnutrition in all its forms.

VII. FUTURE OF FOOD TECHNOLOGY AND PROCESSING

The future of food technology and processing is a captivating journey into a world shaped by evolving consumer preferences, sustainability imperatives, and technological breakthroughs. Personalized nutrition will be a hallmark, with diets tailored to individual genetic profiles and health goals. Sustainable practices will drive food production, from vertical farming to lab-grown meats, addressing environmental concerns. Alternative proteins will continue to flourish, offering enticing alternatives to traditional meat products. Advanced food safety measures will become standard, with technologies like block chain and AI ensuring traceability and transparency. Nutrient-dense foods that balance health and taste will be on the rise. Smart packaging will not only protect food but also communicate freshness and safety to consumers. 3D printing will revolutionize meal customization, allowing consumers to design their dishes. Efforts to combat food waste will intensify, leveraging innovative preservation methods and waste-reducing technologies. Biotechnology will enhance crop yields, nutritional content, and disease resistance. Culinary horizons will expand as globalization blends diverse culinary traditions, creating exciting new flavor profiles. Ethical and transparent sourcing will become paramount, with consumers demanding insight into the origins of their food. In essence, the future of food technology and processing promises a world where innovation harmonizes with our dietary needs, ethical concerns, and culinary aspirations, offering a more sustainable and delectable future.

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INTRODUCTION TO POLYMER CHEMISTRY

The word polymer literally means many (poly) units (mer). Polymer consist a simple chemical units (monomer) repeating itself a very large number of times in the structure. This monomer consist of a single atom, or more commonly, a small group of atoms chemically linked together.

Chemically, polymers are long-chain molecules of very high molecular weight, often measured in the hundreds of thousands. For this reason, the term "macromolecules" is frequently used when referring to polymeric materials. Polymer scientists put the number at about 25,000 g/mol. This is the minimum molecular weight required for good physical and mechanical properties for many important polymers. The number of repeat units in a given polymer molecule is known as its chain length or degree of polymerization. The molecular weight of the polymer is the product of the molecular weight of the repeating unit. Polymer having molecular weight roughly in the range of 1,000 – 20,000 are called low polymer and those having molecular weights higher than 20,000 as high polymers. When more than one kind of repeat units are present in a polymer, it is known as copolymer.

The technology of polymers began with natural rubber obtained as a milky-white latex from the *Hevea* tree. The empirical formula of natural rubber was found to be a linear polymer of isoprene. The establishment of the structure of natural rubber led to the development of synthetic rubber using diene monomers such as butadiene, chloroprene, etc. Beginning early in the twentieth century, synthetic polymers were made by chemical modification of natural polymers, such as hydrogenated, halogenated natural rubber. The developing trend in the decades after 1950 switched the technology of monomer synthesis from natural materials in favour of petroleum as the basic raw material.

SOURCES OF POLMER RAW MATERIALS

NATURAL POLYMERS: Numerous polymeric materials from natural resource including rubber, polysaccharides such as cellulose, starch, proteins, and fats and oils have been applied as raw material or after appropriate modification.

Cellulose: Cellulose is the most abundant constituent of plants. Cellulose esters which include cellulose nitrate, cellulose acetate, etc, find widespread applications as moulded plastics, artificial fibre, film sheets and in coating and lamination.

Starch: Starch is the major form of carbohydrate storage in green plants which consists of six-membered ring glucose units. Several polyhydroxy compounds have been developed from starch for industrial applications such as coating of papers, adhesives, thickeners, and as an environmentally friendly additive in composite materials.

Protein: Proteins are built up of α-amino acids differing in the presence of reactive groups such as amino, carboxyl, amido, hydroxyl, etc. Proteins have been used for the fabrication of materials such as films and coating, adhesives, thermoplastics, paper coatings and leather products.

Vegetable oil: Plant oils with presence of reactive groups which allow polymer formation have been used to synthesize products such polyether, polyesters and polyurethane.

SYNTHETIC POLYMERS: The most important sources of synthetic polymers are crude oil, natural gas and to a minor extent, coal. About 80 % of all petrochemicals end up in polymers, the most important building blocks (monomers) being ethylene, propylene, butadiene and benzene. The first three can be polymerized directly while benzene requires chemical modification.

Ethylene: Ethylene is used directly as a monomer and as co-monomer with other vinyl. It is the major source for ethylene oxide, which is used for synthesis of glycols and ethers. Styrene monomer is produced from the reaction of ethylene with benzene.

Propylene: Propylene is a useful intermediate for building monomers which include propylene oxide, acrylonitrile and methyl methacrylate.

Butadiene: Butadiene obtained from naphtha cracking is used mainly in the production of synthetic rubbers.

Benzene: The catalytic reformation of benzene produces ethylbenzene, toluene and the isomeric xylenes. Ethylbenzene is the source of styrene monomer, while toluene has application in polyurethane production. *Para*-xylene is used as a source of terephthalic acid used in making fibre. *Ortho*-xylene is used to make phthalic anhydride of use in thermosetting resins and paints.

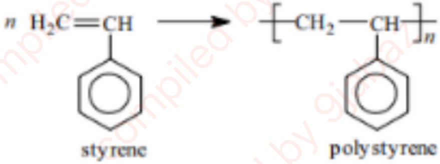
TYPES OF POLYMERIZATION

Polymerization is a process of reacting small molecules (monomer) together in a chemical reaction to form three-dimensional network or polymer chain.

There are two major types of' polymerization methods used to convert small molecules (monomers) into polymers. These methods were originally referred to as addition and condensation polymerization. Addition polymerization is now called chain, chain-growth, or chain reaction polymerization. Condensation polymerization is now referred to as step-growth or step-reaction polymerization.

1. ADDITION OR CHAIN-GROWTH POLYMERIZATION

Chain-growth polymerization is a process by which unsaturated monomers are converted to polymers of high molecular weight in succession by a chain mechanism. In chain-growth polymerization, the π-bonds in each molecules break to give two free bond at each end of the molecules. These bonds can be used to join neighbouring molecules resulting into chin growth. Addition polymers are formed from different class of monomers such as ethylene ($CH_2{=}CH_2$), the simplest olefin, α-olefins ($CH_2{=}CHR$; R is an alkyl group), vinyl compounds ($CH_2{=}CHX$; X = halogens), CN, COOH, COOR, C_6H_5, etc. Typical addition polymers include polystyrene, poly(acrylic acid), polyethylene, poly(vinylchloride) polyacrylonitrile, etc.



Polymerization of styrene.

1. Free Radical Chain-growth Polymerization

A free-radical polymerization has three main steps:

i. Initiation of the active monomer.

ii. Propagation or growth of the active chain by sequential addition of monomers.

iii. Termination of the active chain to give the final polymer product.

The initiation of the chain polymerization may be activated and induced by heat, light, high-energy radiations, or the introduction of initiators or catalysts. The initiation process introduction or generation of highly reactive species R^* (radical, R^*) through dissociation of some monomer molecules (M) under the influence of the initiator or catalyst (I).

An example of addition polymerization is the polymerization of ethylacrylate using benzoyl peroxide as an initiator.

2. CONDENSATION (STEP-GROWTH) POLYMERIZATION

Condensation polymerization the intermolecular reaction between bi-functional or poly-functional monomer molecules which involves the elimination of simple molecules. The molecules condensed intermolecularly in a manner that growth of the chain takes place in controlled steps associated with the formation of condensed inter-unit links and liberation of a small by product such as water, HCl, etc, at each step. Monomers molecules having reactive functional groups such as –OH, -COOH, -NH_2, -NCO, etc, can undergo condensation polymerization. Examples of condensation polymers include polyesters, polyethers, polyurethanes, phenolics, expoxy resin, etc.

i. Formation of Polyesters

Polyesters are resins made from reaction of a saturated acid (adipic acid, phthalic anhydride, isophthalic acid, etc.) and unsaturated acid (ethylene glycol, diethylene glycol, 1,2-propylene glycol, etc.). Polyester resins are commonly used for surface coating and lamination.

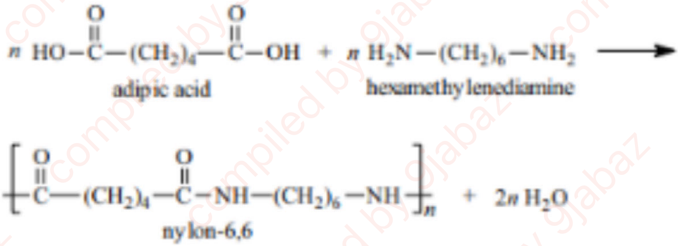
$HO—CH_2—CH_2—OH + HOOC—(CH_2)_4—COOH \longrightarrow$

Ethylene glycol) Adipic acid

$HO(CH_2—CH_2—O—O—C—(CH_2)_4—CO—O\ )_nH + nH_2O$

ii. Formation of Polyamides

Polyamides are made by polycondensation of bi-functional acids and amines. Example of polyamide is poly(Heaxamethylene Adipamide); known as nylon 6,6. Nylon 6, 6 is synthesized by poly condensation of adipic acid and hexamethylene diamine.



$$n\ HO-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-OH + n\ H_2N-(CH_2)_6-NH_2 \longrightarrow \left[\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-NH-(CH_2)_6-NH\right]_n + 2n\ H_2O$$

White is not a colour, all
colours originates from white

Dr. Tawo's Part

CHM 405

1. ① Dyes and pigments
2. ② Steel Industry
3. ③ Soap and detergents
4. ④ Textiles

Chemistry of Dyes and Pigments

Dyes and pigments are important classes of coloured compounds used extensively in textiles, paper, in food, plastics, cosmetics, and art industry, also in automobiles

Both dyes and pigments are substances that impact colour, but they differ mainly in their solubility and the way they interact with the substrate

Differences Between Dyes and Pigment

Feature	Dye	Pigment
① Solubility	Dyes are soluble in water or suitable solvent (water soluble)	They are insoluble in water or organic solvents (water-insoluble) They are soluble in inorganic solvents.
Application	Dyes penerates and chemically bonds with fibers	The adher or stick to surface with dispersion or binders

* Ionic, [illegible] (i) small atom
* Covalent, Close electronegativity difference (ii) high electronegativity

Feature	Dyes	Pigment
③ Bonding Mechanism	Chemical affinity between the dyes and the substrate (ionic) covalent, hydrogen bonding; [illegible]).	It is purely physical adhersi e.g
④ Examples	Methylene Blue, Congo red Alizarin, Methyl orange	Titanium dioxide, prussian blue

Origin and Historical Background

The use of dyes and pigments date back thousands of years, Natural dyes are derived from plants, animals and minerals

Examples

(i) Indigo is obtained from Indigfera tinctoria (blue dye)
(ii) Alizarine from Madder root. Rubia tinctorium,
(iii) Cochineal from carminic acid extracted from insect
(iv) Tyrian purple obtained from mollusc (most expensive)
6, 6'-dibromoindigo

Synthetic Dye

Synthetic dye began with William Henry Perkin's accidental discovery of Mauveine in 1856 from Aniline. This discovery marked the ~~discovery~~ birth of the synthetic dye industry

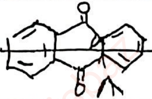
Azo dyes are nitrogen containing dyes

↓ structure

and modern Organic Chemistry.

Classification of Dyes

Dyes can be classified by chemical structure or by their application



Class of dyes	Example	Functional groups / Chromophore
(i) ~~Azo dye~~	~~Metyl orange, congo red~~	
(i) Azo dye	Metyl orange, congo red	$-N=N-$
(ii) Anthraquinone dyes	Alizarin,	Anthraquinone nucleus
(iii) Triphenylmethane dyes	Crystal violet	The central carbon linked to three phenyl ring  chromophore
(iv) Nitro and Nitraso dyes difference??	~~picric~~ acid Picric acid	$-NO_2$, $-NO$ → are able to form metal complexes more readily
(v) Phthalocyanine dye	Phthalocyanine blue	A large macrocyclic system with metal ion

Classification by Application

(1.) Acid dyes: used for wools, silk. Example of such as orange II

(2.) Basic dyes: used to dye acrylic materials. Example is methylene blue

(3.) Direct dyes; Applied directly to cotton. Example; congo red

(4.) Vat dyes: These are (application) insoble dyes reduced to soluble form ~~dye~~ during dye. ~~Vat dye as~~ Example is indigo

(5.) Dispersed dyes: These are used for hydrophobic fibres

Chemical properties of Dyes and Pigments

(1.) Chromophore: Bunch of functional groups that gives colours to substances (functional groups). The colour of the dye is due to certain groups, containing multiple bonds known as chromophores.

NO_2, NO, $-CO-$, $-C=C-$, $-C\equiv C-$, e

Examples; nitro, nitroso, carbonyl

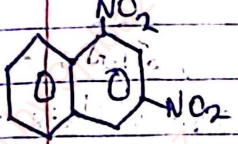
As the number of chromophore increases for a dye, the colour of the dye a~~lso decreases~~. deepens

(2.) Auxochromes: They are not chromophores in the sense that they don't give colour, but their presences increases the intensity of the colour, it deepens the dye. They are groups that modify the solubility and the intensity of the colour.

(2c) Auxochromes:

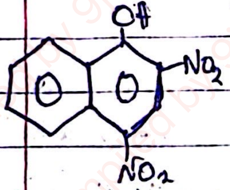
Examples, $-OH$, ~~Ro~~ NH_2, NHR, NR, (Cl, Br, I), $-SO_3H$,
$-COOH$

For example, 1, 3, dinitronaphthalene



Pale yellow

But when Auxochrome is present, e.g OH



(2, 4, dinitronaphthol)

yellow -> orange red

The colour becomes, orange red.

③ Resonance and Conjugation

Extended π-conjugation lowers the energy gap between the HOMO and LUMO. This results in the shifting of absorption into the visible region

④ Acid-Base properties

① pH can change dye colour due to structural resonance
e.g phenolphthalein

*valence is the number of bond surrounding an atom
* valency is the combining power

⑤ Valence Bond theory

In the ground state, the electron pair of a molecule are in a state of oscillation, not vibration and absorb a photon of appropriate energy and gets excited when placed in the path of a beam of light.

The wavelength of the photon of light absorbs depends upon the energy difference between the ground state and the excited state.

⑥ Molecular orbital Theory

According to molecular orbital theory, whenever a molecule absorbs a photon of light, one electron is transfered from bonding (non bonding orbital) to an antibonding molecular orbital. Based on different type of electron present in a molecule, different types of electronic transition are possible.

Synthesis of Dyes

(1.) Azo dyes: These dyes constitute the largest part of the synthetic dyes. The chromophore of the Azo dye is the aromatic system joined with the azo group and the sence of an auxochrome

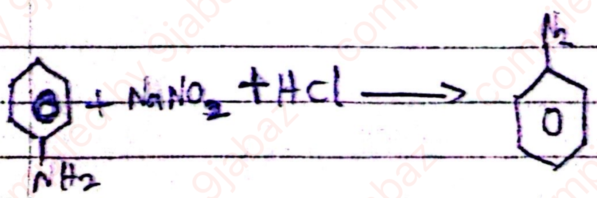
Sodium 4 4 dimethyl amino
di

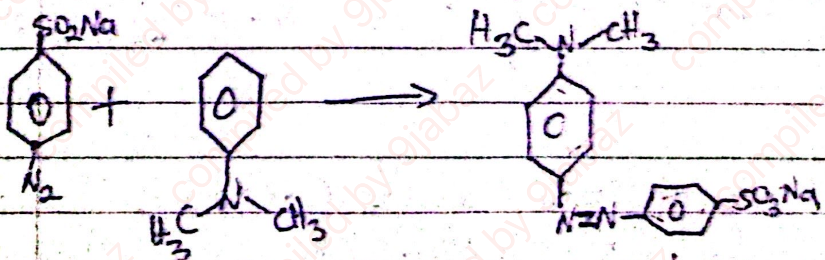
Azo dyes are classified according to the number of azo groups in the molecule. We can have a monoazo dyes, diazo dyes, triazo dyes.

Examples: methyl orange, an example of monoazo dyes

1st step: Methyl orange is synthesized/obtained by converting aniline into a diazonium salt (diazotization)

2nd step: Coupling reaction: The diazonium salt reacts with another aniline in an alkaline medium





Methyl orange.

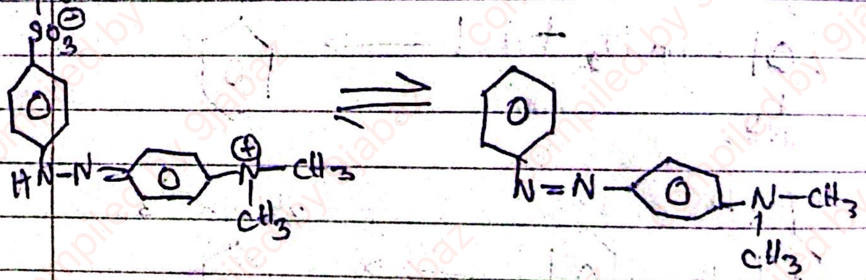
Properties of Methyl orange

Methyl orange is a colouring dye for wool and silk, but its colour fades on the exposure to light and washing, usually it is not used as dye, but used as an indicator in the acid base titration

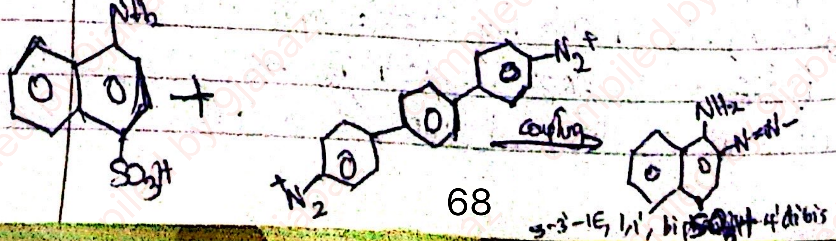
The ~~PP~~ pH range of methyl orange is between 3.1-4.4

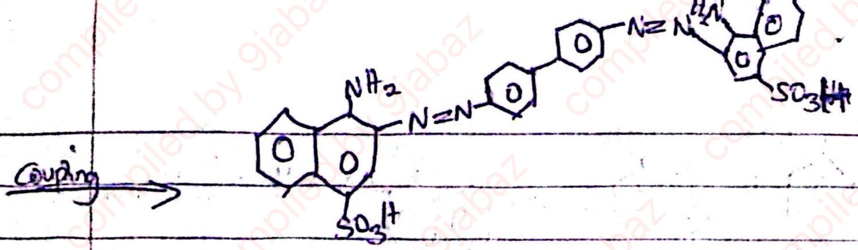
It is yellow in basic solution and red in acidic solution

The colour change takes place because of the change in the colour of ions ~~because~~ in of basic and acid medium. In acidic medium, the ion contains p-quino , while in basic medium it contains azo chromophore



Congo red: It is an example of diazo dye. It contains two azo groups. It is prepared by coupling of tetrazotized Pensidine with two molecules ~~[illegible]~~ naphthonic acid (4-aminonaphthalene-1-sulfonic acid)





It is a direct dye and Sodium salt of this dye gives red colour on the application to cotton

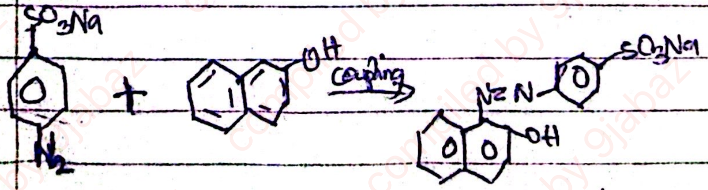
On addition of acid, its colour changes, because of this, it is not used as dye generally, mostly, It is used as an indicator.

It is blue in acidic solution and red in solution above pH of 3

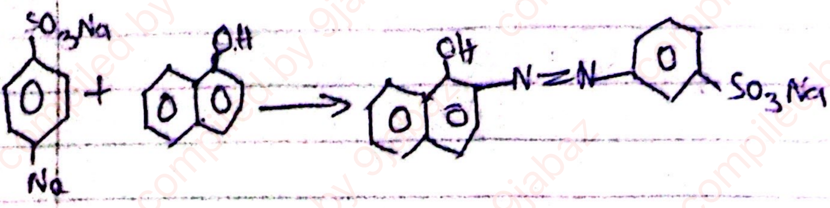
The change in colour from red to blue in acidic solution is due to the resonance among the charged canonical structure

Orange I:

Orange I and Orange II which are examples of acid dyes can be obtained by coupling diazotized sulphonic acid with α- and β-naphthol

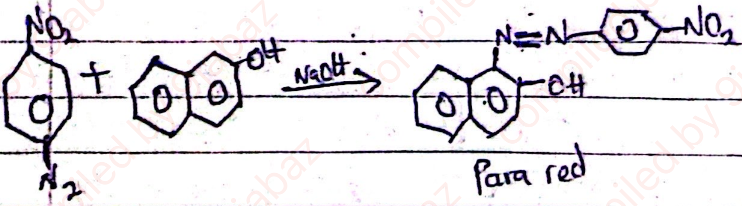


orange I



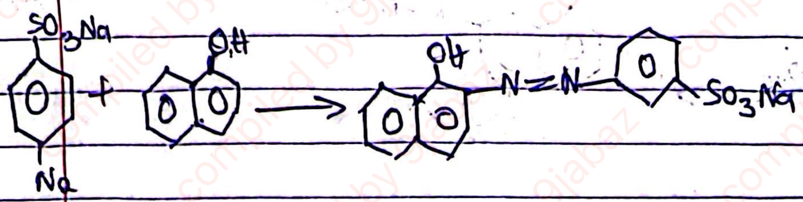
Para Red

Para red are used in foodstuffs, cosmetics, drugs and as an indicator



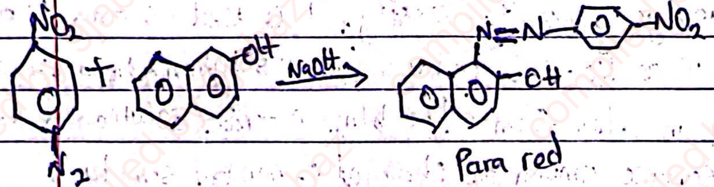
Para red

1-(4-nitrophenyl) diazenyl)
naphthalone-2-ol



Para Red

Para red are used in foodstuffs, cosmetics, drugs and as an indicator



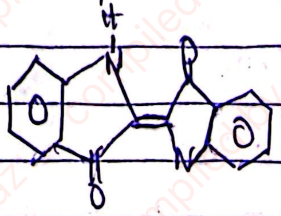
Para red

1-(4-nitrophenyl) diazonyl)
naphthalone-2-ol

17/11/25

② Vat Dyes

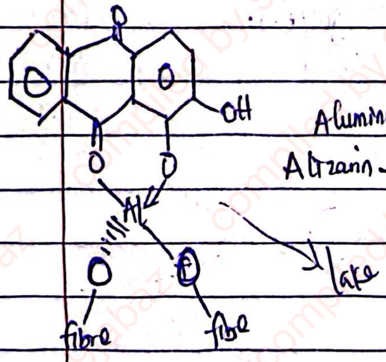
They are insoluble in water so they cannot be used directly for dye. They are first reduced to soluble colourless form (leuco form) with a reducing agent such as an alkaline solution of sodium hydrosulphite. Under these conditions, the leuco form develops an affinity for cellulose fibres. Hence, these dyes are mainly used to dye cotton fibres. Example is indigo

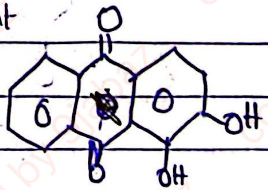


structure of indigo

E—2,2 biindolilene

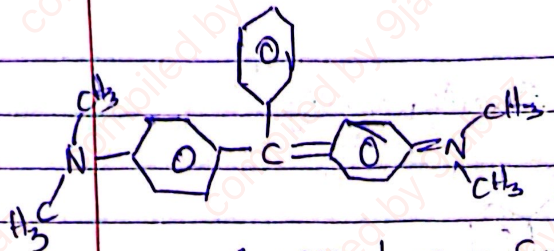
③ Mordant Dyes: These dyes do not bind directly but requires a mordant to bind to the fabric, so the mordant acts as the binding agent between the dye and the fabric. Metal ions are used as mordant for the acid dyes while tannic acid is used as mordant for the basic dyes



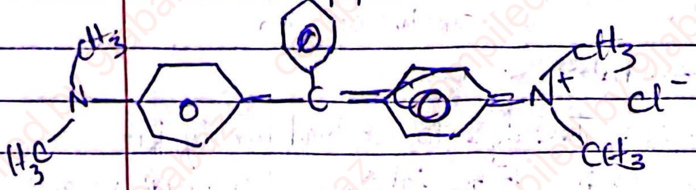


mordant red:

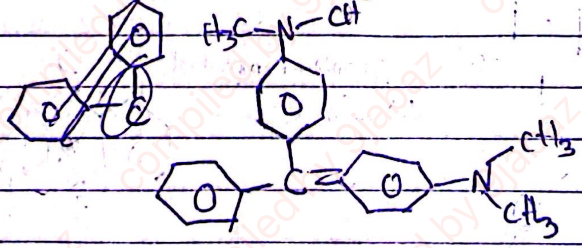
Malachite green is used for dyeing wool and silk directly and cotton mordanted with Phthaline. The colour of it fades slowly on addition of acid and base



when prepared as a Salt$^+$;

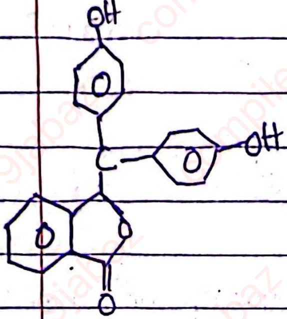


Crystal Violet: A weakly acidic solution of crystal violet is purple. Then in a strongly acidic solution (H_2SO_4, HCl etc) the colour is green. And still, in more acidic solution (more concentrated) the colour is yellow.

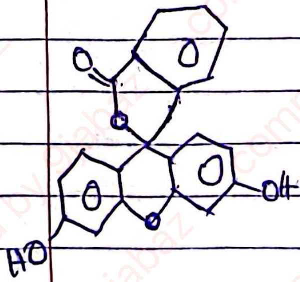


Pthalein dyes: An example is phenolphthalein. Phenolphthalein is insoluble in water but dissolves in alkalines to form a deep red solution. When excess of strong alkaline is added, the solution of phenolphthalein becomes colourless.

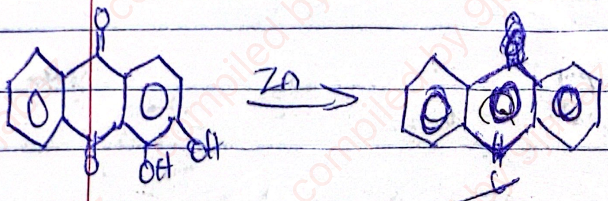
Because of the colour change, it is used as an indicator in acid base titration. It is also used as a powerful laxative.



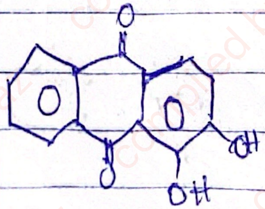
Floresain : It is a Zamtam derivative, it is more closely resemplen phthalein dyes. It is a red powder which is insoluble in water. It dissolves in alkaline to give a reddish brown in colour, which on dilution, it gives a strong yellowish-green florescence



Alizarine: It is one of the important anthraquinone dyes. It occurs in madder root in form of its glucoside called rubberthric acid. On reduction with Zn dust, it gives anthracene



This implies that alizarine is a derivative of anthracene. It forms a ruby red crystals insoluble in water and alcohol, but dissolves in alkalines to form purple solution. It sublimes on heating. It is mordant dye and the colour of the lake depends on the metal used. Aluminium gives a red lake, ferric salt gives violet black, while chromium salt gives a brown-violet lake.



1,2-dihydroxyanthrace-9,10-dione

PIGMENTS

These are organic and inorganic substances which are widely used as surface coatings. They are also used in ink, plastics, rubber etc, to impact colour. A large number of pigments are used for commercial manufacture of paints.

Classification of Pigments

Pigments are mainly classified into two;

(1) white pigments : Grp-1 or 2

(2) Coloured pigments : transitional metals

White Pigment: They are various types, the compositions, properties and applications of some white pigments are as follows

Type	Chemical Compositions	
(1) White Lead	$2PbCO_3 \cdot Pb(OH_2)$	The composition of Lead Carbonate is 68.9% while hydroxide is 37.1%. It is used in the manufacture of paints

Properties

(i) It is easily applied

(ii) It has high covering power

(iii) It is highly toxic in nature

(iv) It yellows badly on exposure to atmosphere.

(v) It is soluble in alkaline

Type	Chemical compositions	Properties
② Sublimed white Lead (basic Sulfate)	$PbSO_4$ (75%), PbO (20%) ZnO (5%)	① It has high specific gravity and refractive index ② It slow chalken out of the film producing a rough surface
③ Zinc oxide	ZnO It is opaque to UV light and thus protects from UV (ii) It prevents chalking as well	Composition ~~① It is opaque to UV light and thus protects from UV~~ ~~(ii) It prevents chalking as well~~ Properties ① Brilliantly white hereby having ② It causes no discolouration even on contact with CO_2 gas. ③ It is more durable in combination with white Lead
④ Lithopone	ZnO (28.38%), $BaSO_4$ (72.70%) It is widely used for cold water paint, traffic plants, floor covering, and oil cloth industry	① Extremely fine and cheap Pigment. ② It has a good hiding power. ③ It is not as durable as white Lead and ZnO
⑤ Titanium dioxide	It contains Titanium and Iron oxide FeO_3, TiO_2 It is widely used in paint, paper and textile industry	(i) It has high capacity and hiding power (ii) It has high oil absorbing capacity (iii) Spreading power is almost doub

Properties

(iv) No tendency for chalking

~~(2) Blue pigment~~

~~(2) Blue Pigment Ultra marine blue and Cobalt~~

Blue Pigments: Ultra marine blue and cobalt blue are the most

There are three Varieties of ultra marine, which are;
(i) blue (ii) white (iii) green.

It is used as blueing in laundry to neutralize the yellow stone in cotton and linen fabrics

White Ultra Marine Blue consists of $Na_8 Al_3 Si_3 SO_{12}$

Green Ultra Marine Blue consist of $Na_5 Al_3 Si_2 S_2 O_{12}$

Blue Ultra Marine Blue $Na_5 Al_3 Si_2 S_3 O_{12}$

Properties

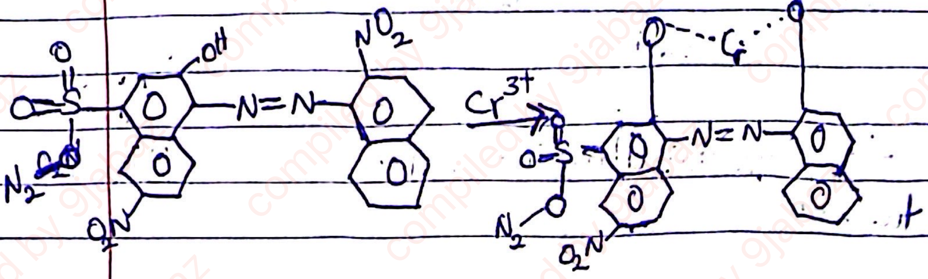
① Silicate Skeleton has a potential ~~sequence~~ influence on the colour

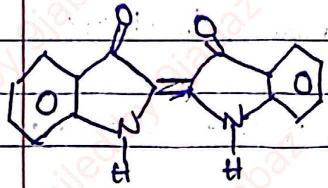
② Because of the presence of sulphur, it formed as a polysulfide S'

9,10 anthra

Mordant Dyes

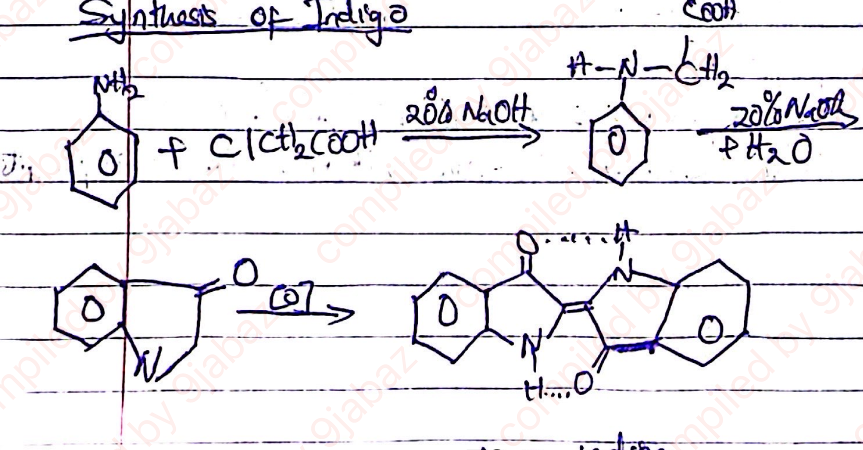
With cromium





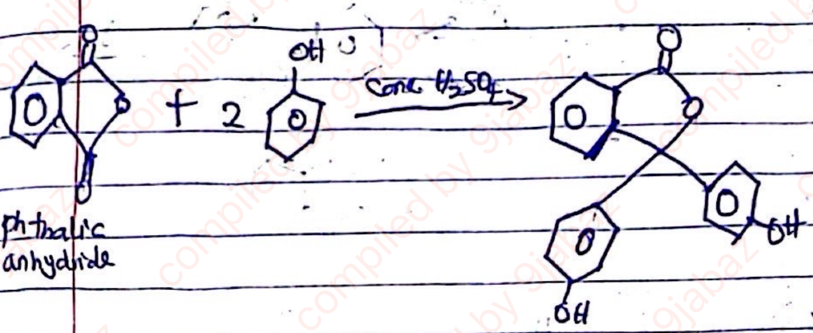
cis indigo

Synthesis of Indigo



trans- Indigo

* Phenol is not an alcohol phenolsulphophthalein

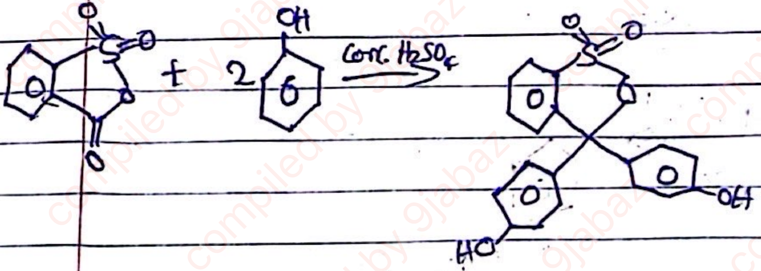


phthalic anhydride

phenolphthaleine

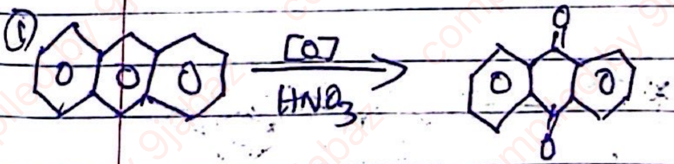
Phenolsulphophthalein Synthesis

Sulphobenzoic anhydride is used instead of phthalic anhydride



Anthraquinone dye Synthesis

(i)

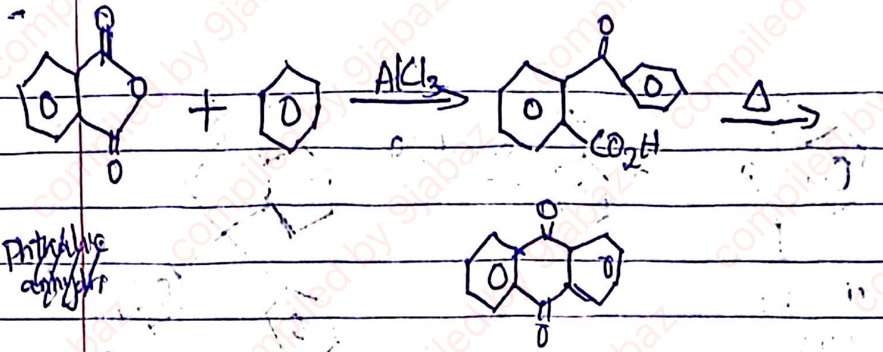


anthraquinone

9,10-anthraquinone

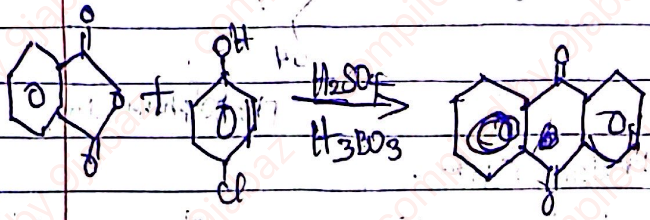
Most

②

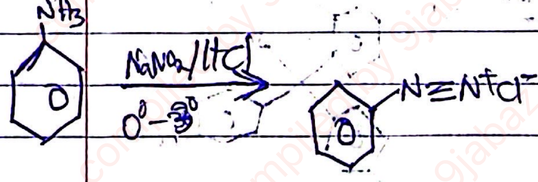


Phthalic anhydride

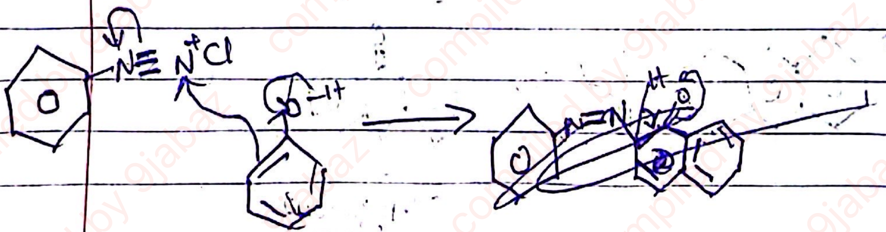
③



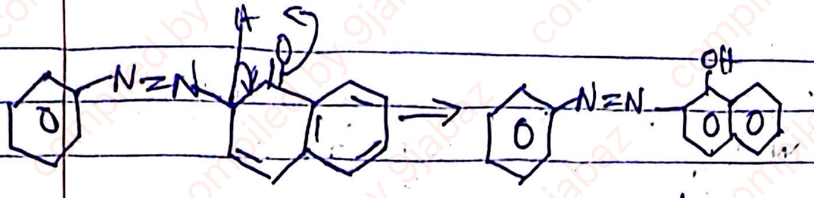
Benzoazo dyes synthesis



Diazotized salt

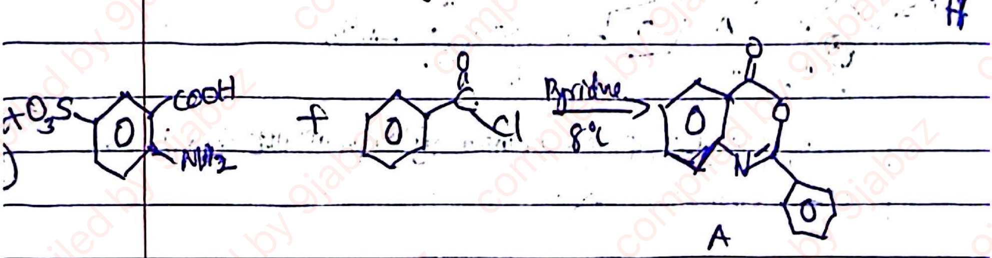


*Ester is electron deficient, electrophilic



bright red

Synthesis of ~~quinazoline~~ Quinazolin dyes



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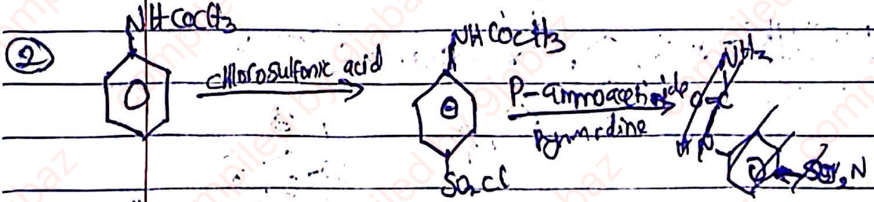
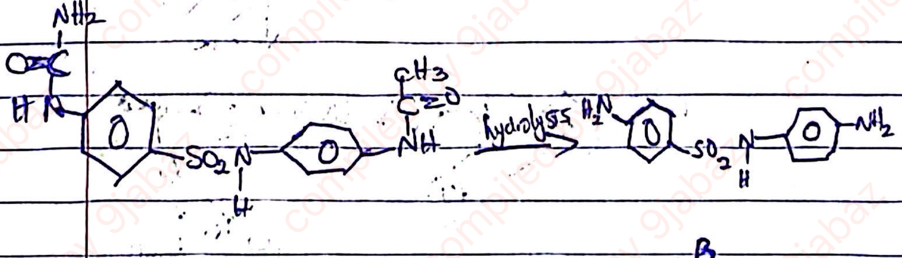
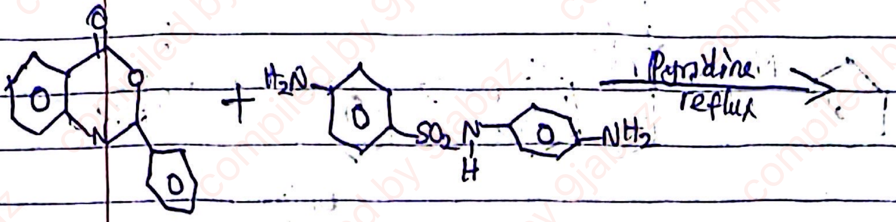
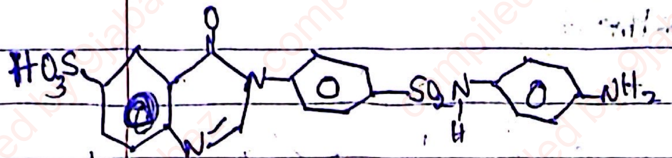




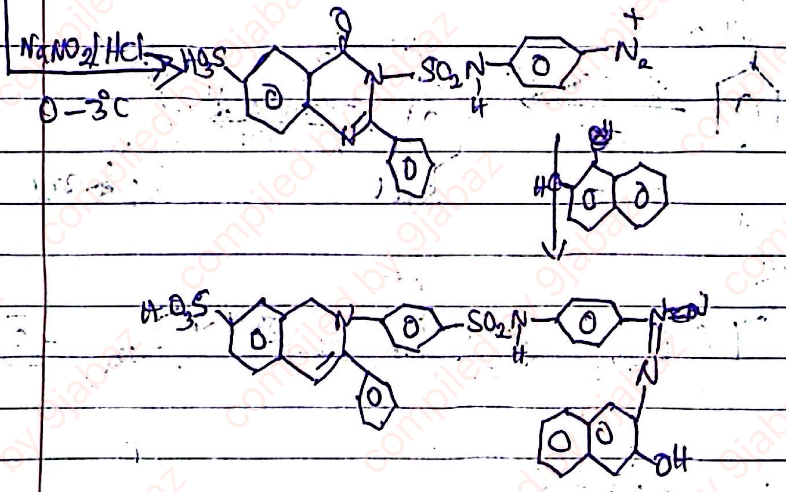
Reacting A and B;

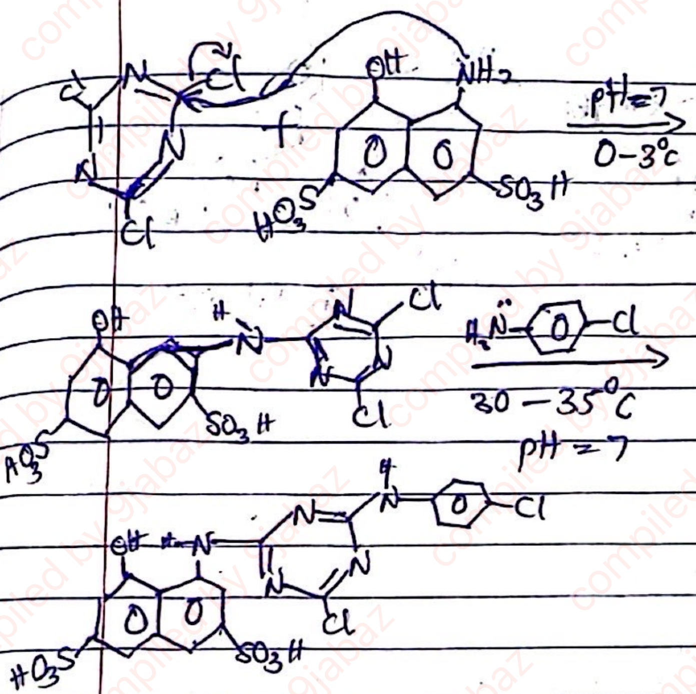




2,-phenyl-3, 4', 4'-aminophenylsulphuramido phenyl-4-
quinazoline-6-Sulphonic acid

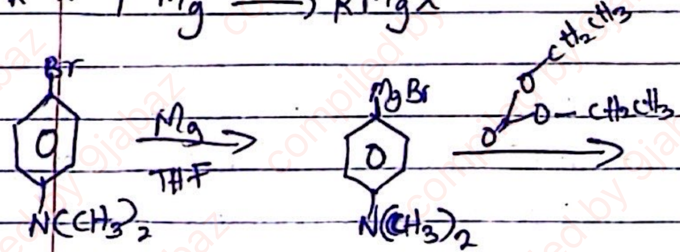
A

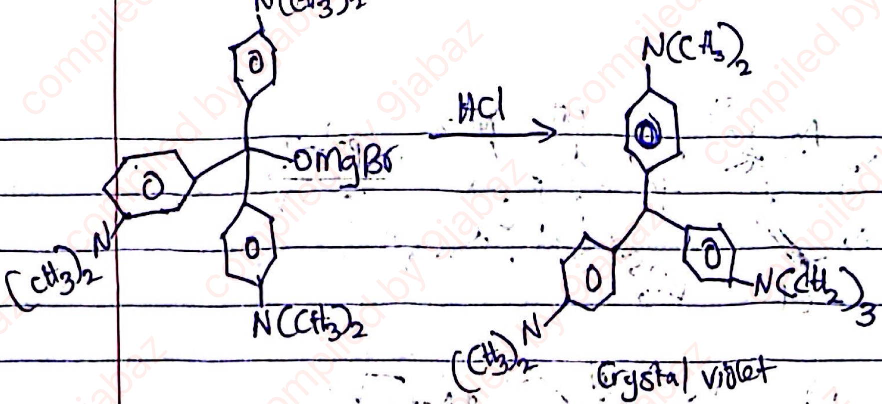




Systhesis of Crystal violet with Grignard Reagent

$R-X + Mg \longrightarrow RMgX$





Crystal violet

Aebeabraselies

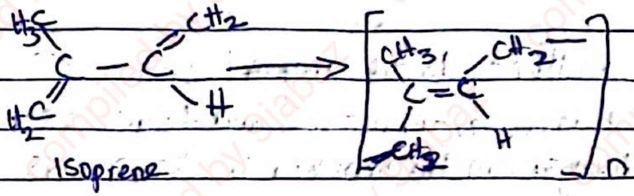
1/12/25

Rubber

Rubber is a natural product made by plants and its also a Very essential industry. Throughout the history of humanity and the rise of human civilization, rubber has played a significant role. Today we obtain 99% of the natural rubber produced

What is rubber? Rubber is a natural polymer that can Stretch and shrink. It is an elastomer that after being deformed may revert back to its previous shape Rubber is made by polymerization of isoprene (2-methyl-1,3-butadiene)

- [illegible] of
  Carbon Present



Hence rubber is an elastic material produced from the episilon of some tropical plant or extracted from petroleum and ~~or~~ natural gas. Rubber is an elastic flexible and tough substance, therefore it can be used to manufacture tyres for vechicles, aircraft, bicycle, etc.

Types of rubber

1. ① Natural rubber (we can also have vulcanized rubber)
2. (ii) Synthetic rubber

① Natural rubber: This is the type of rubber obtained naturally from the milky liquid or latex obtained from the rubber tree. It is also known as india or gum rubber.
Natural rubber can be vulcanized into many different types of rubber products.

Properties

① It is not resistant to heat, so it melts ~~easily~~ at a temperature about 80°C

(ii) It has excellent elastic properties
(iii) It is abbrasion-resistant and tear-resistant
(iv) It Strength can be improved by the process called Vollcanization of rubber

Preparation of Natural Rubber

The latex sap of the rubber tree is used to make natural rubber. The latex is harvested by affixing a Container to the rubber tree which is reffered to as tapping. After which formic acid is used to coagulate the latex. This rubber is then completely dried either with a series of rollers or by allowing them to air dry for several days under the natural air.
This natural rubbers are now ready for processings to make a Series of products.

Synthetic Rubber

From the word synthetic, it means it's a man made or artificial polymer. Any artificial elastomer is reffered to a synthetic rubber. Synthetic rubber is typically made up of additional polymers of Polyane monomers.

What is elastomer? An elastomer is a material that has the mechanical properties or being able to bend far more elastically under stress than most materials while still returning to its original size without permanent distortion.

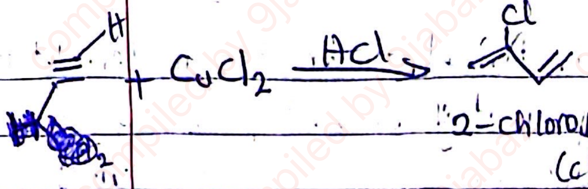
In many circumtances, synthetic rubber can be used in the place of natural rubbers especially where better material qualities are required.

An example of synthetic rubber is Neoprene which is made up of monomer unit, chloroprene.

Synthetic of Neoprene

Neoprene, commonly known as polychloroprene is a homopolymer made from chloroprene polymerized by free radicals. It has a strong oil resistance and it is used to make convey belt, hoses and gasket among others

The conventional method for synthesizing ~~mono~~ monovinyl acetylene involves a series of reactions initially acetylene was allowed to react with cuprous Copper chloride and the resulting compound ~~product~~ was subsequently treated with HCL ~~acetylene~~ to produce chloroprene



2-chlorobuta-1,3-diene
(chloroprene)

The process of Neoprene synthesis involves utilization of chloroprene free radical polymerization mechanism. The polymer is synthesized via the addition of free radical emulsion.

The initiation of the polymerization process is achieved by ~~using~~ employing $K_2S_2O_8$ Potassium persulphate
A variety of substances like bifunctional nucleophiles or metal oxides e.g zinc oxides, thiourea are used to make easier for polymer chains to link up with each other
vinyl

- The process of emulsification of chloroprene in water followed by polymerization catalyzed by free radical initiators enables the transformation of chloroprene into rubber

The chloroprene repeating unit demonstrate the capacity to adopt various structures along the polymer chain with trans polychloroprene being the predominate configuration.

Buna—S

Buna-S is formed by co-polymerization of 1,3-butadiene and styrene. It has a high tensile strength and can be used as natural rubber alternatives. It is utilized to create car tyres, footwear components, cable insulators, etc.

B

Buna-N is a copolymer made by polymerizing 1,3-butadiene with acrylonitrile in the presence of peroxide catalyst. It is resistant to oils, petrol and some organic solvents therefore they are typically utilized to make tank linings and oil seals

Vulcanized Rubber

Vulcanized rubber is an elastomer that has been strengthened by the biochemical process of vulcanization.
A curing agent typically sulphur is mixed with the milky latex of the rubber tree and heated under pressure

What is Vulcanization? Vulcanization is a process of hardening rubbers. The term originally comes solely from the reaction of natural rubber and sulphur. Which is the most common practice. But it is has also grown to increase the hardening of other synthetic rubber via various means. For example, silicon rubber

Also chloroprene rubber, e.g neoprene ~~compounding~~

Process of Rubber

(i) Compounding
(ii) mixing
(iii) Shaping
(iv) Vulcanization

(i) Compounding: Rubber is ~~fortified~~ formed with additives and chemicals to improve its tensile strength and characteristic. Carbon black, fillers, are added to rubber to boost its tensile strength and prevent it from ultraviolet ~~degrada~~ radiation degradation

(ii) Mixing: Rubber must be well mixed with additives before it is used. The temperature is raised for this purpose and the additives are thoroughly blended. It takes ~~at~~ place very high temperature.

(iii) Shaping: Extrusion, calendering, moulding or coating and casting are four common method for shaping rubber items.

Extruders force a highly plastic rubber through a series of screw extruders to create rubbers. Calendering follows this phase which involves passing the rubber through a series of rubber gaps through a series of smaller gaps between rollers. This roller die method combines extrusion and calendering to create a superior result.

The coating is the application of a rubber coat or the pushing of rubber into cloth or other materials. Rubber coating are used to make tyres, water proof textile tents, raincoats, convoy belts and other items

Moulding or moulds are used to make rubber products such as as [illegible] shoe soles, heels, suction cups, seals, and bottle stops.

~~(iv) Vulcanization.~~

(iv) Vulcanization: The ~~rubber process~~ rubber-processing process is finished with vulcanization. Sulphur cross-connections between rubber polymers are formed during vulcanization. Rubbers that has fewer cross-connections between its polymers is soft.

The elasticity of the rubber is ~~produced~~ reduced as the number of cross-connection increase.

Uses of Rubber

① One of the largest consumer of rubber is the tyre and tube industry. To make natural rubber more durable, it is combined with synthetic rubber

② Rubber is employed in other areas of the veechicle or automobile. e.g seals and various types of cushion for different car parts are made from natural rubber. Other examples are breakpads, ~~and~~ seals window seals, wind shield seals in automobiles

③ Rubber is used to produce airbags which protect ~~pass~~ passenger from ~~danger~~ damage caused by accident

④ Clothing: because natural rubber is elastic in its fibrous form it is utilized to make clothing that is tight fitting and expandable. Such as swimmers and cycling short

⑤ Rubber is utilized to make flooring in variety of business establishment, kitchens and even playground. It creates cushion surface that i also slip resistance and water proof.

8/12/25

IRON & STEEL

Introduction:

Iron and steel form the foundation of modern Civilization. They have wide application in construction, transportation, manufacturing, energy and technology stem from unique, chemical physical and mechanical properties

Iron (Fe), a transition metal is among the most abundant element on the earth crust and it is found naturally in several minerals. Fe is moderately reactive metals which combines readily with non-metals such as Oxygen to form the Oxides. This is why Iron is not found as a pure iron on the earth crust.

Instead, it is found as an ore in which Fe is chemically combined with Oxygen and other non metals

Steel and alloy derived from iron incorporates controlled amount of carbon and other alloying elements to enhance strength, toughness, corrosion resistance and durability

Occurence of Iron and Iron Ores

Iron occurs mainly as oxides and carbonates.

Classification of Iron Ores

Composition

(I) Red or Reddish black ore (Hematite, Fe_2O_3)

⇒ most important in industry

(II) Black ore (Magnetite) — Fe_3O_4 (It is a mixture of Fe(II), Fe(III))

(III) Grey or Whitish ore (siderite) — $FeCO_3$

(IV) Brown ore (Limonite) — It is an hydrate iron oxide $Fe_2O_3 \cdot nH_2O$

The purity and composition of this ores influences the efficiency and the chemistry of the extraction process. Eg We can calculate the amount of Fe in these ores.

ⓐ Fe_2O_3 ⓑ Fe_3O_4

Steel Making Process

This involves two stages;

① Purification/extraction of iron

Extraction of Iron

The Blast furnace process: The blast furnace is a tall steel-lined construction used to reduce iron oxide to molten iron using CO, coke, limestone and hot air. The process is about three processes;

① Combustion and heat generating reaction

$$C + O_2 \rightarrow CO_{2(g)}$$

The CO_2 that is generated rises and reacts with more coke at higher levels

$$CO_2 + C \rightarrow 2CO$$

The CO formed is the primary reducing agent responsible for converting iron oxides into metallic iron.

② Reduction of Iron Ores

$$\underset{\text{Hemitite}}{Fe_2O_3} + CO \rightarrow \underset{\text{magnetite}}{Fe_3O_4} + CO_2$$

$$Fe_3O_4 + CO \rightarrow 3FeO + CO_2$$

$$FeO + CO \rightarrow Fe_{(s)} + CO_2$$

The molten iron collects at the bottom of the furnace

③ Removal of Impurities: Limestone decomposes to produce lime

$$CaCO_3 \rightarrow CaO + CO_2$$

The silica is removed by the CaO.

$$CaO + SiO_2 \rightarrow CaSiO_3 \text{ (slag)}$$

The slag floats on the molten iron and removed seperately

Types of Iron

Depending on the carbon content and impurities, iron exists in three main forms;

① Pig iron: 3–5% Carbon, it is brittle.
It is melted and oxidized to eliminate most of the carbon, down to 0.5%

② Wrought Iron < 0.1%, malleable and ductile
It is produced by mixing pig iron with slag. Wrought iron is relatively soft, malleable and worked by blacksmith to create different tools, horse shoes, furniture and so on

When heated wrought iron is malleable, bendable and easy to work with

③ Cast Iron : 2–4% carbon
It is hard and brittle. It is made by melting pig iron along with substantial quantity of scrab iron
Cast iron is used in civil engineering only where the loading on the material system is predominantly or exclusively comprehesive

② Steel Manufacturing process

Steel is produced by refining pig iron reducing carbon contents and removing impurities such as sulphur, phosph and silicon

There are two major industrial process;

① Basic oxygen furnace (BOF)

(ii) Electric Arc Furnace (EAF)

Basic Oxygen Furnace (BOF)

Pure oxygen is blasted through molten pig iron - oxidizing impurities (C, S, Si, P)

① $C_{(s)} + O_{2(g)} \Rightarrow CO_{2(g)}$

$C + \frac{1}{2}O_2 \longrightarrow CO_{(g)}$

$S + O_2 \longrightarrow SO_2$

$4P + 5O_2 \rightarrow 2P_2O_5$

$P_2O_5 + 3CaO \Rightarrow Ca_3(PO_4)_2$ (slag)

The slag containing oxidized impurity

② Electric Arc Furnace (EAF)

This is used mainly for recycling scrab steel and producin alloy steel.

$$Fe + \frac{1}{2}O_2 \longrightarrow FeO$$

$$FeO + C \longrightarrow Fe + CO$$

This process allow precise control of ~~iron and~~ alloy and Carbon content.

Chemistry of Alloy Elements n with steel

Alloy elements enhance steel properties, Carbon (0.02-2%) Fe_3C it increases to hardness.

Mn: When Mn is added to Iron, it forms deoxidizers It improves toughness and forms stable carbide.

Cr: When Cr is added to iron, it forms protective layer of Cr_2O_3 (Stainless steel)

Ni: Nickel improves ductility, then it stabilizes Austenite

Mo: Molybdenum enhances high temperature strength

V: It is a grain refiner and forms vanadium carbide (VC)

W: Tungsten improves hot hardness and forms Tungsten carbide (WC)

Corrosion of Iron

This is an electrochemical basis. Rusting is an electrochemical process requiring water, oxygen and electrolyte

Anodic reaction　　　　Cathodic/reaction

$Fe \longrightarrow Fe^{2+} + 2e^-$

Cathodic reaction

$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$

Subsequent reaction $Fe^{2+} + 2OH^- \longrightarrow Fe(OH)_2$

$Fe(OH)_2 + O_2 + H_2O \rightarrow Fe(OH)_3 \rightarrow \underset{\text{rust}}{Fe_2O_3 \cdot nH_2O}$

Rusting weakens structure and leads to significant economic loss.

Prevention of Corrosion

① Galvanization: It is process of coating with Zn
$Zn \longrightarrow Zn^{2+} + 2e^-$ (it takes place at the anode)

② cathodic protection using sacrificial anode e.g Mg, Zn

③ Painting,

④ Greasing or electroplating

(4) Alloying (with Cr or Ni to form stainless steels)