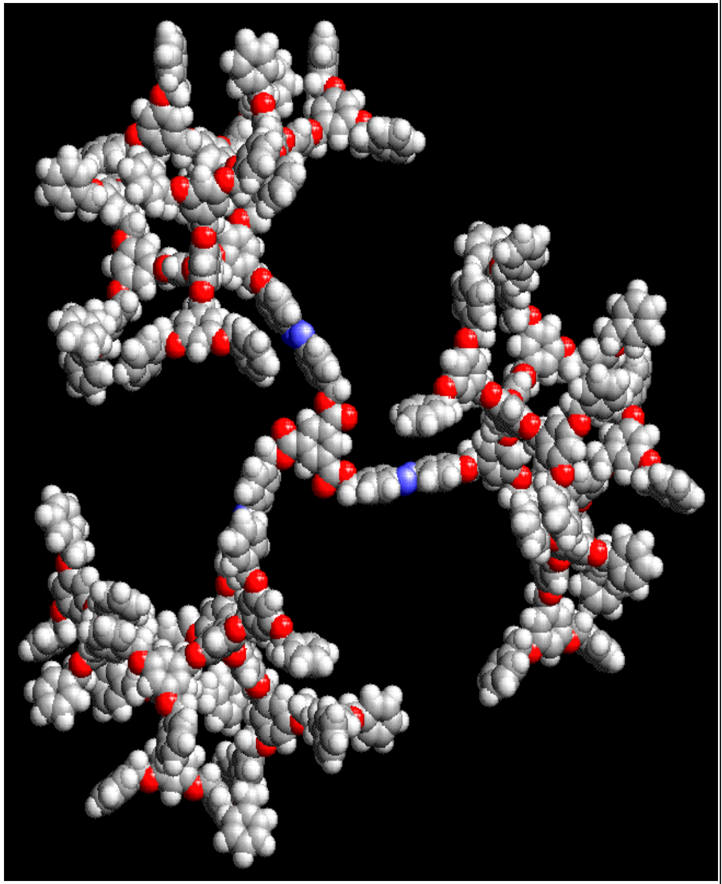
Chapter-4
Plastics, Rubber and Fibers

1. Introduction to polymers

"polymer"= greek poli (many) + meros (unit) = many units

- Polymers are a large class of materials consisting of many **small molecules** (called **monomers**) that can be linked together to form **long chains;** known as **macromolecules** (term introduced by H. Staudinger in 1920's).
- A typical polymer may include **tens of thousands of monomers** and are classified as macromolecules because of their large size.
- Polymers occur naturally in the form of proteins, cellulose(plants), starch(food) and natural rubber.
- Engineering polymers, however, are usually synthetic polymers



2. Definitions

- **Polymer –** large molecule consisting of several repeating units with molecular weight typically several thousand or higher
- **Repeating unit –** the fundamental recurring unit of a polymer
- **Monomer –** a smaller molecule(s) that are used to prepare a polymer
- **Oligomer –** a molecule consisting of reaction of several repeating units of a monomer but not large enough to be considered as polymer
- **Single repeat unit**: Monomer
- **Many repeat units:** Polymer
- **Degree of polymerization** - the number of the repeating units

3. Application of polymers

- The field of synthetic polymers or plastics is currently one of the fastest growing materials industries
- The interest in engineering polymers is driven by their **manufacturability**, **recyclability**, **mechanical properties**, and **lower cost** as compared to many alloys and ceramics
- The macromolecular structure of synthetic polymers provides good **biocompatibility** and allows them to perform many **biomimetic tasks** that cannot be performed by other synthetic materials, which include drug delivery, use as grafts for arteries and veins and use in artificial tendons, ligaments and joints.

4. Nomenclature of polymer

a. Nomenclature Based on monomer source

The addition polymer is often named according to the monomer that was used to form it

Example : poly(vinyl chloride) PVC is made from vinyl chloride

$-CH_2-CH(Cl)-$

Poly-X

If " X " is a single word the name of polymer is written out directly

ex. polystyrene $-CH_2-CH(Ph)-$

If " X " consists of two or more words parentheses should be used

ex , poly (vinyl acetate) $-CH_2-CH(OCOCH_3)-$

b. Based on polymer structure

- The most common method for condensation polymers since the polymer contains different functional groups than the monomer

Ex. Polyamide, which is formed from carboxylic acid and amine

Nomenclature of polymers …. continued

PC = Polycarbonat

PPE = Polyphenylether

SMA = Styrol-Maleinsäureanhydrid

ABS = Acrylnitril-Butadien-Styrol

PMMA = Polymethylmethacrylat

PS = Polystyrol

SAN = Styrol-Acrylnitril-Copolymere

PVC = Polyvinylchlorid

PET = Polyethylenterephthalat (PETP)

PBT = Polybutylenterephthalat (PBTP)

PA = Polyamid

POM = Polyoxymethylen

RF-PP = Resorcin-Formaldehyd-Polypropylen

PE-UHMW = Polyethylen-ultra high molecular weight

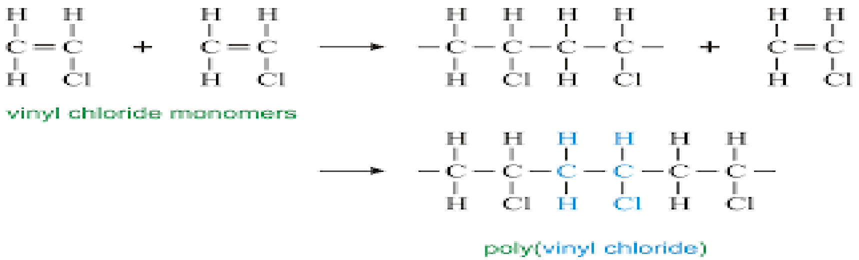
PP = Polypropylen

PE-HD = Polyethylen hoher Dichte (<u>H</u>igh <u>D</u>ensity)

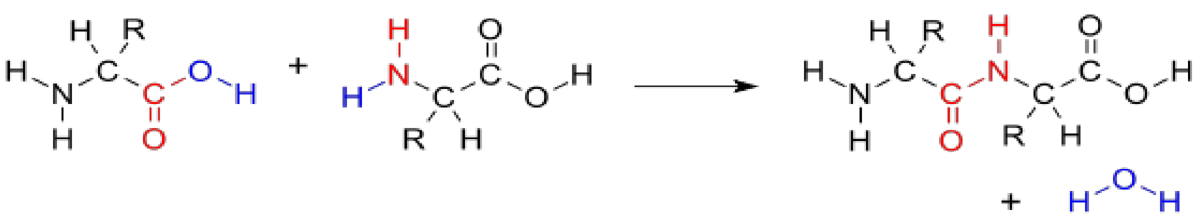
PE-LD = Polyethylen niedriger Dichte (<u>L</u>ow <u>D</u>ensity)

5. Addition and condensation polymerization

- **addition polymerization**: monomers react to form a polymer without the formation of by-products



- **Condensation polymerization:** any kind of **polymers** formed through a **condensation** reaction where molecules join losing small molecules as by-products such as water



- The condensation of two amino acids to form a peptide bond (red) with expulsion of water (blue)

6. Classification of polymers

- **Main classifications of the polymers**:
  - ✓ by origin
  - ✓ by Monomer composition
  - ✓ by chain structure
  - ✓ by thermal behavior
  - ✓ by kinetics or mechanism
  - ✓ by application

A. Classification by Origin

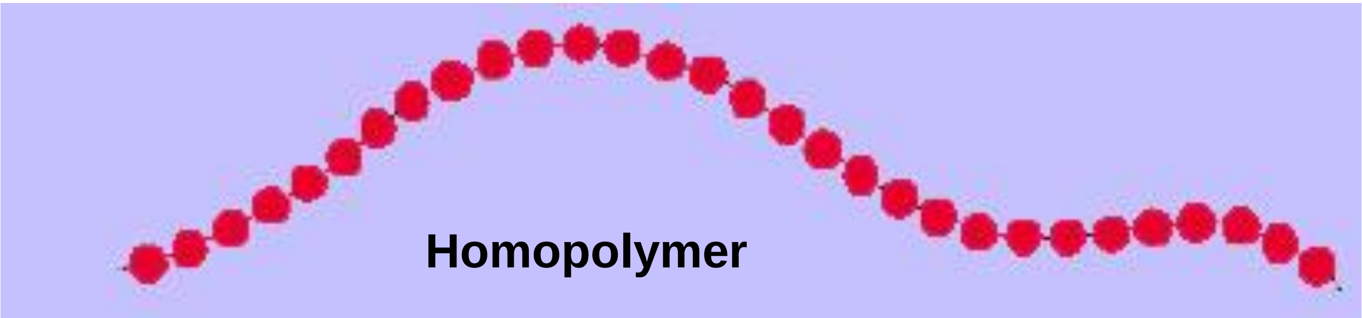
- Synthetic organic polymers
- Biopolymers (proteins, polypeptides, polynucleotide, polysaccharides, natural rubber)
- Semi-synthetic polymers (chemically modified synthetic polymers)
- Inorganic polymers (siloxanes, silanes, phosphazenes)

B. Classification by Monomer Composition

- Homopolymers
- Copolymers
  - ✓ Block
  - ✓ Graft
  - ✓ Alternating
  - ✓ Statistical

i. Homopolymers - consist of only one type of constitutional repeating unit (A)

AAAAAAAAAAAAAAA



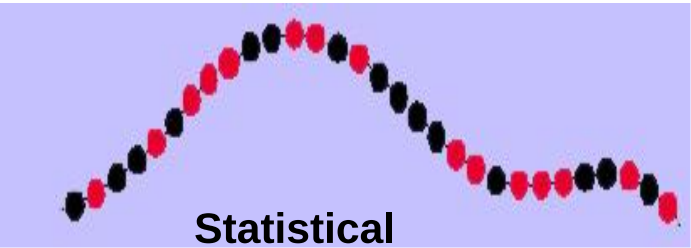
ii. Copolymers

- Consist of two or more constitutional repeating units (A-B)
- Several classes of copolymer are possible

✓ **Statistical copolymer** (**Random**)

- two or more different repeating unit are distributed randomly

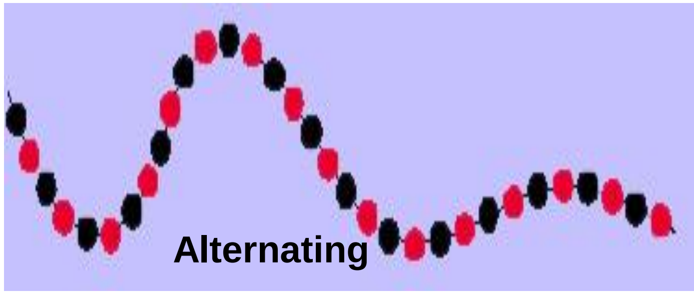
ABAABABBBAABAABB



✓ **Alternating copolymer**

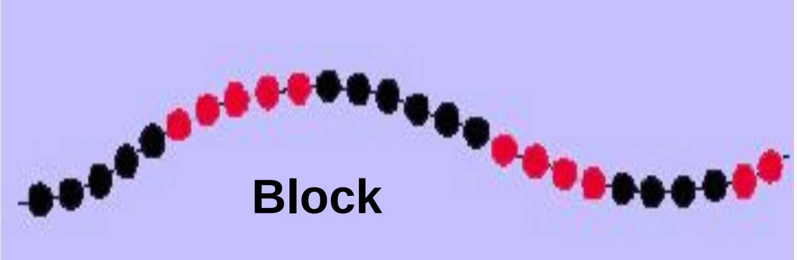
- made of alternating sequences of the different monomers

ABABABABABABABAB



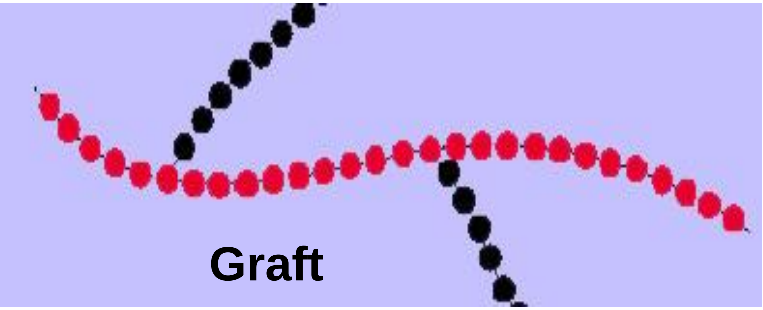
- **Block copolymer**
  - ✓ long sequences of a monomer are followed by long sequences of another monomer

    AAAAAAAAABBBBBBBBB



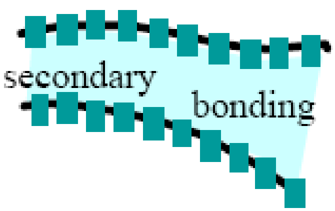
- **Graft copolymer**
  - ✓ Consist of a chain made from one type of monomers with branches of another type

AAAAAAAAAAAAAAAAAAA
B B B
B B B

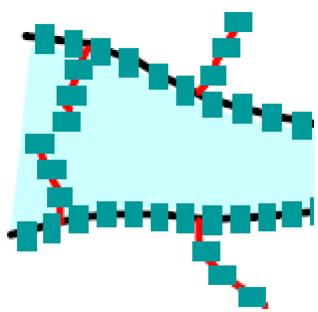


C. Classification by Chain structure (molecular architecture)

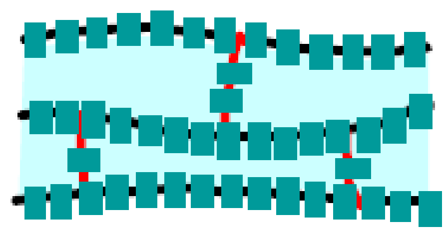
- **Linear chains**: a polymer consisting of a **single continuous** chain of repeat units
- **Branched chains**: a polymer that includes **side chains of repeat** units **connected onto the main chain** of repeat units
- **Cross linked polymer**: a polymer that includes interconnections between chains
- **Network polymer**: a cross linked polymer that includes numerous interconnections between chains



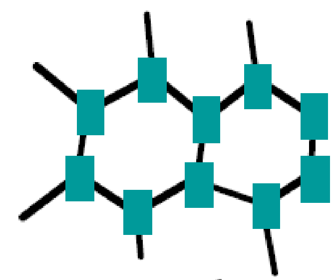
Linear



Branched



Cross-linked



Network

Direction of increasing strength →

D. Classification by Thermal Behavior

- Polymers may be classified as follows, according to the mechanical response at elevated temperatures:
  - ✓ Thermoplastic
  - ✓ Thermosetting

➢ **Thermoplastic**

- Thermoplastic polymers **soften** when **heated** and **harden** when **cooled** and are able to repeat these processes
- On the molecular level, when the **temperature is raised**, secondary **bonding forces** are **diminished** so that the **relative movement** of adjacent chains is **facilitated** when a stress is applied.

Thermoplastic … continued

- Most **Linear polymers** and those **having branched structures** with **flexible chains** are thermoplastics

- Thermoplastics are **very soft** and **ductile**
- Commercially available thermoplastics are;
  - ✓ Poly(vinyl Chloride) (PVC)
  - ✓ Poly(methyl methacrylate)
  - ✓ Polystyrene

- **Thermosets**

- Thermosetting polymers become **soft during their first heating** and become **permanently hard when cooled**
- They **do not soften** during subsequent heating and hence, they cannot be **remolded/reshaped** by subsequent heating
- In thermosets, during the initial heating, **covalent cross-links** are **formed** between **adjacent molecular** chain which **anchor the chains together** to **resist** the **vibration** and **rotational** chain motions at high temperatures
- Cross linking is usually extensive in that 10 to 15% of the chain per units are cross linked

➢ Thermosets ... continued

- Only **heating to excessive temperatures** will cause **severance** of these crosslink bonds and polymer degradation
- **Thermoset polymers** are **harder**, **stronger**, **more brittle** than **thermoplastics**
- They are **more usable** in processes **requiring high** temperatures
- Most of the **cross linked** and **network** polymers which include the following;
  - ✓ Vulcanized rubbers
  - ✓ Epoxies
  - ✓ Phenolic
  - ✓ Polyester resins
- Thermosets cannot be recycled, do not melt, are usable at higher temperatures than thermoplastics, and are more chemically inert

E. Classification Based on Kinetics or Mechanism

- Step-growth
- Chain-growth

F. Classification by Application

- Plastics
- Fibers
- Elastomers
- Coatings
- Adhesives

7. Main physical properties of polymers

1. **Primary bonds** : the **covalent bonds** that connect the atoms of **the main chain**

2. **Secondary bonds** : **non – covalent** bonds that hold one polymer chain to another including **hydrogen bond** and other **dipole –dipole attraction**

3. **Crystalline polymer** : solid polymers with **high degree** of **structural order** and **rigidity**

4. **Amorphous polymers** : polymers with a **low degree of structural order**

5**. Semi** – **crystalline polymer** : consist of **both crystalline** domains and **amorphous domains** with properties **between** that expected for a **purely crystalline** or purely **amorphous polymer**

6. **Glass**: the **solid form** of an **amorphous polymer** characterized by **rigidity and brittleness**

7. **Crystalline melting temperature (Tm)**: **temperature** at which crystalline polymers **melt**

Main physical properties of polymers … Continued

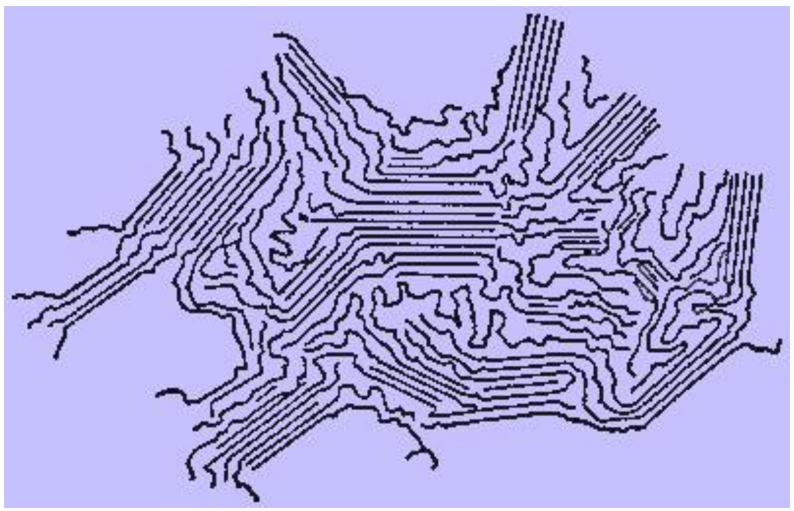
8. **Glass transition temperature** (Tg) : **temperature** at which an **amorphous polymer** converts to **a liquid or amorphous** domains of a **semi crystalline polymer melt**
9. **Thermoplastics (plastics);** polymers that undergo **thermally reversible** Interconversion between the **solid state** and the **liquid** state
10. **Thermosets** : polymers that continue **reacted at elevated temperatures** generating **increasing number of crosslinks** such polymers **do not exhibit melting or glass transition**

11- **Liquid – crystalline polymers** : polymers with a **fluid phase** that retains some order

12- **Elastomers** : **rubbery** , **stretchy** polymers the effect is **caused by light crosslinking** that pulls the chains back to their original state

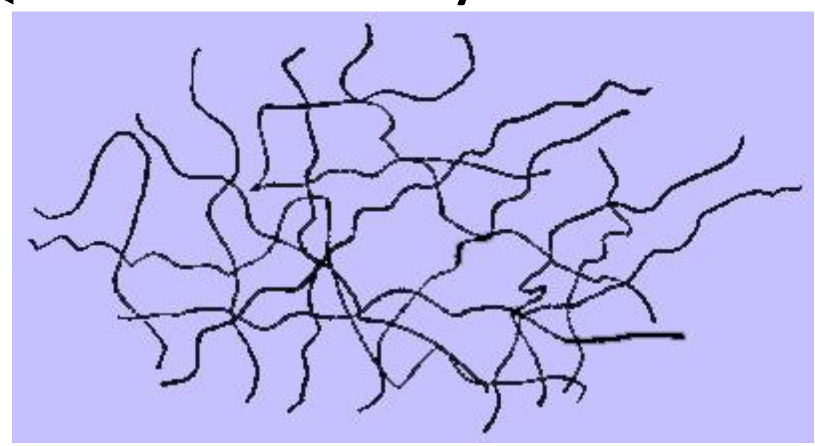
8. Polymers in the solid state

Semi-crystalline



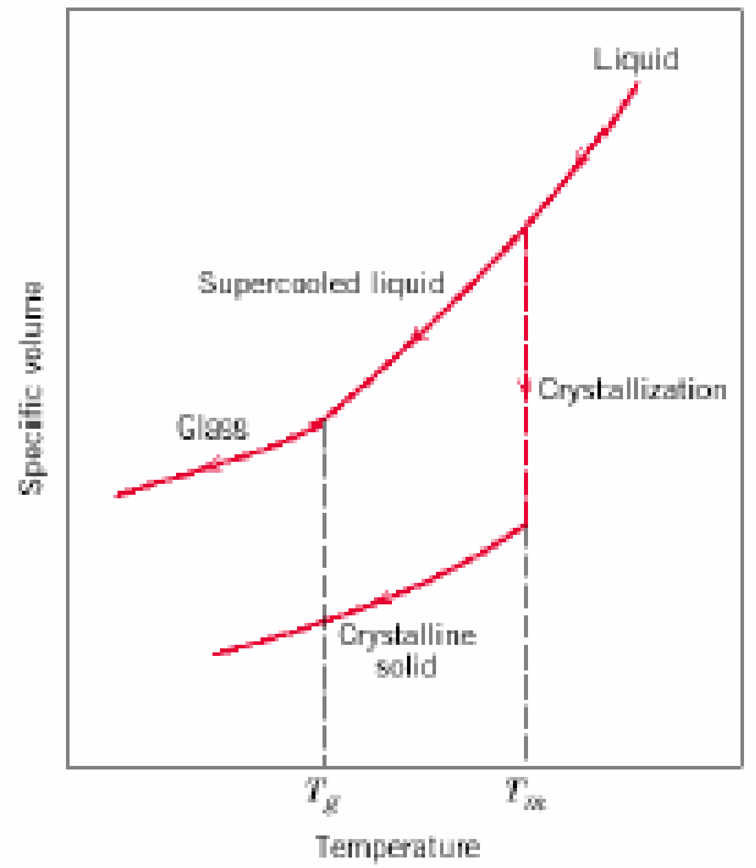
Amorphous

Glassy ⇄ **Rubbery**



9. Glass Transition Temperature

- **The glass transition**, **Tg**, **is temp**. below which a polymer OR glass is **brittle or glass-like**; above that temperature the material is **more plastic**.
- The Tg to a first approximation is a measure of the strength of the secondary bonds between chains in a polymer; the **stronger the secondary bonds**; the **higher the glass** transition temperature.
  - ✓ Polyethylene Tg = 0° C;
  - ✓ Polystyrene = 97 ° C
  - ✓ PMMA (plexiglass) = 105 ° C.
  - ✓ Since room temp. is < Tg for PMMA, it is brittle at room temp.
  - ✓ For rubber bands: Tg = - 73° C….



10. Crystallinity

Crystallization in **linear polymers**: **achieving a very regular** arrangement of the poly*mers*

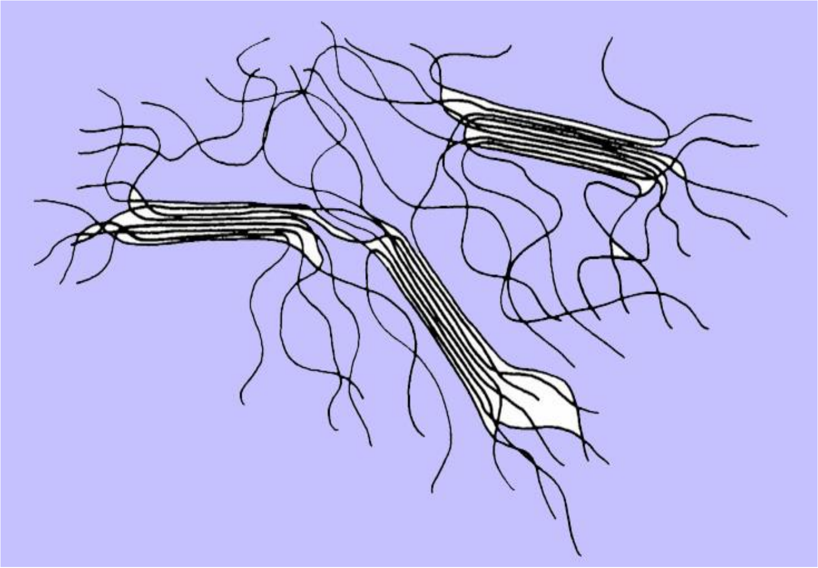
- Induction of crystallinity
  - ✓ cooling of molten polymer
  - ✓ evaporation of polymer solution
  - ✓ annealing — heating of polymer at a specific temperature
  - ✓ drawing — stretching at a temperature above T_g

➢ **Effects:**

- ✓ Increased Density
- ✓ Increases Stiffness (modulus)
- ✓ Reduces permeability
- ✓ Increases chemical resistance
- ✓ Reduces toughness

11. **Crystalline polymers (vs amorphous polymers)**

- **tougher, stiffer** (due to stronger interactions)
- **higher density, higher solvent resistance** (due to closely packing morphology)
- **more opaque** (due to light scattering by crystallites)



12. Raw materials for synthetics

- Synthetic polymers
- scientists evolved a mechanism to polymerize the monomers of certain substances like rubber, silicone and petroleum products such as ethane, propane, benzene, toluene, styrene, ester, and others.
- **All these are raw materials for synthetic plastics**

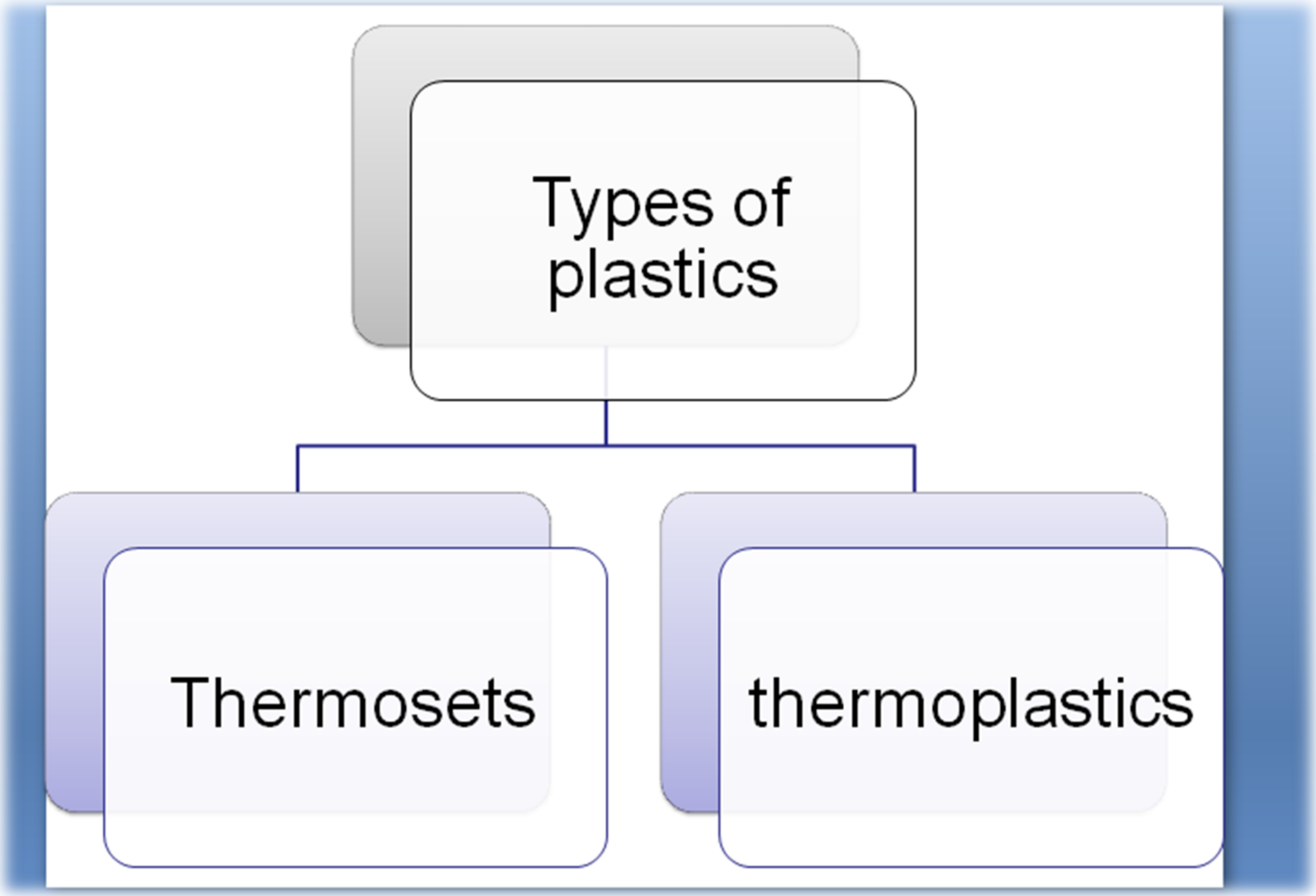
Plastic products

Application of plastics

- there is a great variety of plastics made from different chemicals

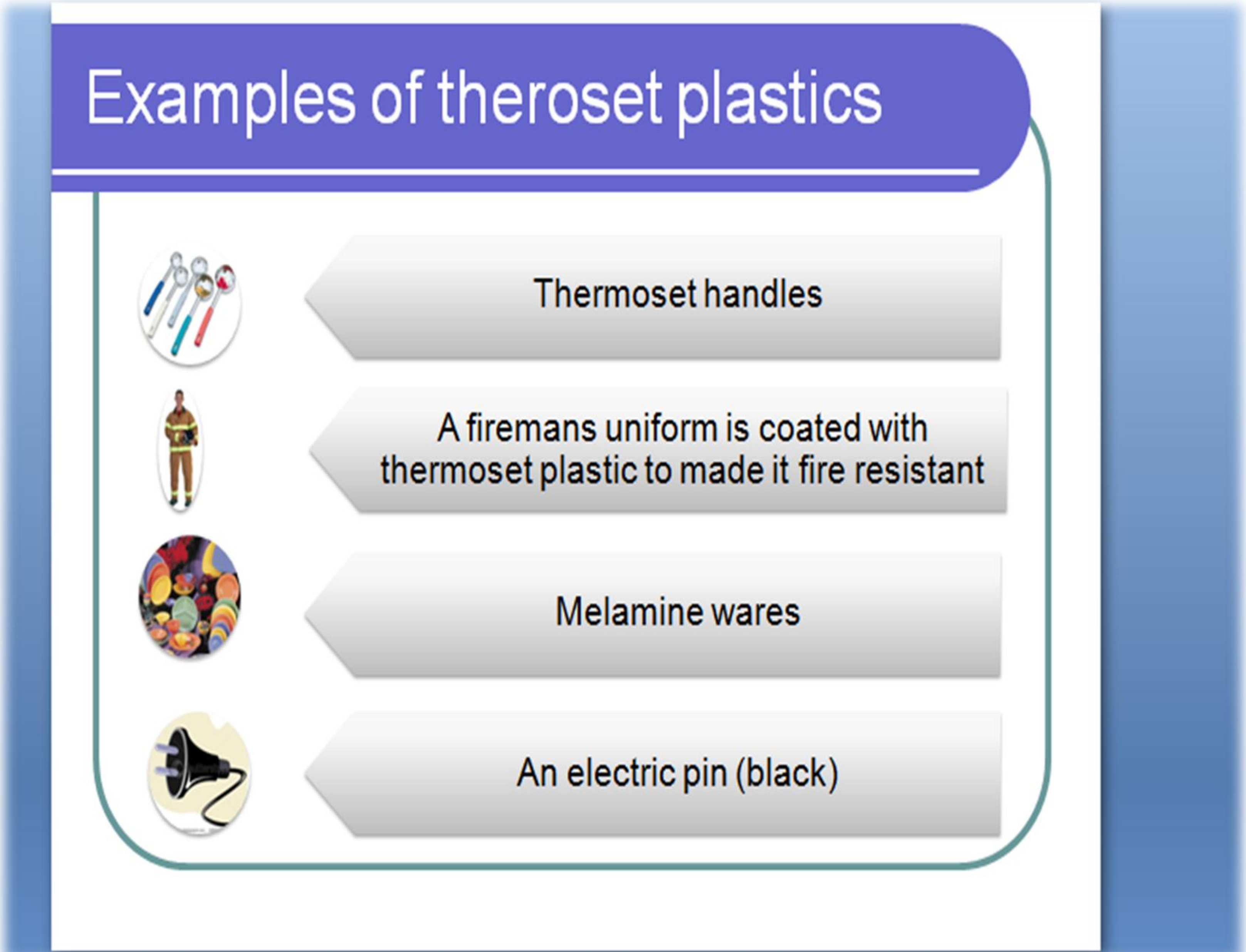
- **Property** and **uses** of each kind of plastic **depend upon** the **material being used** for its synthesis (polymerization)


Plastic Milk & Juice Bottles
Plastic Lumber (decking, docks, etc.)
Play Sets
New Bottles
=
Plastic Detergent Bottles
Buckets
Containers
Frisbees
Stadium Seats
Plastics


Types of plastics
Thermosets
thermoplastics

Thermoset plastics

- **Thermoset plastics** are **hard and rigid** such as **Bakelite and melamine**
- Thermoset is **dark** in **color**, **hard** and **resistant** to **heat** and **electricity** which can be **molded to set it in any shape,** but it **cannot be remolded**
- **thermoset plastic** is being widely used for making **handle of kettles and pans, telephone sets**, **electric switches**, **electric lamp holders**, **pins** and **plugs**.
- It is also being used as a part of **fiber glass sheet** in the making of **helmets**
- Melamine is a kind of Thermoset plastics used in **good quality tableware,** a **coating on uniforms** of **firemen** to make them **fire resistant**


Examples of theroset plastics
Thermoset handles
A firemans uniform is coated with thermoset plastic to made it fire resistant
Melamine wares
An electric pin (black)

Thermoplastics

- Thermoplastics are **soft and flexible** through they are **not elastic** like rubber and steel springs
- They **melt on warming** and **regain** their **shape on cooling**
- Thermoplastics can be **drawn** into **fine fibers**, **molded** to any **desired shape** or **stretched** or **spread as sheets**.
- Some of the better **known thermoplastics** are nylon (polyamide), polyesters, polyethylene, polyvinyl chloride (PVC), acrylic, polyurethane, polypropylene (PP), poly-tetra-fluoro-ethylene (PTFE) etc

Thermoplastics examples

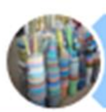

Plastic table and chairs


Plastic food containers


Plastic toys

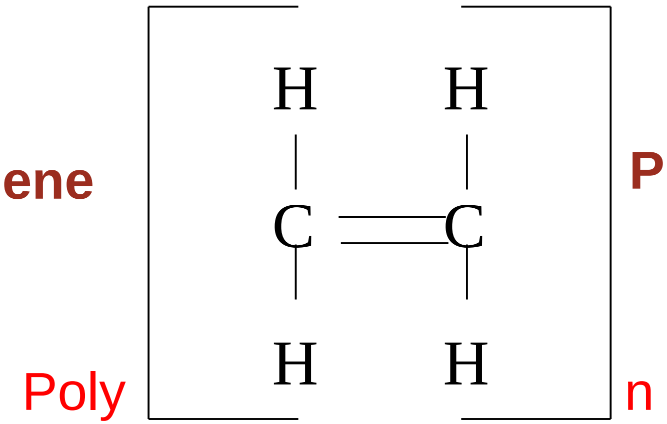

Plastic spoons and forks


Plastic cups

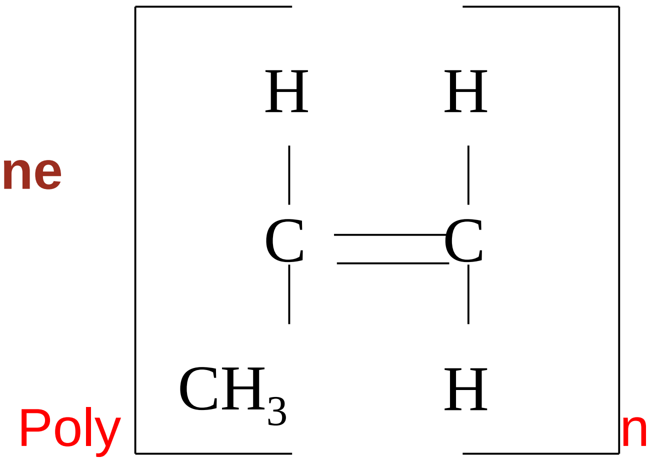

Plastic daily use items

Principal Olefin Monomers

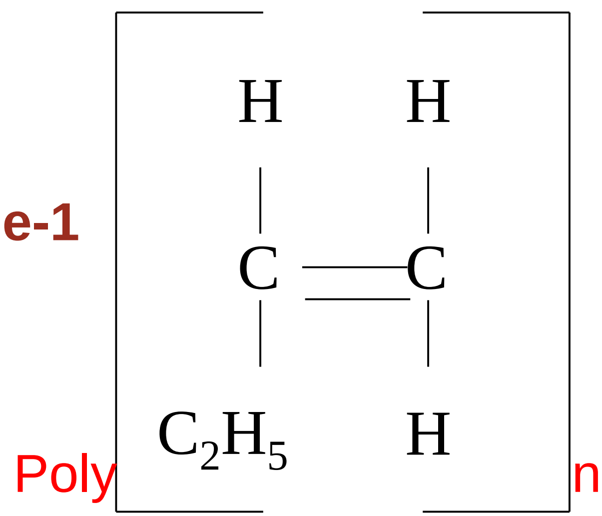
Ethylene



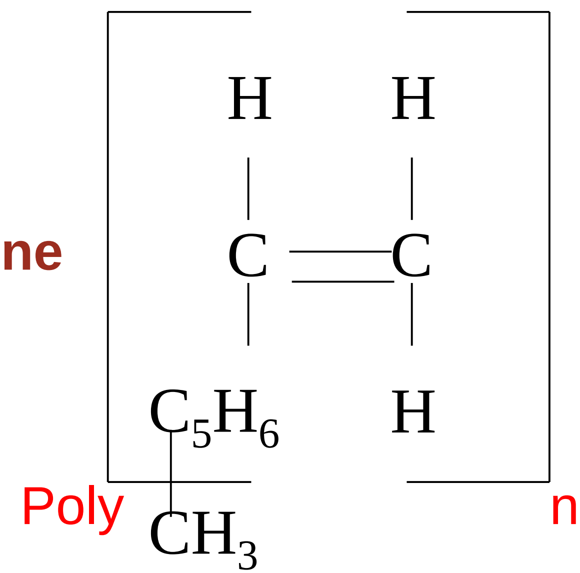
Propylene



Butene-1



4-Methylpentene



Mechanical properties of polyethylene

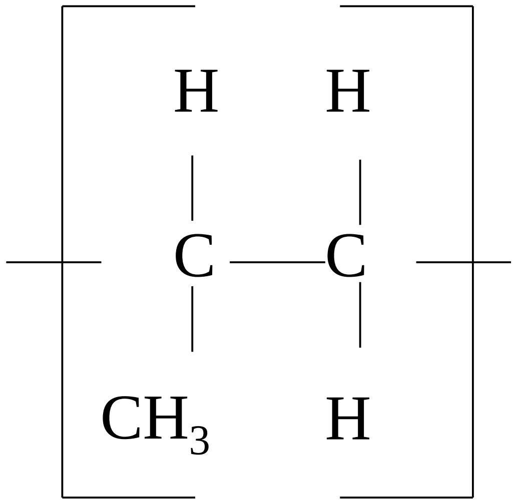
- Type 1: (Branched) Low Density of 0.910 - 0.925 g/cm^3
- Type 2: Medium Density of 0.926 - 0.940 g/cm^3
- Type 3: High Density of 0.941 - 0.959 g/cm^3
- Type 4: (Linear) High Density to ultra high density > 0.959 g/cm^3

Mechanical Properties

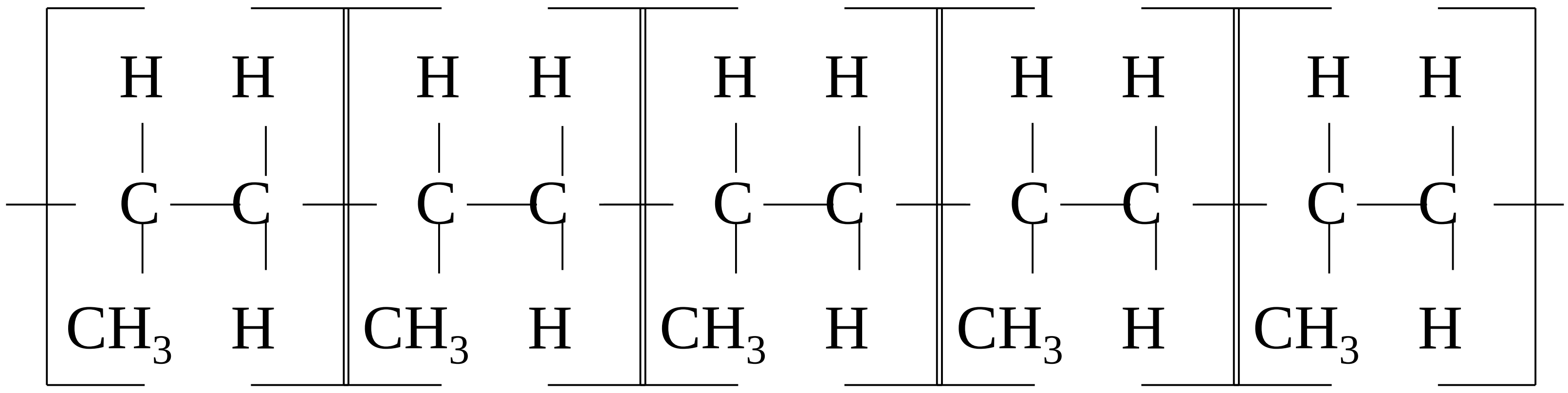
	Branched Low Density	Medium Density	High Density	Linear High Density
Density	0.91- 0.925	0.926- 0.94	0.941-0.95	0.959-0.965
Crystallinity	30% to 50%	50% to 70%	70% to 80%	80% to 91%
Molecular Weight	10K to 30K	30K to 50K	50K to 250K	250K to 1.5M
Tensile Strength, psi	600 - 2,300	1,200 - 3,000	3,100 - 5,500	5,000 – 6,000
Tensile Modulus, psi	25K – 41K	38K – 75 K	150K – 158 K	150K – 158 K
Tensile Elongation, %	100% - 650%	100%- 965%	10% - 1300%	10% - 1300%
Impact Strength ft-lb/in	No break	1.0 – no break	0.4 – 4.0	0.4 – 4.0
Hardness, Shore	D44 – D50	D50 – D60	D60 – D70	D66 – D73

Polypropylene structure

- polypropylene



- Isotactic- CH_3 on one side of polymer chain (isolated) where commercial PP is 90% to 95% Isotactic



Advantages/disadvantages of polypropylene

- **Advantages**
  - ✓ Low Cost
  - ✓ Excellent flexural strength
  - ✓ Good impact strength
  - ✓ Processable by all thermoplastic equipment
  - ✓ Low coefficient of friction
  - ✓ Excellent electrical insulation
  - ✓ Good fatigue resistance
  - ✓ Excellent moisture resistance
  - ✓ Service Temperature to 126^{o}C
  - ✓ Very good chemical resistance

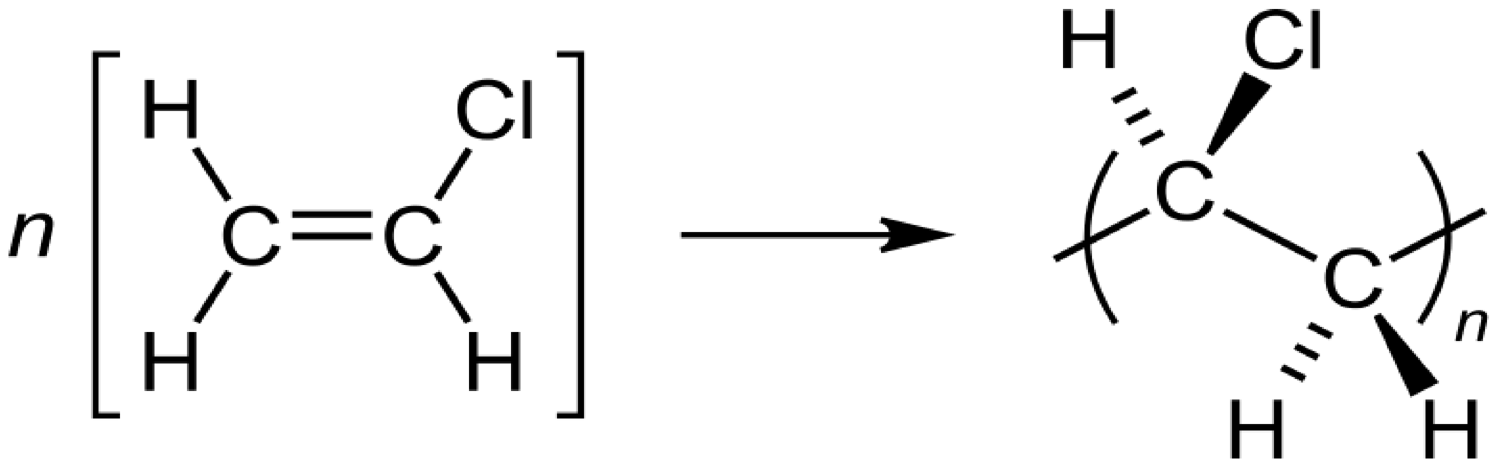
- **Disadvantages**
  - ✓ High thermal expansion
  - ✓ UV degradation
  - ✓ Poor weathering resistance
  - ✓ Subject to attack by chlorinated solvents and aromatics
  - ✓ Difficulty to bond or paint
  - ✓ Oxidizes readily
  - ✓ flammable

Physical properties of polypropylene-polyethylene

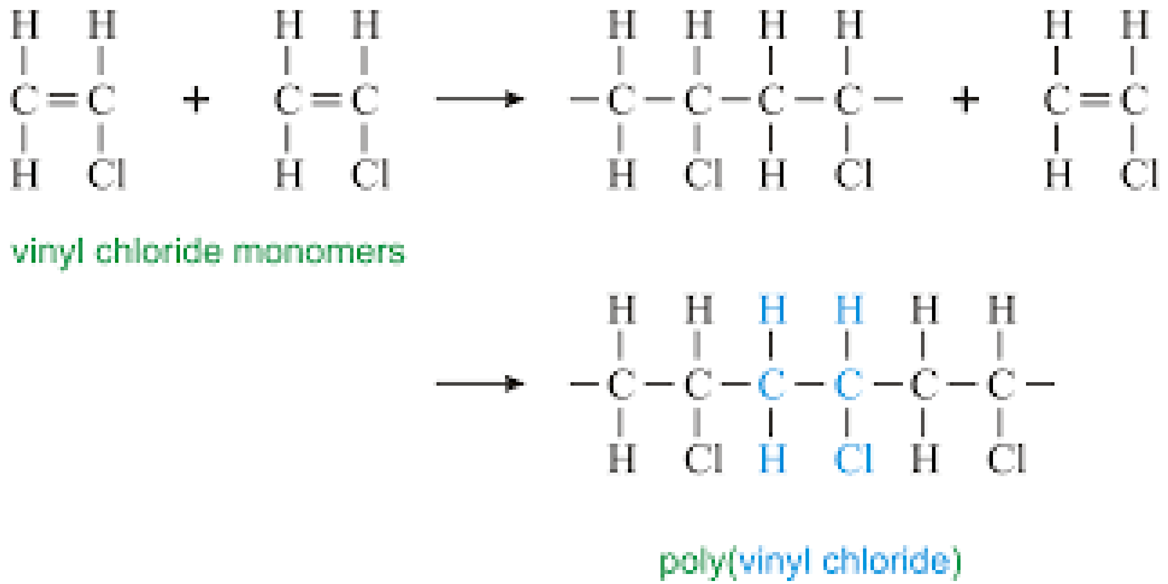
	Polypropylene	LDPE	HDPE
Optical	Transparent to opaque	Transparent to opaque	Transparent to opaque
Tmelt	175 C	98 – 115 C	130 –137 C
Tg	-20 C	-100 C	-100 C
$H_2$0 Absorption	0.01 – 0.03	Low < 0.01	Low < 0.01
Oxidation Resistance	Low, oxides readily	Low, oxides readily	Low, oxides readily
UV Resistance	Low, Crazes readily	Low, Crazes readily	Low, Crazes readily
Solvent Resistance	Resistant below 80C	Resistant below 60C	Resistant below 60C
Alkaline Resistance	Resistant	Resistant	Resistant
Acid Resistance	Oxidizing Acids	Oxidizing Acids	Oxidizing Acids

Polyvinylchloride (PVC)

- It is made from monomer vinyl chloride, which has a chlorine atom in place of the H's
- The polymerization of vinyl chloride;



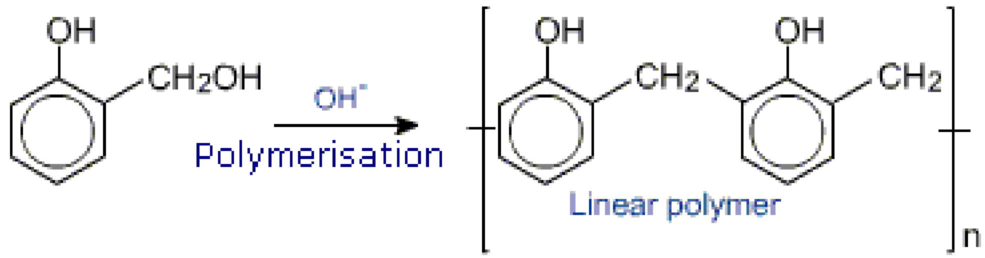
Polyvinylchloride (PVC)



- PVC is made into a huge variety of items including pipes, artificial leather and so on

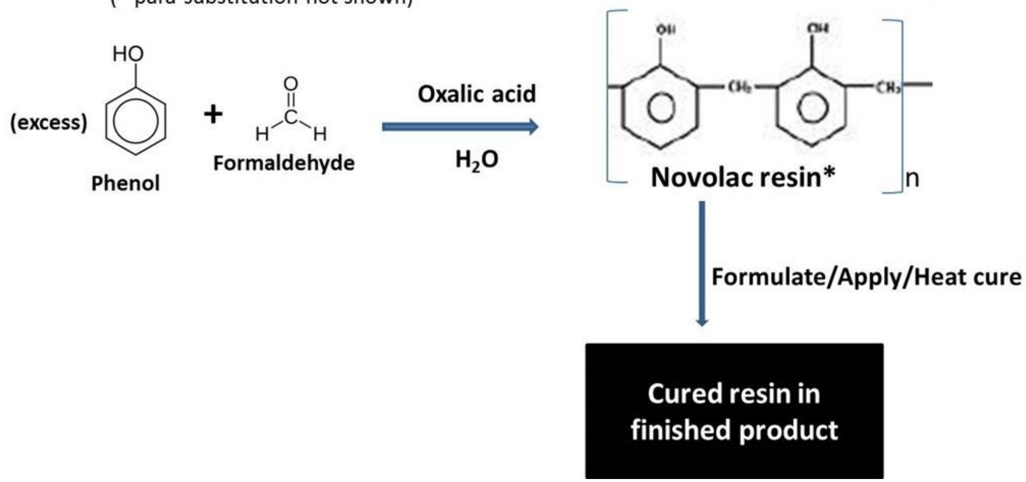
Bakelite

- Bakelite (Phenol Formaldehyde Resin)
- It is made from **phenol and formaldehyde** in the presence of base catalyst.



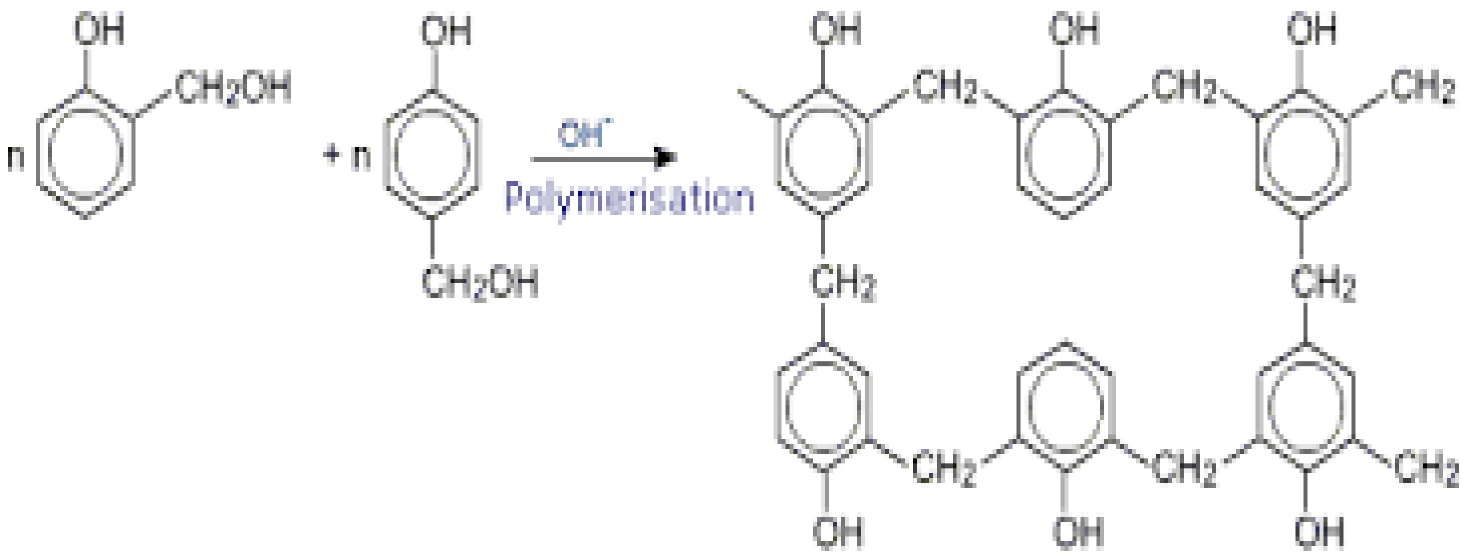
called Novalac

Figure 1. Formation of a Novolac resin
(* para-substitution not shown)



Bakelite

- On further heating with HCHO, undergoes cross-linking to an infusible solid called bakelite which is hard scratch and water resistant



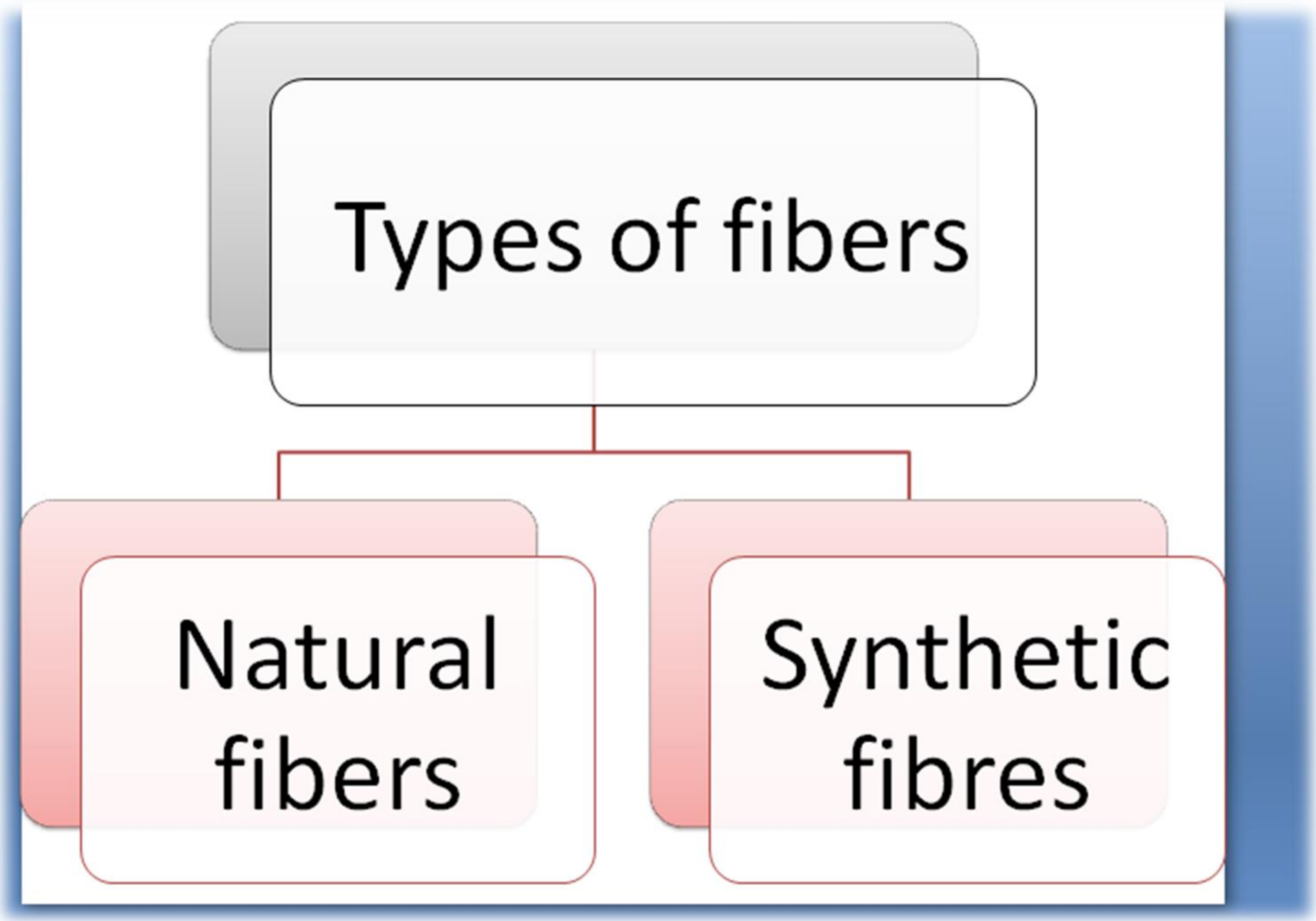
Cross linked polymer - bakelite

Bakelite

- **Soft bakelite** (low degree of polymerization)
- Used as bonding for laminated wooden planks, in varnish and paint
- **Hard bakelite** (High degree of polymerization)
- It possesses **excellent electrical insulating** character and hence its major use in making **electrical goods**
- Used to make **combs**, **gramophone records** and soon.

Fiber

- Fiber is a thread or filament from which a vegetable tissue, mineral substance, or textile is formed.


Types of fibers
Natural fibers
Synthetic fibres

Natural and synthetic

Natural fibers come from natural sources like plants and animals.

Synthetic fibres are man-made fibres. Synthetic fibres are made from different chemicals, hence each kind of synthetic fibres have their own properties. Synthetic fibres are more in length and are long lasting. The only limitation in synthetic fibres is that they are poor absorbents of moisture and they catch fire easily

Monomers and polymers

- Substances that are made up of units
- A substance having a single unit structure forming its particles called a **monomer**
- In certain substances thousands of units join together to form a large unit, called polymer (poly means many). Polymer is made of many repeating units.
- The process of joining together monomers to form a polymer is called polymerization

Polymers may be natural

Natural polymers:

- Natural fibers like cotton, wool and silk are polymers
- Cotton is a polymer glucose
- Wool and silk are the polymers of amino-acid (protein)
- Spider silk is one of the strongest natural polymers

Polymers can be synthetic

Synthetic polymers:

- Synthetic polymers are made from chemical substances
- They are plastic in nature
- **Nylon** and **polyester** are synthetic fibers

Synthetic polymers ...Continued

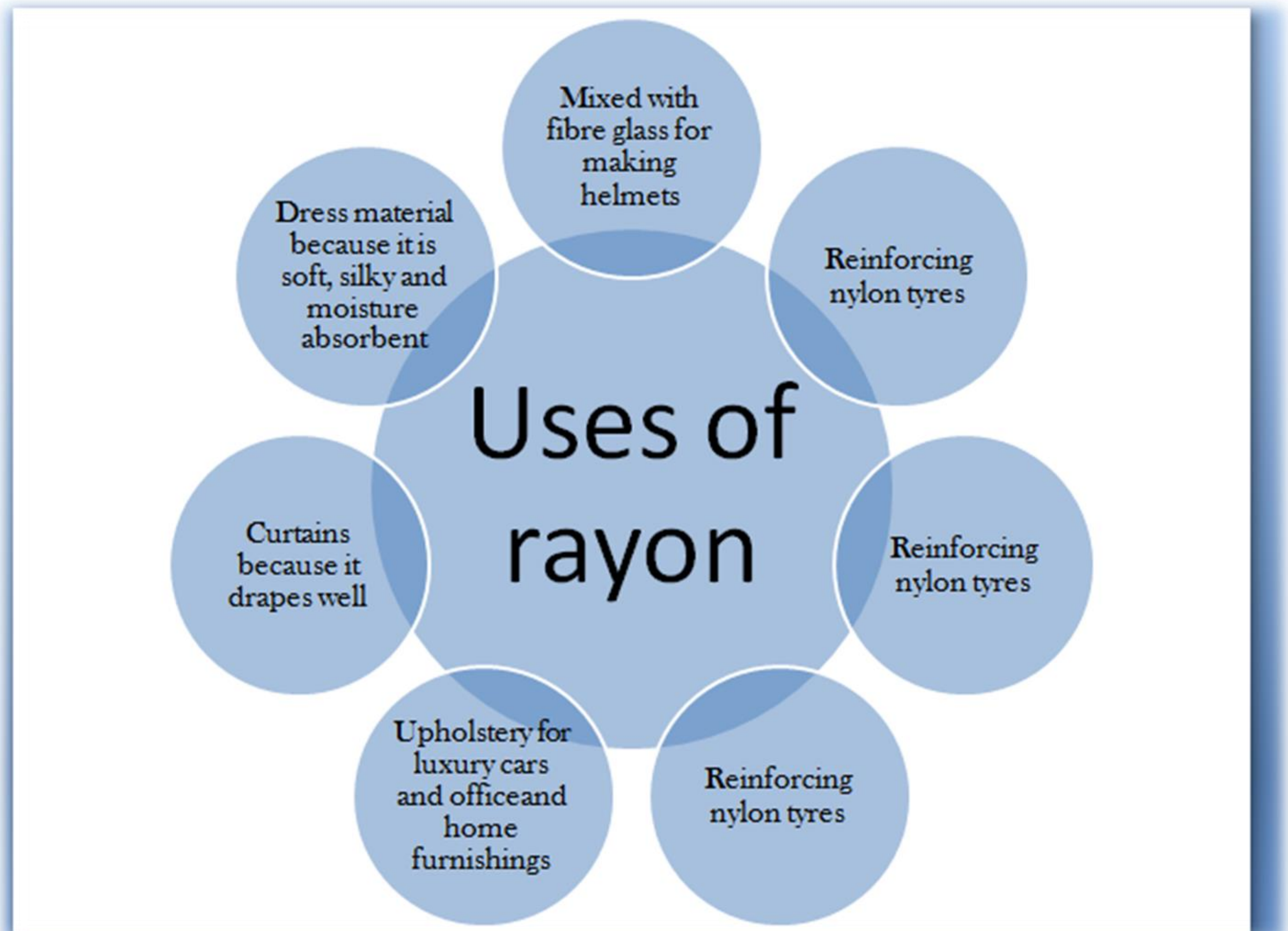
- **Most synthetic fibers** are obtained from **petroleum products**, **natural gas** and **coal** by the process of polymerization

Rayon

- **Rayon** is prepared **from cellulose**
- Though cellulose is a natural polymer it **needs extensive chemical treatment** to form rayon
- Hence it is also considered as a **semi-synthetic fiber**

➢ Advantage of rayon :

- ✓ it is **cheaper to produce** as compared to cotton itself since **waste cotton** and **paper** is used for **making rayon**
- ✓ rayon can be **blended** with other **fibers** like **wool** and **silk**


Uses of rayon
Mixed with fibre glass for making helmets
Reinforcing nylon tyres
Reinforcing nylon tyres
Reinforcing nylon tyres
Upholstery for luxury cars and officeand home furnishings
Curtains because it drapes well
Dress material because it is soft, silky and moisture absorbent

Nylon

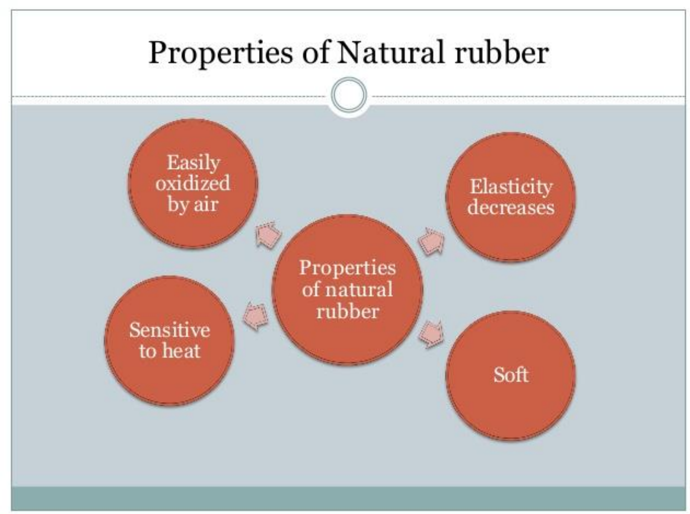
- first developed by American scientist, **Wallace H. Carothers** for M/S Dupont de Nemours & Company of America in **1935**
- Chemically it is a '**polyamide**', a polymer which is the **strongest synthetic plastic** material and **can be molded to any shape**
- has several uses **as fiber**, **as sheet** and as **molded solids**
- People believe that nylon has been named since its products were **simultaneously launched** in **New York (NY) and London (LON)**

Natural and synthetic rubber

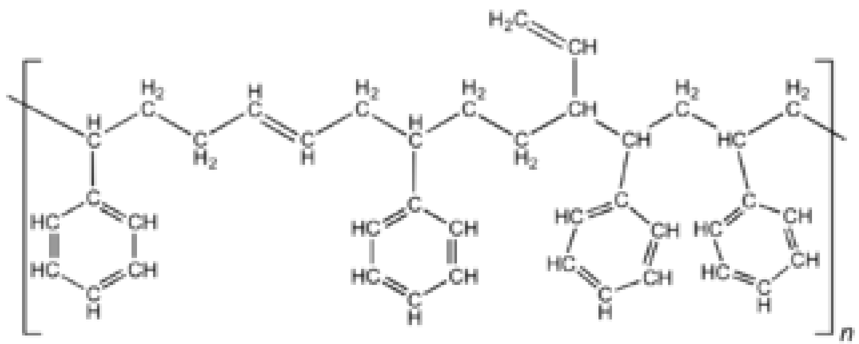
- **Natural rubber exists as a white solid** at room temperature
- The presence of a **double bonds** in the **polymer greatly affects** the **property** of natural rubber such as **susceptible to vulcanization** and sensitive to **ozone cracking**
- **Vulcanization**: hardening of rubber or rubber-like material by treating it with sulphur at a high temperature.

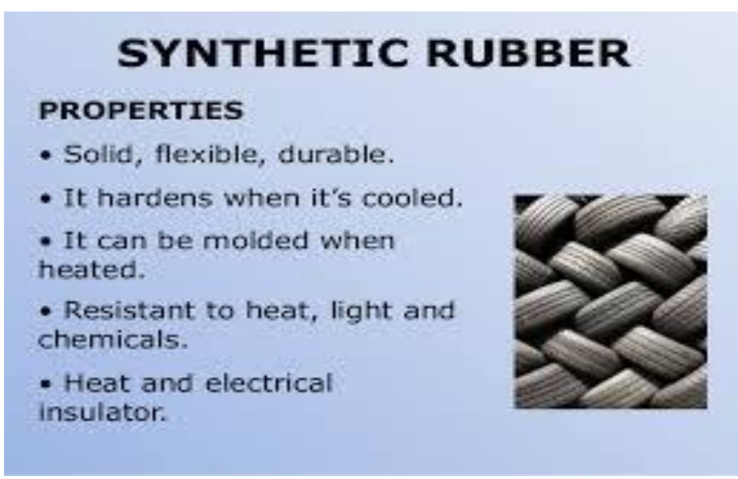
$$n\,CH_2=\underset{\displaystyle CH_3}{\underset{|}{C}}-CH=CH_2 \longrightarrow -[-CH_2-\underset{\displaystyle CH_3}{\underset{|}{C}}=CH-CH_2-]_n-$$

isoprene [2- methyl butadiene] → natural rubber [poly isoprene]



- **A synthetic rubber** is any artificial elastomer
- These are mainly polymers synthesised from petroleum byproducts
- Synthetic rubber, like natural rubber, has uses in the automotive industry for tires, door and window profiles, hoses, belts, matting, and flooring
- **Styrene-butadiene** or **styrene-butadiene rubber** (SBR) is an example of synthetic rubbers derived from styrene and butadiene





☺Thank you ☺

1. Mention two examples for each of synthetic and natural ploymers
2. Write the difference between;
    i. Repeating unit and monomer
    ii. Polymer and monomer
3. Write the four nature that derive the interest in engineering polymers.
4. What are the two basis for nomenclature of polymers?
5. Mention the four classes of copolymers
6. Based on what do we classify polymers as linear, branched, cross-linked and network?
7. Briefly describe thermoplastics and thermosetting plastics

5 - SUCROSE INDUSTRY

1. Introduction

- Table sugar, '**sucrose**', one of the family of **saccharide** in the grouping called **carbohydrates**
- **Sucrose**, $C_{12}H_{22}O_{11}$, is a **disaccharide**, a **condensation molecule** made up of **two sugar** molecules

$$\text{Glucose} + \text{Fructose} \longrightarrow \text{Sucrose}$$

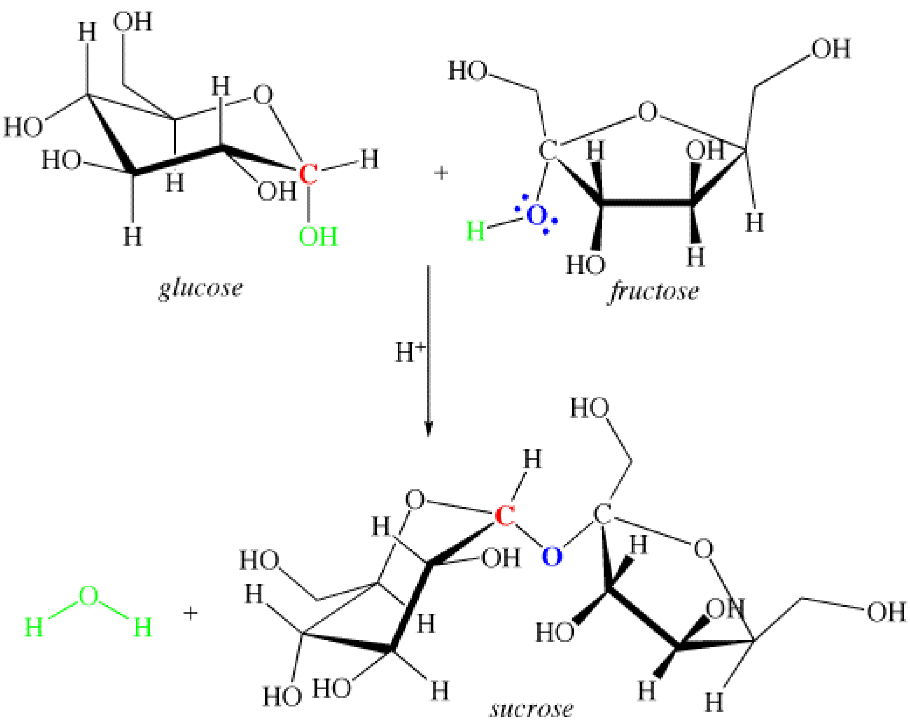
- Plants make **sugars** by **photosynthesis** cytosol of photosynthesizing cells

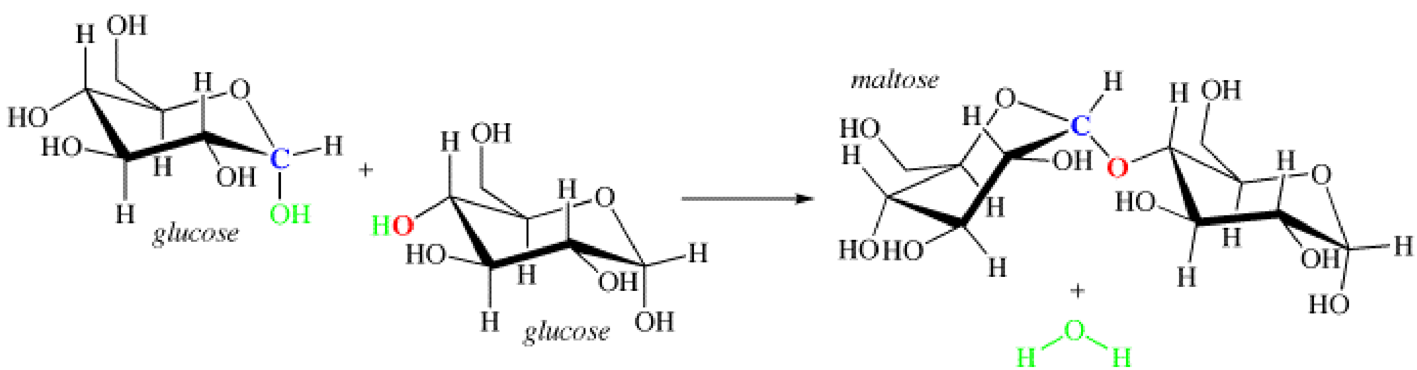
$$12\ CO_2 + 11\ H_2\ O \longrightarrow C_{12}\ H_{22}\ O_{11} + 12\ O_2$$

$$\text{carbon dioxide} + \text{water} \longrightarrow \text{sucrose} + \text{oxygen}$$

Introduction

... Continued





5.2 Manufacture from Cane Sugar

Cane sugar Production Process

- Sugar production major process is proceeded as follows;

a. Entry of the sugar cane

b. Milling

c. Clearing up

d. Evaporation

e. Crystallization

f. Separation

g. Refining

h. Drying

i. Storage


alamy stock photo

a. Entry or transportation of the sugar cane

- Sugar is obtained from the **cane at mills** located near centers of production
- The cane first goes through a **washer, cut** into small pieces by **revolving knives**
- the **small pieces are shredded** with a **large powerful hammer** mill that **shreds** the cane into a fibrous material
- After this procedure, the **juice from the sugar cane** can be extracted

b. Milling Train

- The **shredded cane** is fed through a series of **crushing mills** to **extract the sugar rich juice**
- The crushers consist of **two large grooved rollers** mounted horizontally and then one above of the others where heavy hydraulic pressure is maintained on the upper roller
- Pumped for further processing **leaving behind** the **fiber** is called **Bagasse**

c. Clearing up

- The limed juice enters a **gravitational settling tank**, **a clarifier**
- The **juice travels** through the clarifier at a **very low speed so** that the **solids settle** out and **clear juice** exits
- The **mud** from the clarifier **still contains valuable sugar** so it is **filtered on rotary vacuum** filters
- the residual juice is **extracted,** and **the mud** can be **washed** before **discharge**, producing a sweet water, finally the **juice** and the **sweet water** are returned to process

d. Evaporation

- The **clear juice** is **concentrated** to **syrup by boiling-off** excess water in a series of connected vessels
- Under **automatically controlled** conditions in the evaporator station, each subsequent vessel **operates under decreasing** pressure with the **last one** being under almost a **total vacuum**
- After this step the **syrup is ready to go to the high-vacuum boiling pans**

e. Crystallization

- **Concentration of the syrup** from the evaporator is continued in **vacuum pans**
- Very small seed **crystals are introduced** to the concentrating syrup and these **begin to grow in size**
- When the crystals **reach the required size**, the mixture of **crystals and syrup** is discharged from the pan

f. Separation

- The **sugar crystals are separated** from the syrup in **centrifugal** machines
- After **leaving the centrifugals**, the moist **raw sugar is dried** in a **stream of air** and **transferred to bulk storage bins**
- The **separated syrup is re-boiled** and further sugar is crystallized
- After **three boiling no further** sugar can be economically removed and the **residual sugar** which is called **molasses** will be obtained

g. Sugar refining

- The **purpose of the refinery** is to **remove impurities** from sugar crystals
- The feed material **refinery** is **raw sugar** which is **dissolved** melted) and the color is removed by bleaching agents such as **carbon filters**
- The final refining steps include **melting the brown or raw**, **decoloring** by passing through carbon filters, **recrystallizing** in **vacuum boiling pans**, and drying by **centrifuging**

2. Manufacture of Sugar from Beet Root

- The **extraction and production** of sugar from **beet root** takes place at factories **on a large scale**
- Other products are also produced such as **icing sugar**, **caster sugar**, **dark and light brown sugar** and **syrups**
- **Co-products** from the production including **animal feed**, **soil, stones** & **electricity**

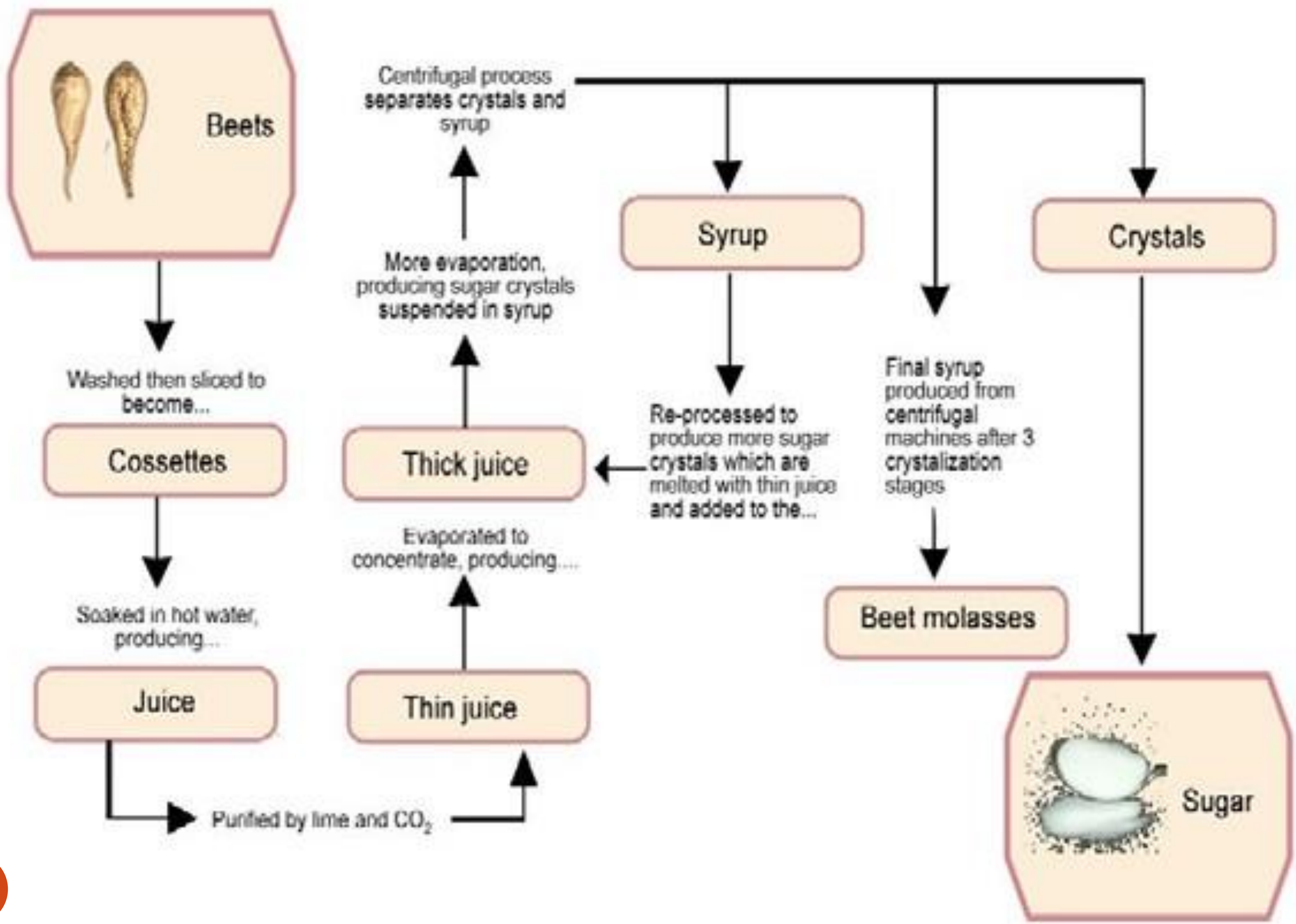
Sugar Production Process from Beet Root ... Cont'd

- Sugar production process is proceeded as follows;

1. Weighing of the beet root
2. Cleaning of the beet root
3. Slicing and diffusion
4. Purification
5. Evaporation
6. Crystallization
7. Packing

1. Weighing of the beet root

- A sample from each delivery of **sugar beet** entering the factory is **weighed** and then **tested** to **determine** its **sugar content**
- On average **one hectare** of sugar beet crop yields about **41 tones** of **clean, chopped roots** from which **7 tones of sugar** can be **extracted**


Beets
Washed then sliced to become...
Cossettes
Soaked in hot water, producing...
Juice
Purified by lime and CO_2
Thin juice
Evaporated to concentrate, producing....
Thick juice
More evaporation, producing sugar crystals suspended in syrup
Centrifugal process separates crystals and syrup
Syrup
Re-processed to produce more sugar crystals which are melted with thin juice and added to the...
Final syrup produced from centrifugal machines after 3 crystalization stages
Beet molasses
Crystals
Sugar

2. Cleaning of the beet root

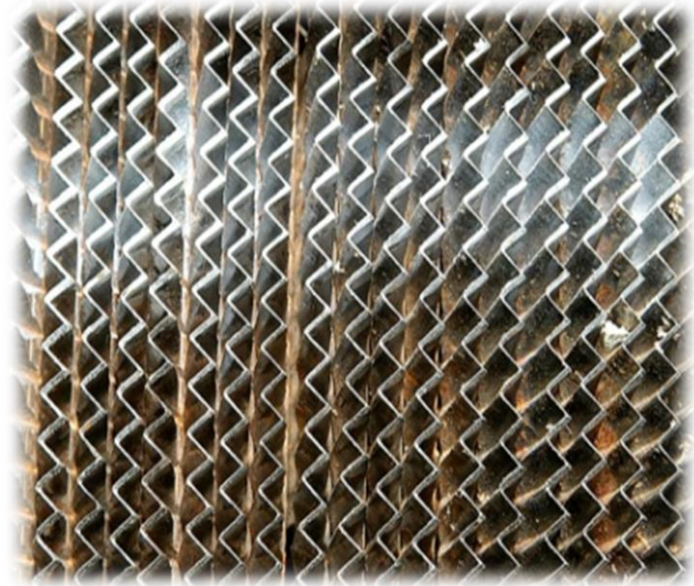
- The sugar beet is **washed in large** quantities of **water**, allowing it to pass through **weed** and **stone separators**, before being separated from the **water by a vibrating screen**, known as a **dewatering screen**
- The **sugar beet flows** through the **separators** by the **force of gravity**
- The **co-products** of this process are **topsoil** and **stones**, **removed at this stage**

Sugar Production Process from Beet Root … Cont’d

dewatering screen

3. Slicing and diffusion

- The **slicers slice up** or **cut** sugar beet into thin **'v' shaped strips** called **cossettes**
- **Cossettes** pumped into **three** diffusion **towers/diffusers** and mixed with **hot water to extract the sugar**
- Water temperature in the diffusers is **about 70 ^{0}C** and sugar passes from the **sugar beet plant cells** into the **surrounding water**



Sugar Production Process from Beet Root ... Cont'd

- The process produces **two important substances**, the **pulp** and the **raw juice sugar** in the **water**
- The pulp **Cossettes** is **mechanically pressed** to extract remaining sugar and water, Molasses is added, dried at 880° C and formed into **pellets**
- The **pellets are sold** as **animal feed** for **cattle**, **sheep**, **horses** and **other livestock**

4. Purification

- The **raw juice** from the diffusion process **passes through purification stage** called **carbonation** where **Milk of lime** ($CaOH_2$) and **carbon dioxide** (CO_2) gas are **added**
- The $\mathbf{CO_2}$ and $\mathbf{Ca(OH)_2}$ combine to produce **calcium carbonate**, $\mathbf{CaCO_3}$ which **precipitates out**, taking **most of the impurities** with it which is also called **Defecation**
- The **solid waste** which contains **trace elements** such as **potassium** and **magnesium** is **removed** through a **filtration system** and then **sold** to farmers as a soil **improving fertilizer**

5. Evaporation

- **Thin juice** from the **purification** process is enters into **evaporation** where the water is **boiled-off** in a series of six evaporator vessels called **multiple effect evaporators**
- Evaporation **increases the solids content** of the juice from **16 - 65%**
- The **liquid that remains** is known as **thick juice** which then goes through the **crystallisation** process

6. Crystallization

- The **thick juice** is placed in **pans** which **boil** the juice under pressure, to **lower** the boiling point
- The **thick juice** is **seeded** with **tiny sugar crystals** which provide the **nucleus** for **larger** crystals **to grow**
- A solution which is **about to crystallise** is known **as super saturated**

Sugar Production Process from Beet Root ... Cont'd

- Once the crystals have reached the **desired size**, **crystallization** process will be **stopped**
- The resultant mixture of **crystal sugar** & **syrup**, known as **massecuite,** is **spun** in **centrifuge** to **separate** the sugar from the **mother liquor**
- After **sugar crystals** have been removed, the **remaining juice** is **returned** to the process to be **spun again**
- The **sugar crystals** then **washed**, **dried**, **cooled** and **transported** to **storage** tower at a rate of **1,200 tonnes** on an average day

7. Packaging

- The sugar that is produced in the factory is sent to the **packaging complex** where it is packed via a series of **automated machinery**
- A machine **automatically channels** and **measures** the amount of bags going through and pulls them onto a pallet where the bags of sugar are **shrink** and **wrapped to protect** them from **moisture**

Summary

- The stages of sugar production include:
  - ✓ Weighing and sampling
  - ✓ Cleaning
  - ✓ Slicing and diffusion
  - ✓ Purification
  - ✓ Evaporation
  - ✓ Crystallisation
  - ✓ Packaging

Sugar

- Monosaccharides
  - ✓Glucose, Fructose
- Disaccharides
  - ✓Lactose (glucose and galactose) – milk sugar
  - ✓Maltose (glucose and glucose) – malt sugar
  - ✓Sucrose (glucose and fructose) – table sugar
- **Reducing** sugars - contains **hemiacetal** groups
  - ✓Examples: glucose, lactose, fructose
- **Non-reducing** sugar - contains **no hemiacetal** groups.
  - ✓Example: sucrose

Testing of sugar

Benedict's Test For Reducing Sugars

- reducing sugars are **simple sugars** which include all monosaccharides and most disaccharides
  - Examples
    - ✓**monosaccharides** - **glucose**, **fructose** and **galactose**
    - ✓reducing **disaccharides** - **lactose** and **maltose**
- **all** monosaccharides and **most disaccharides** will reduce **Benedict's reagent giving positive test**
- **reducing sugars** produce precipitate of **copper (I) oxide** up on **heating**

Benedict's reagent

$$\underset{\text{Copper sulfate pentahydrate}}{CuSO_4.5H_2O} + \underset{\text{Sodium carbonate}}{Na_2CO_3} + \underset{\text{Sodium citrate}}{Na_3C_6H_5O_7}$$

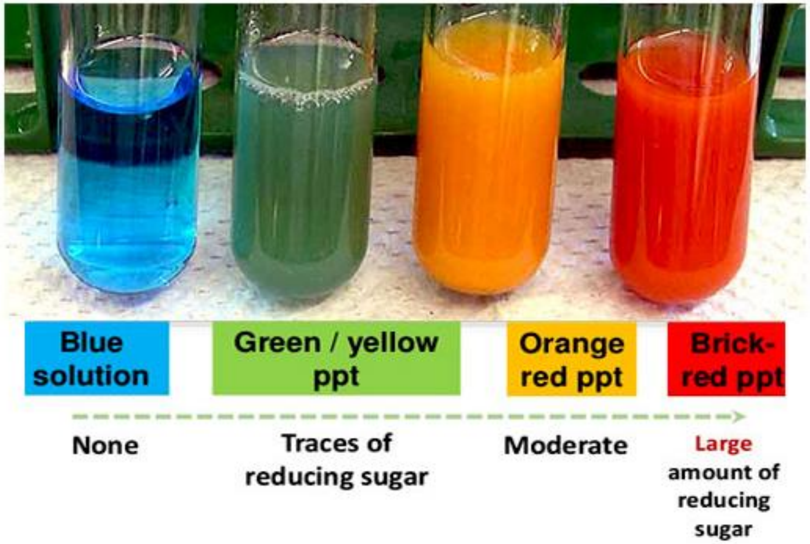
- **Benedict's reagent** is an aqueous solution of **copper (II) sulphate**, **sodium carbonate** and **sodium citrate**
  - ✓ **Sodium carbonate** provides the **alkaline conditions** which are required for the redox reaction
  - ✓ **Sodium citrate complexes** with the copper (II) ions so that they do not deteriorate to copper(I) ions during storage

Benedict’s Test

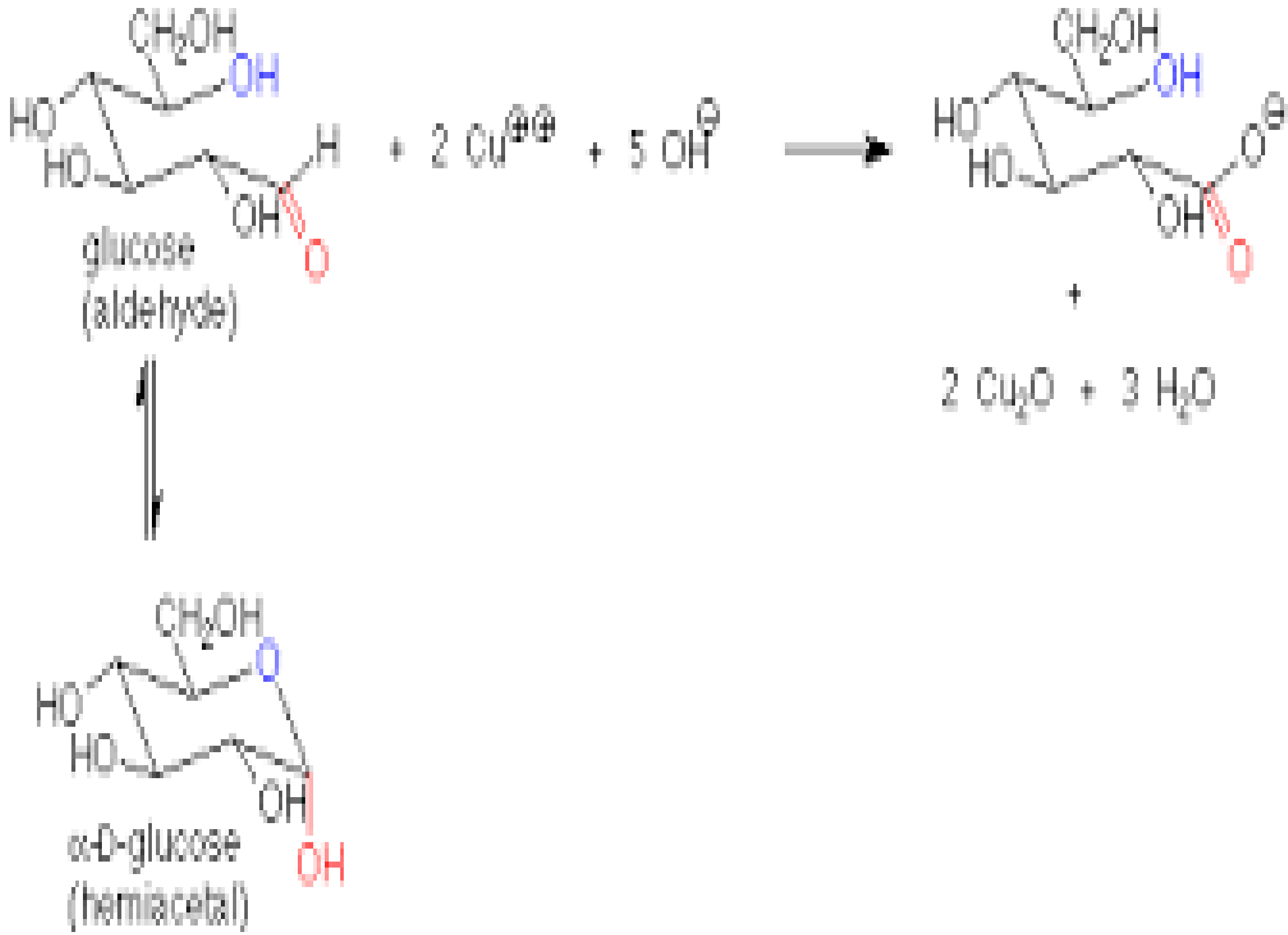
- used to test for **simple carbohydrates** to detect **reducing sugars** (monosaccharide’s and some disaccharides), which have free **ketone** or **aldehyde** functional groups
- reducing sugars such as **glucose** are **capable of transferring hydrogens** (**electrons**) to other compounds
- When reducing sugars are mixed with **Benedict's reagent** and heated, a reduction reaction causes change in colour
- the colour varies from **green** to dark/brick red or rusty-brown, depending on the **amount** of and **type** of sugar

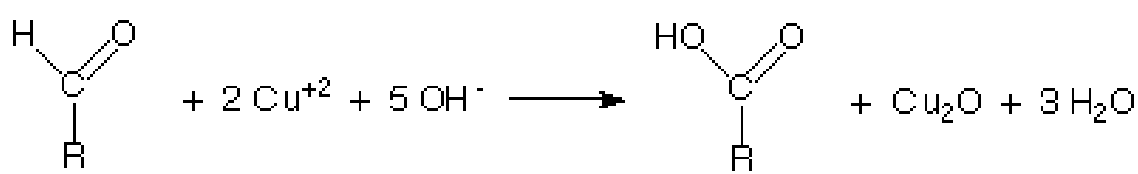
Benedict's Test

- The test done as follows;
  - Grinding up & dissolving sample
  - Mixing equal quantity of test solution and Benedict's reagent
  - Shaking and heating for a few minutes at 95°C in a water bath
    - ✓ **Brown/Brick red** precipitate = reducing sugars
    - ✓ Original **Pale Blue** = no reducing sugar



Reaction


glucose
(aldehyde)
α-D-glucose
(hemiacetal)
+ 2 Cu⊕⊕ + 5 OH⊖
+
2 Cu2O + 3 H2O


+ 2 Cu+2 + 5 OH-
+ Cu2O + 3 H2O

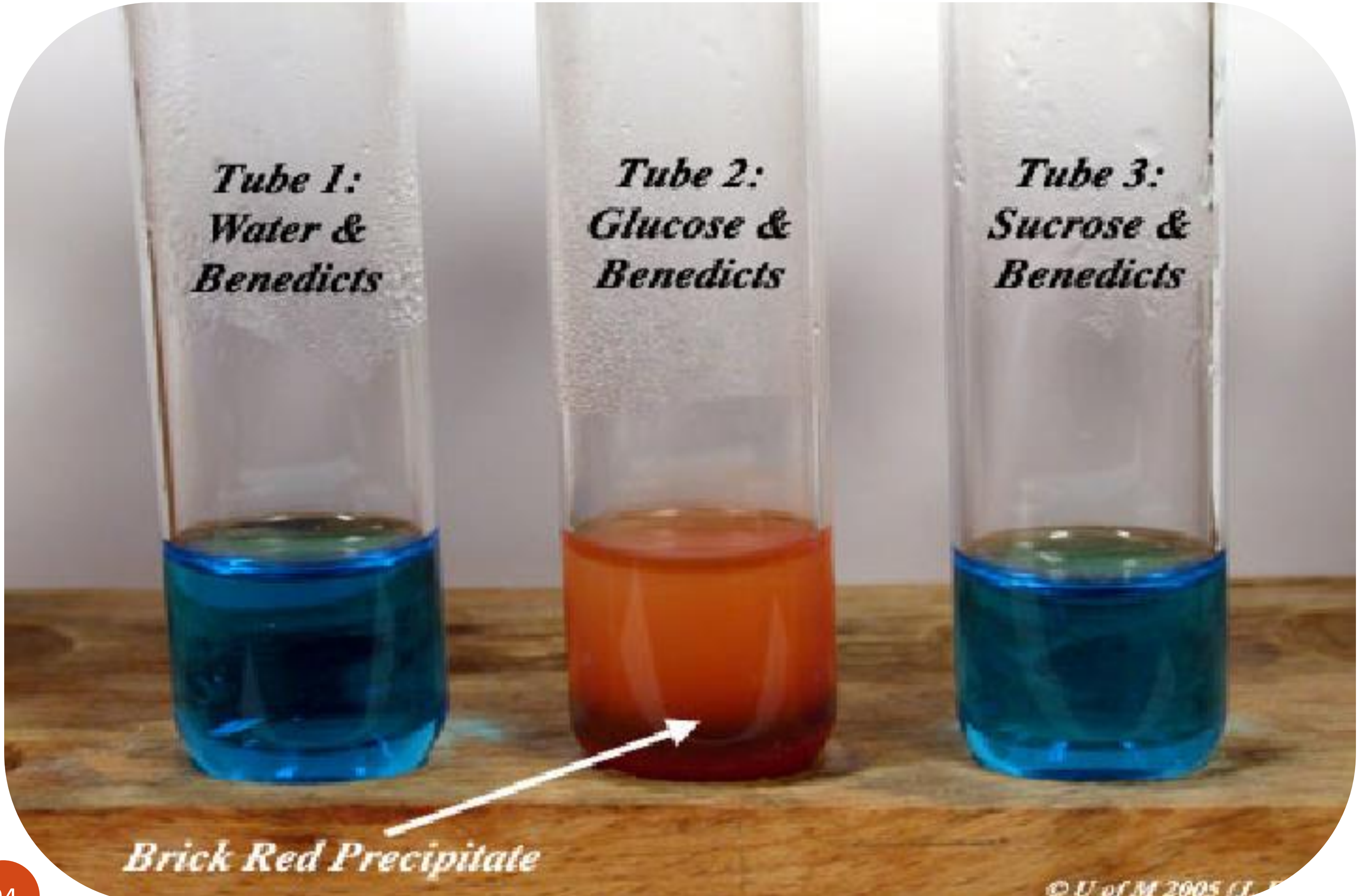
Principle of Benedict's Test

- **copper (II)** ions in the Benedict's solution are reduced to **Copper (I) ions,** the **cause** of **colour change**
- **red precipitate** formed is **copper(I) oxide** which is **insoluble in water** and precipitated out of solution
- as the **concentration** of reducing sugar **increases,** the nearer final colour is to **brick-red** and the **greater** the precipitate formed
- **Complex** carbohydrates such as **starches DO NOT** give **positive** result with the Benedict's reagent
- they are needed to be **converted** in to simpler form through **heating** or **hydrolysis** by acid

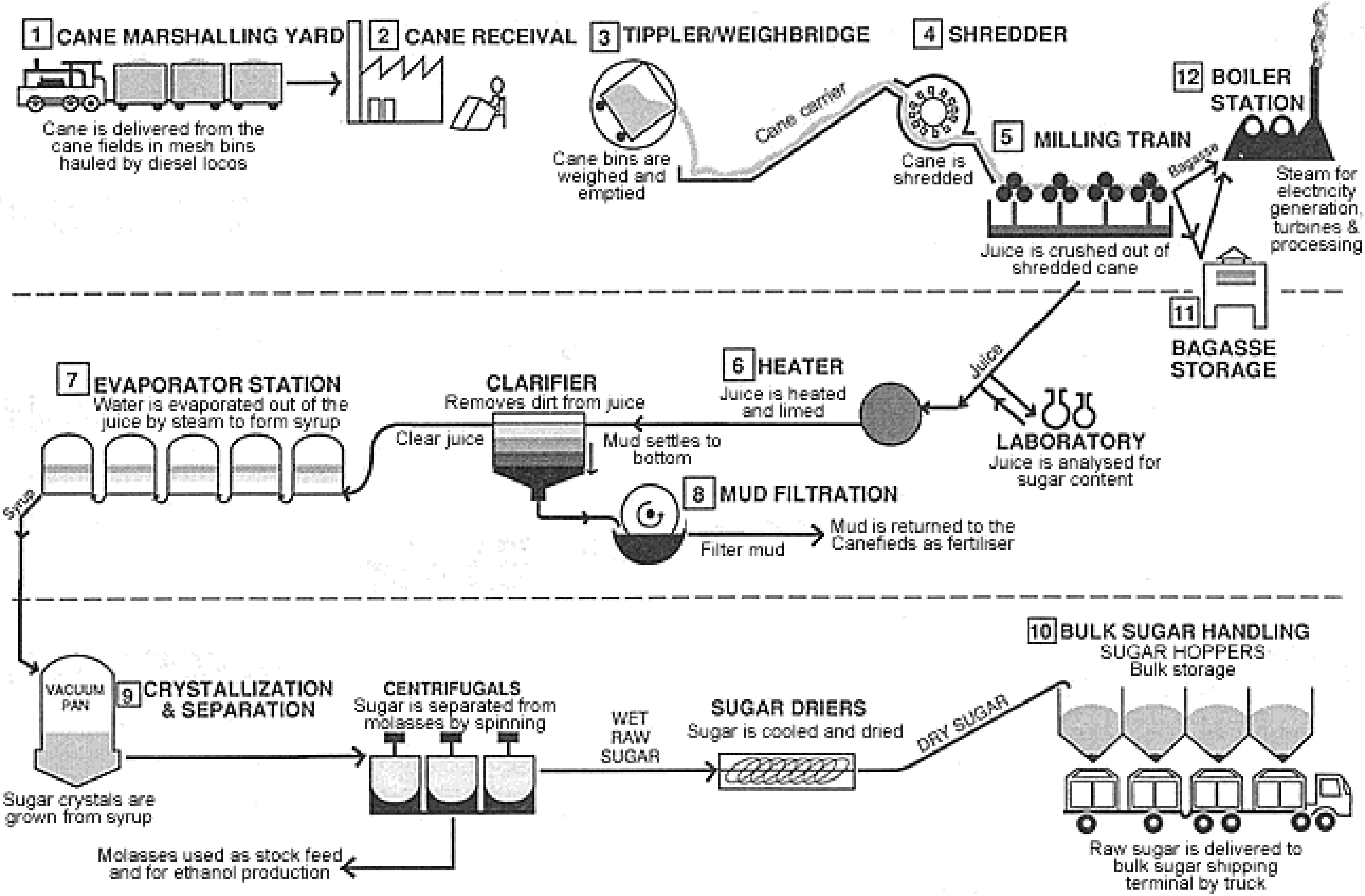
Benedict's Test for Non-Reducing Sugars

- **Non-Reducing** sugars **do not reduce Benedict's reagent**, however, if it is **first hydrolysed** to its constituent **monosaccharides**, it will then give a **positive Benedict's Test**
  - ✓ First test a sample for reducing sugars, to see if there are any present before hydrolysis
  - ✓ Then the test can be proceeded using a separate sample as follows

Result of Benedicts test for reducing sugars



Observations	Interpretations
No Colour Change (Blue)	No reducing sugars (RS) present
Green	Trace amounts of RS present
Yellow	Low amounts of RS present
Orange	Moderate amounts of RS present
Brick-red	Large amounts of RS present


1 CANE MARSHALLING YARD
Cane is delivered from the cane fields in mesh bins hauled by diesel locos
2 CANE RECEIVAL
3 TIPPLER/WEIGHBRIDGE
Cane bins are weighed and emptied
Cane carrier
4 SHREDDER
Cane is shredded
5 MILLING TRAIN
Juice is crushed out of shredded cane
Bagasse
12 BOILER STATION
Steam for electricity generation, turbines & processing
11 BAGASSE STORAGE
Juice
6 HEATER
Juice is heated and limed
LABORATORY
Juice is analysed for sugar content
CLARIFIER
Removes dirt from juice
Clear juice
Mud settles to bottom
7 EVAPORATOR STATION
Water is evaporated out of the juice by steam to form syrup
Syrup
8 MUD FILTRATION
Filter mud
Mud is returned to the Canefieds as fertiliser
VACUUM PAN
9 CRYSTALLIZATION & SEPARATION
Sugar crystals are grown from syrup
CENTRIFUGALS
Sugar is separated from molasses by spinning
Molasses used as stock feed and for ethanol production
WET RAW SUGAR
SUGAR DRIERS
Sugar is cooled and dried
DRY SUGAR
10 BULK SUGAR HANDLING
SUGAR HOPPERS
Bulk storage
Raw sugar is delivered to bulk sugar shipping terminal by truck

THANK YOU
FOR YOUR ATTENTION

Review Questions

1. The following observation was made for Benedict's test performed for 5 samples of sugar, write interpretation for respective observations (2.5 Pt)

Observations	Interpretations
Green	
Orange	
Blue/No Colour Change	
Brick-red	
Yellow	

Review Questions ... Continued

2. Mention the name and the use of fiber which left behind after processing of sugar cane in milling train.
3. List major process which are involved in sugar production sequentially with byproduct (if any).
4. Describe average quantity of clean and chopped roots and sugar that can be extracted from one hectare of sugar beet.
5. Non-Reducing sugars can reduce Benedict's reagent and give a positive Benedict's Test. Explain.
6. Explain how the Benedict's test is performed and the principle behind this test.

Review Questions

7. Discuss what Benedict’s reagent is and give the roles of each of the components.
8. Mention the stages of sugar production from sugar cane and describe each stage briefly.
9. Describe the following and write their use if they have any:
    i. Bagasse
    ii. molasses
    iii. pulp
    iv. Cossettes
    v. Defecation
    vi. massecuite

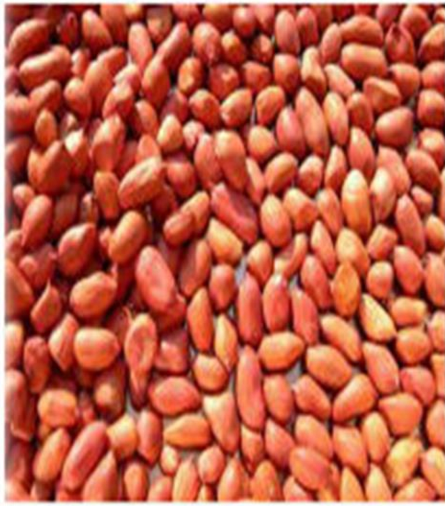
Chapter 6
Oil, Fat & Detergent



Introduction to Oils, Fats and Detergents

Introduction to Oils, Fats

- **oils** (liquid) and **fats** (solid) **common** and **important** items in the **diet** of **humans**
- **most** of the ones we use **come from seeds** (or **animals**)
- the **use of seed oils** is **ancient practice**
- in contrast to **essential oils**, these substances are **made** up of **triglycerides** and are **non-volatile**



Peanut

bean

sunflower

olive

rapeseed

coconut

cottonseed

sesame

Introduction to Oils, Fats

- **triglycerides** contain **fatty acids** and **glycerol**
- the **structures** of the fatty acids **determine** many of the properties of the **oils** and **fats**
- **triglycerides** are a **food reserve** for the germinating **embryo**
- the **longer** the **chains** of the fatty acids, the **higher boiling points of** the oils or fats are

Introduction to Oils, Fats

- **peanut oil** has lots of **C_{20} fatty acids** and has **high boiling points**
- **sites of** unsaturation **lower** the boiling point and **increase** the **sensitivity** to oxygen
- **oils** with **2** or **3** sites of unsaturation **polymerize** readily and have often been **used in paints**
- the properties of **highly unsaturated oils** that make them valuable also make them **undesirable** for **food products** because they tend to **turn rancid** readily
- **unsaturated** oils can be converted to **saturated** oils by **hydrogenation** with a **catalyst** (usually **nickel**) which **raises** the **melting point**

- **non-drying** oils (**saturated**) - typically tropical plants **palm**, **peanut**, **olive**, **rape**, **castor**, **almond**
- **semi-drying** oils (**moderately unsaturated**) – from cottonseed, sunflower, sesame, croton, corn
- **drying oils** – (**highly unsaturated**, **polyunsaturated**) linseed, tung, soybean, hempseed, nut, poppy, safflower
- many seeds contain **quite large** quantities of oils such as **Sesame seed**, which can give **nearly half** of its total weight

Extraction methods

- the seeds are usually **cleaned** and then **dehusked** (husk will be removed)

Crushing

- done mostly with rollers today, a **screw press** makes it possible to have a **continuous feeding** of seeds
- because there is still **2 - 4% oil** in the **meal**, the material is **extracted again** with solvents in some cases, or the **kernels** are **broken** or **flaked** before **extraction**

Extraction methods

Expression

- cold and hot (where seeds are cooked first and pressed mechanically to extract oil from the seed)
- involves the use of mechanical power to remove oil from the seed, such as batch hydraulic pressing and continuous mechanical pressing (screw presses)

Extraction

- solvents (petroleum ether (hexane), chlorinated solvents)

Boiling

- centrifugation

Subsequent treatment of oils

- most oils are **treated** to render them **odorless** and **tasteless** appearance
- after **isolation**, the oil is **treated with caustic soda** to **remove** any **free fatty acids** present, **bleached**, **deodorized** with **steam**, and/or **winterized**
- **bleaching** is usually done with **Fuller's earth (**clay material that has capability to decolorize oil**)** or **activated charcoal**
- **winterizing** is **cooling** down the oil to **remove** materials that will **precipitate** out up on cooling
- **fatty acids** and **triglycerides** that **precipitated** out are called "**foots**"

Uses of fats and oils

- almost all **oils** and **fats** come from seeds (except for olive and avocado), which are **required in the diet** of most animals
  - ✓ **lubricants**
  - ✓ **soap** - now largely replaced by synthetic detergents
  - ✓ **paints** - now largely replaced by synthetic polymers
  - ✓ **chemical precursors** for nylon polymers - probably the best **petroleum substitute**
  - ✓ **press cake** is usually used for **livestock feed**
  - ✓ **biofuels**

Soap

- soaps are the **salts of fatty acids**
- **potassium** and **sodium** soaps are the most **commonly used**
- **magnesium** and **calcium soaps** are found as **bathtub ring**
- **lead** and **zinc** are used to make **medicinal soaps**
- **lithium soaps** are used to make **lubricants**
- **aluminum soaps** are used for **waterproofing**

Soap

- **oils** and **fats** are treated with **lye** (**sodium hydroxide** or **potassium hydroxide**) to yield **salt** of the **fatty acids**
- **formerly**, extracts of **wood ashes** were used
- **potassium** gives **soft soaps** and **sodium** gives **hard soaps**
- **detergents** often made by **sulfonation** of other types of **organic molecules**
- **saponins** from plants **used** in some societies as **soap** or **detergent** substitutes
- **coconut oil** is still the **most** commonly used oil for **soap**

Paints

- many **polyunsaturated** oils are **incorporated** with **pigments** into **paints** and **varnishes**
- **linseed oil** and **tung** are among the **most common** of this type
- the Flemish combined pigments and oils to make oil paints in the 15th century
- they perfected technique of **painting over** the **pictures** with **glazing**, and **translucent coatings** over an **undercoating** in order to give an **illusion of depth**

Introduction to detergents

- we use detergents every day, in one form or another
- like **plastics**, **most detergents** are made from **petroleum products**
- there are **two types** of detergents:
  - ✓ **soap less detergents** (or synthetic detergents) and **Soapy detergents** (or soaps)

Fig. 1 Detergents for different cleaning jobs

Fig.2

Soapless detergents include washing powders, washing-up liquids, shampoos and hair conditioners. They are called ‘soapless’ because they contain no soap.

Fig.3

Soapy detergents include bath soaps, laundry soaps and liquid soaps.

Structure of detergents

General structure of detergent particles

- usually **sodium** (or **potassium**) **salts** of long-chain **organic acids** consisting of **two parts**:
  - i. an **ionic group** (the 'head')
  - ii. a **hydrocarbon** chain (the 'tail')
- hence detergent **anions attracted** toward **both water** and **oil**
- this **dual nature** explains **two** important **properties of detergents** the **wetting property** and the **emulsifying property**

Detergent as a wetting agent

- water has a **high surface tension,** however**,** detergent **reduces** this **surface tension of water**
- as a result of this, **water spreads** over the surface and **wets** surfaces more easily
- **detergent** thus acts as a **wetting agent** as it **reduces surface tension of water** and **increasing** the **wetting power** of water
- **tap water does not wet** the piece of **cloth easily**, but a detergent **solution does**

Detergents as an emulsifying agent

- **oil** and **water do not mix,** they form unstable **oil-water emulsion**
- on **standing**, **tiny oil** droplets rapidly **join together, grow larger** to and form separate **oily layer again**
- **detergents** are **cleansing agents** which are **surfactants** (surface active agents), work by **reducing the surface tension** of water enabling it to **wet things** more effectively by **emulsifying grease**
- **ionic groups** of detergents which are on hydrocarbon chains having **12 to 20 carbon** atoms show **good detergent properties**

Structure of detergents

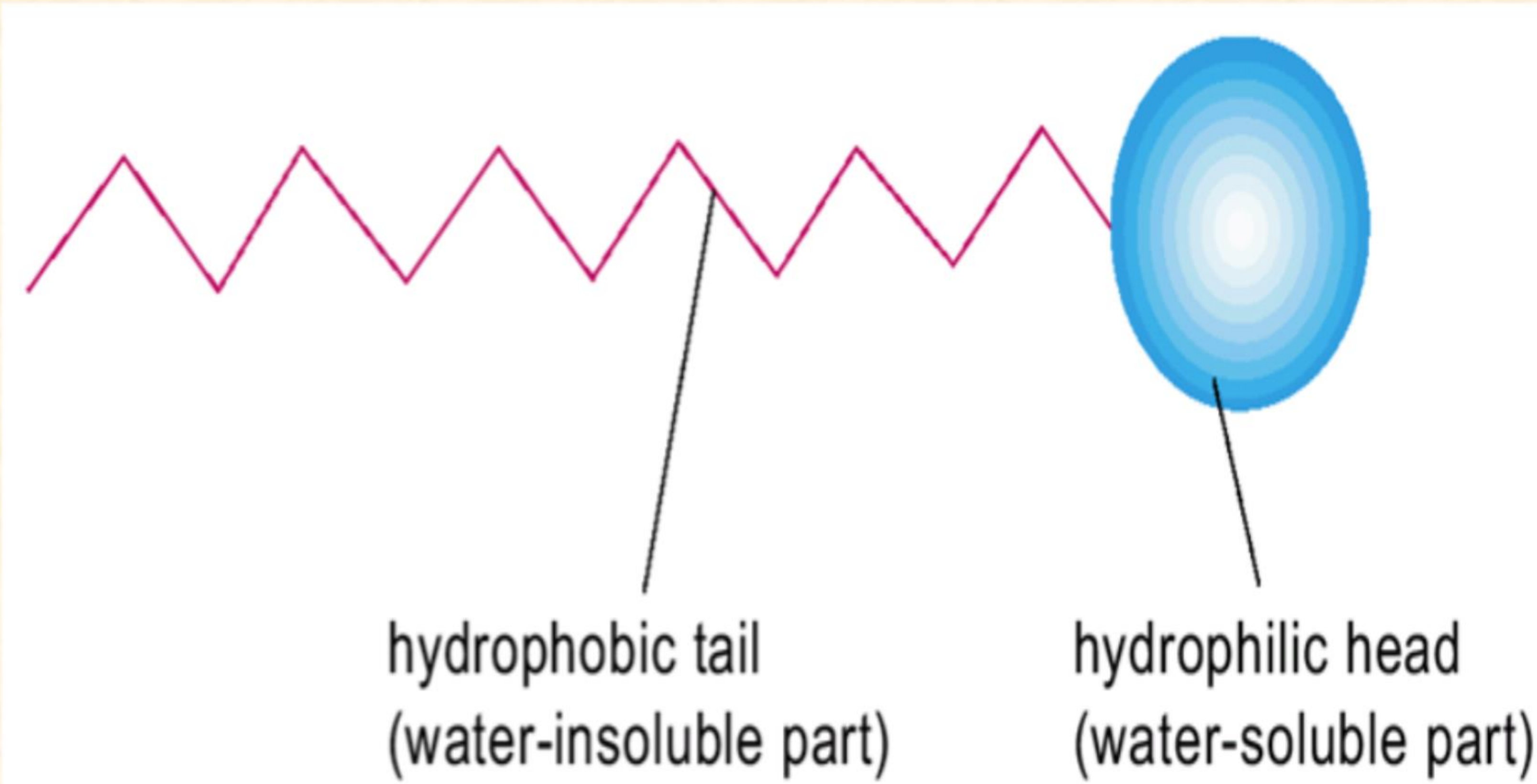
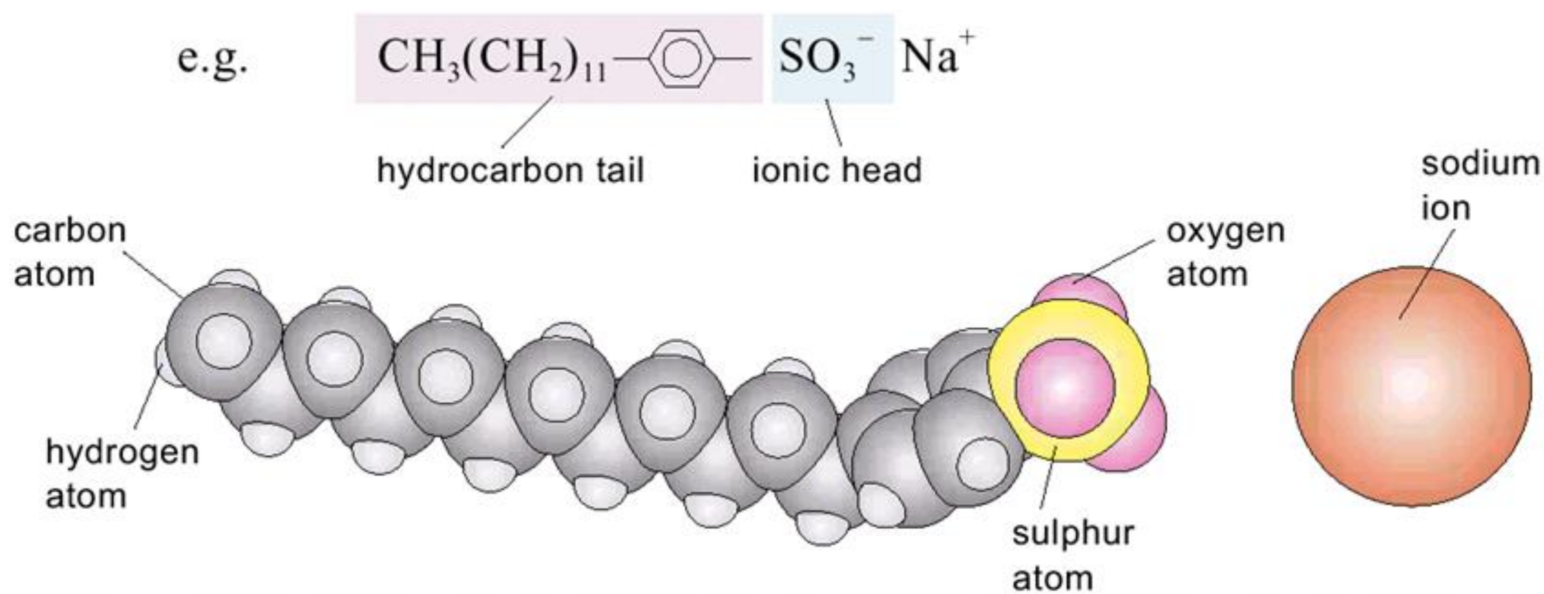


Figure .4 General structure of a detergent anion.

Structure of soapless detergent particles

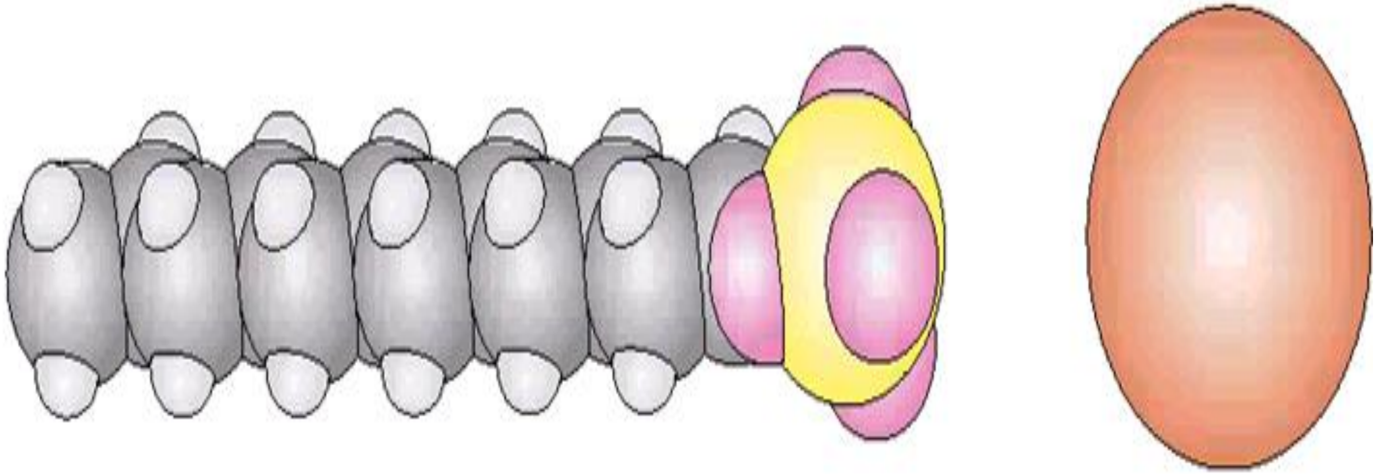
- the two common soap-less detergents are:
  - ☞ sodium alkylbenzene sulphonate and
  - ☞ sodium alkyl sulphate

sodium alkylbenzene sulphonate



Sodium alkyl sulphate

e.g. $\underbrace{CH_3(CH_2)_{11}}_{\text{hydrocarbon tail}} - \underbrace{O - SO_3^-}_{\text{ionic head}}\ Na^+$

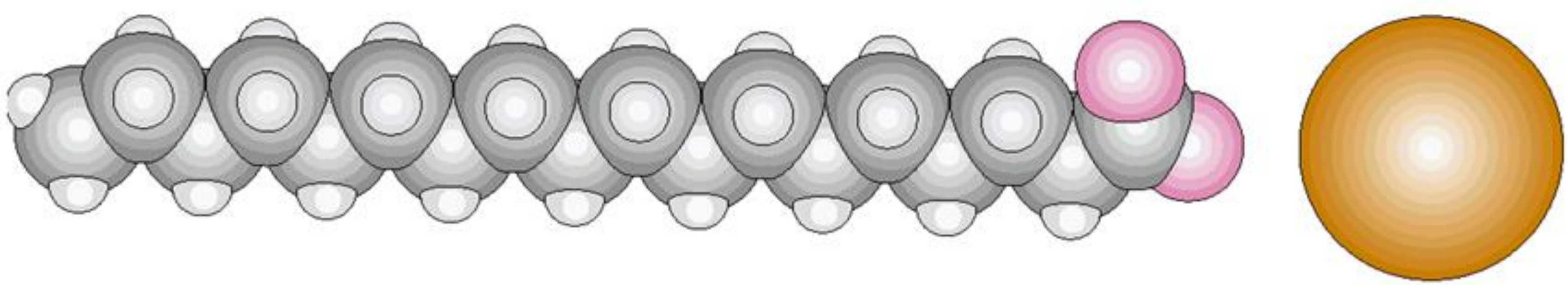


Structure of soap particles

- soaps are **sodium** (or **potassium**) salts of **long-chain alkanoic** acids
- the **ionic head** of soaps is always a **carboxylate group** (**–COO**)
- **common** soap is **sodium stearate**

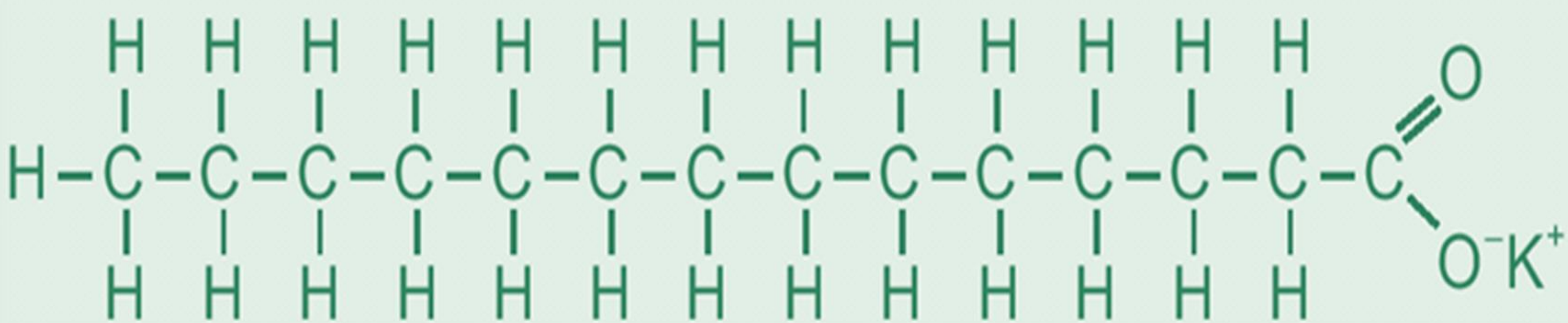
$$CH_3(CH_2)_{16} - COO^- \quad Na^+$$

hydrocarbon tail	ionic head



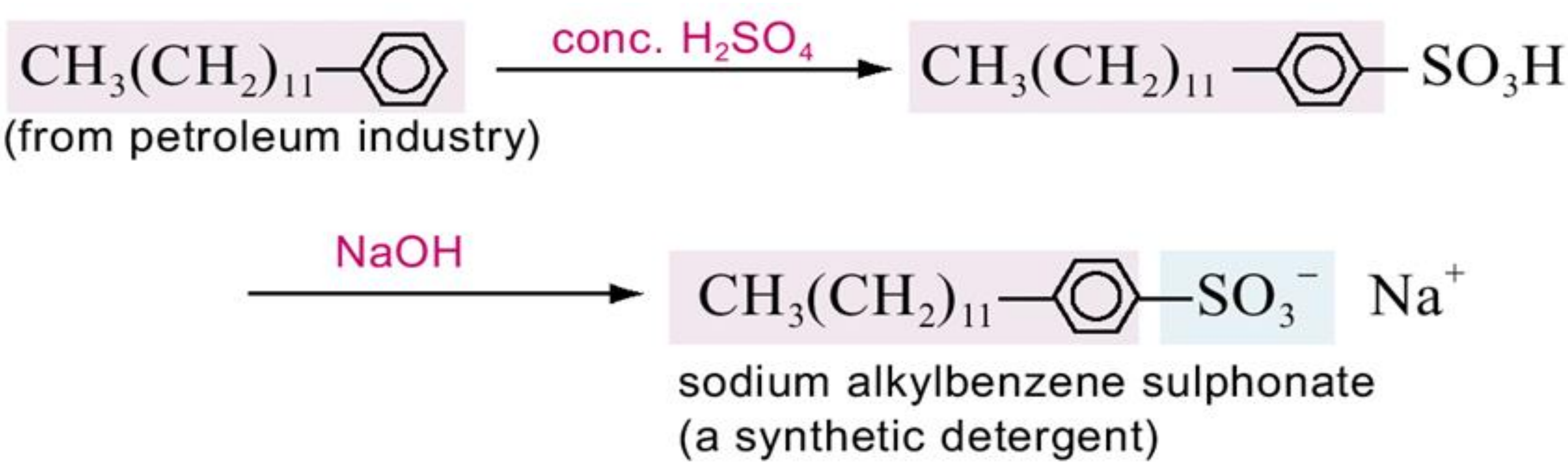
Structure of soap particles

The ‘O’ and ‘K’ atom in the structure should *not* be linked by a covalent bond. The formula should be written as:



Making detergents

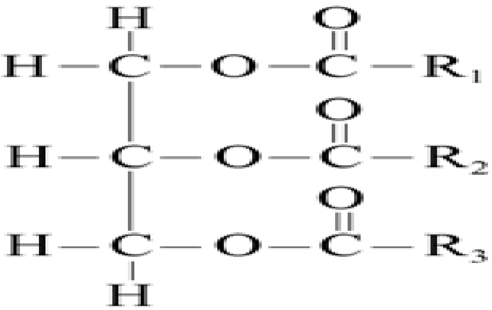
- detergents are **sodium** or **potassium** salts of long-chain organic acids (usually with number of **carbon atoms** between **12 and 20**)
- **soapless** detergents are **manufactured** from **hydrocarbons** obtained from **petroleum**



Making Soaps

Fig. 5 The palm oil from these palm trees can be used to make soap

- **fats** and **oils** are naturally occurring **tri - esters**
- in general, the formula of **fats and oils** can be represented as:



Where R_1, R_2 and R_3 represent the same or different hydrocarbon chains

8
Chemical Foodstuff Processing

Introduction to Fermentation

- **food science is** defined as **the discipline** of **applying chemistry**, **engineering**, **microbiology**, **medicine,** and **molecular biology** to **create**, **prepare**, and **process foods**
- **food scientists** use **science** and **engineering** to **produce**, **process**, **evaluate**, **package**, and **distribute foods** that are **nutritious**, **palatable**, and **safe**
- technological advances in **genetics**, **soil science**, **food processing** and **purification**, and **marketing** have helped produce food for the world
- **farmers** and **ranchers** grow the food we **eat**, including **fruits**, **vegetables,** **cereal grains**, **meat**, and **other foods,** which must then be **processed**, **cooked**, **packaged**, and **transported**

Biological Conversion

- **conversion of the biomass** to **fuel** by exposing it to certain **microorganisms** is called **biological conversion**
- **secondary fuels** are produced as a result of **metabolic activity** of the microorganisms
- **fermentation and anaerobic digestions** are the **two** most common **biological conversion processes** and **products** of these processes are **ethanol** and **biogas**
- today, ethanol is widely used as an **alternative source of liquid fuels** for the transport sector in countries and regions like **USA**, **EU** and **China**
- **ethanol** as a **fuel offers** many **advantages** such as **high-octane** number (**99**) than petrol (**80–100**), **low emission**

Fermentation

- the term "**fermentation**" is derived from the Latin verb **fervere**, that means to **boil**, thus describing the appearance of **the action of yeast** on extracts of **fruit** or **malted grain**
- **fermentation** is a **natural process initiated** by **microorganisms**, similar to common yeast cultures, under anaerobic conditions
- **ethanol** can derive from **any material** which contains **sugar**
- in the **fermentation** process, **sugar elements** such as **glucose**, **fructose** and **sucrose** are converted into **ethanol** and **carbon dioxide** as **metabolic waste products**
- the **net chemical equation** for the production of **ethanol from glucose** is:

$$\boxed{C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2}$$

Fermentation

Bio-ethanol

- the **raw materials** used in the **production of ethanol** via **fermentation** are mainly classified into three types as **sugars, starches**, and **cellulose materials**
- **sugars** (extracted from **sugarcane**, **sugar beets**, **molasses**, and **fruits**) can be converted into ethanol **directly**
- **starches** (from **corn**, **cassava**, **potatoes**, and **root** crops) and **cellulose** (from **wood**, **agricultural residues**, **waste sulfite liquor** from **pulp**, and **paper mills**) are needed to **pre-treated prior** the fermentation

Beer

➢ What is beer?

- **Beer** is an **alcofermented**, **hop flavored**, **malt sugared**, **liquid** made up of **basic ingredientes** such as **water**, **malt**, **hops**, and **yeast**

- The **major variation** in beer is the **type of yeast** used to ferment the product

hops

yeast

malt

Manufacture of Beer

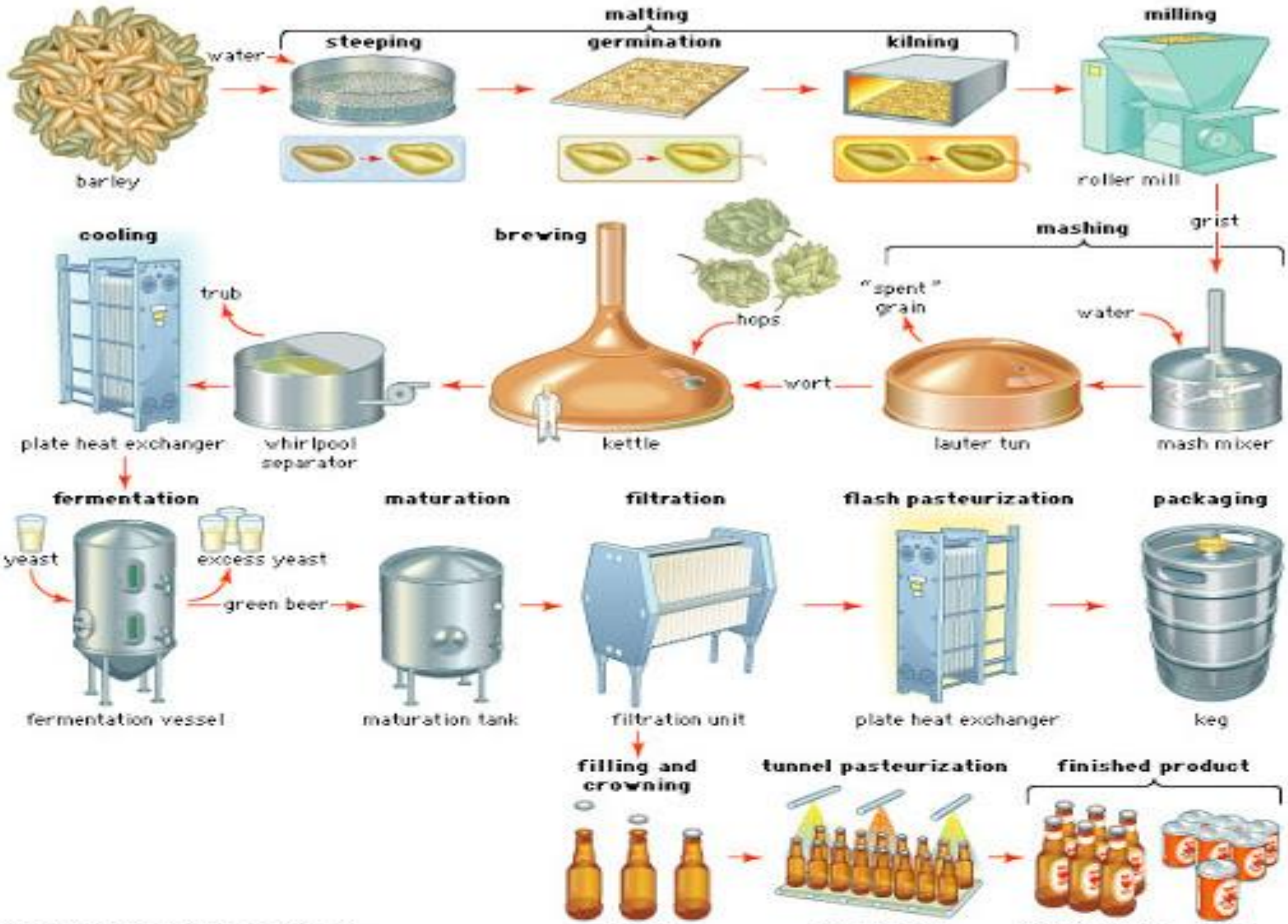
- the process of **making beer** is known as **brewing**
- dedicated **building** for the **making of beer** is called a **brewery**

➢ **Main Ingredients:**

- Malt
- Hops
- Yeast
- Water

➢ **Production stage processes**

1. Milling
2. Mashing
3. Boiling
4. Cooling
5. Fermenting
6. Filtering
7. Conditioning
8. Pasteurizing
9. Packaging


malting
steeping
germination
kilning
milling
water
barley
roller mill
grist
mashing
cooling
brewing
trub
hops
"spent" grain
water
wort
plate heat exchanger
whirlpool separator
kettle
lauter tun
mash mixer
fermentation
maturation
filtration
flash pasteurization
packaging
yeast
excess yeast
green beer
fermentation vessel
maturation tank
filtration unit
plate heat exchanger
keg
filling and crowning
tunnel pasteurization
finished product
bottles
conveyor belt
labeled bottles
cans

Main Ingredients

- **cereals** such as b**arley**, **rice** or **wheat** may also be used to reduce the percentage of proteins in the wort
- **unmalted cereals** give the beer a **lighter colour** and **specific characteristics** according to the type of cereal chosen
- generally; the **Ingredients** have the following **functionalities**;
  - ✓ **Malt/Barley** – the body & soul of beer
  - ✓ **Yeast** – the life of beer
  - ✓ **Hops** – the spice of beer and
  - ✓ **Water** – the integrity & purity of beer

Main Ingredients

1. **Malt** is one of **the main** ingredients of beer from **barley**, which is subjected to a process of **germination** under controlled conditions, called **malting**

- **marying conditions** during the malting process (**temperature** and **humidity**) allows **different types of malt** to be obtained, giving **different colours** and **flavours** to the beer

2. Hops (humulus lupulos)

- **hop** (humulus lupulos) - an **aromatic plant** that gives beer its **flavour** and **bitterness**
- it **contributes** to the formation of a **good froth** and **protects** the **beer against contamination** by microorganisms
- today, **extracts** from this plant are used **industrially**, obtained in such a way as to preserve its qualities
- **hop** varieties are **classified** in terms of **bitterness** and **flavour**, which **vary** according to the **amount of resin** and **essential oils** they contain
- there are **two primary hop** styles: **Aroma Hops** – Saaz, Fuggle & Hallertua and **Bitter Hops** – Brewer's Gold & Unique

3. Yeast … "Life of Beer"

- **responsible for fermentation** (metabolizing sugars from the malt) and can **influence** the **flavour** of the beer
- yeast is the **catalyst** of change, **single celled** micro-organism which produces **carbon dioxide** and **alcohol**
- **two types** of **yeast** are used to **produce beer**: **ALE** and **LAGER**
  - ✓ **ale – top fermenting** : ale is synonymous for beer, top **fermenting yeasts**, ferment at higher temperatures (64 – 72°C), ferments **less fully** and **less discriminately**, characterized by **more - fruity flavors & aromas** with a malty, full bodied flavor
  - ✓ **lager – bottom fermenting :** There are literally thousands of brewers yeast that create a variety beer styles

4. Water – "Integrity & Purity"

➢ **Role of Water in beer**:

- **water** makes up **92%** of beer
- through **filtration** or **boiling**; impurities, aromas and **flavor differences** can be **mitigated**
- Water styles can **effect flavor:**
  - ✓ **hard water** – helps add **crisp cleaness**
  - ✓ **soft water** – adds **smoothness**


WATER
MALTS
HOPS
YEAST


Water
Grain
Hops
Yeast

Production Process

- The **first phase** in the process of beer production is the **preparation of the wort, t**he process with four stages:
  - ✓ **Milling**: In order for the **malt components** to be **rapidly extracted** and **converted**, the malt is milled to obtain **coarse flour**; **unmalted cereals** are also **milled** to **varying degrees**
  - ✓ **Mashing**: The **flour from** the cereals (**malt** and **unmalted** cereals) is **mixed with water** and subjected to certain processes to obtain **a wort** of a **suitable** composition for the kind of **beer being** produced (**varying times**, **temperature** and **PH**)

Production Process

- ✓ these conditions encourage the **development of complex starch** molecules and **proteins** in other simpler ones by means of **enzymes** formed during the production of the malt
- ✓ mashing lasts **2 to 4 hours** and **finished** with a **temperature** of approximately **75 ^{0}C**
- ✓ **Filtration of the wort**: After **mashing**, the **whole volume** is **filtered** in order to **separate** the **spent grains** (which is an excellent **animal feed**) from the wort itself
- ➢ **filtration** is done by **passing water** through the **mash** at the **right temperature** in a **filter press** or **lauter tun**, which lasts around **2-3 hours**, conducted at a temperature of **75 - 80 ^{0}C**

Production Process

- ✓ **Boiling the wort**: **hops** are **added** to **diluted** and **filtered** wort and **boiled** for around **2 hours** to:
  - ☞ **transform** and **make soluble** the **bitter** substances in the **hops**
  - ☞ **eliminate undesirable volatile** substances;
  - ☞ **sterilise** the **wort**
  - ☞ **provoke** the **precipitation of proteins** of high molecular weight
  - ☞ **establish** the **final concentration** of wort
- ✓ after boiling, **precipitated protein** and the **insoluble hop** components will be **separated** from the **hot wort** which may be carried out in a **decanter** using **gravity** or with **centripetal force** in a "**whirlpool**"
- ✓ **the hopped wort** is **cooled** to a temperature of around **9 ºC** and **aired** in **sterile conditions before it** goes into the **fermentation tanks**

Production Process

- ✓ **fermentation,**
  - ☞ **wort sugars** are converted into **alcohol** and **CO_2** by action of **culture of yeast selected** for the **type of beer** being produced which is added to the **cooled oxygen-saturated wort**
  - ☞ **takes** place at **controlled temperatures** and **lasts around 7 days**, which **is quite violent** at **first**, and then **slows down gradually** until the yeast is **deposited on the bottom** of the tank
- ✓ **Maturation**
  - ☞ the phase **after fermentation**, the period in which **the beer is allowed to rest** at **suitable temperatures** in order for the **undesirable volatile components**, which might affect the final «**bouquet**» of the beer, **to be released**

Production Process

- **stabilisation:**

  ☞ the next operation **after maturation** which consists of **letting the beer stabilise** at temperatures of **between 0 ^{0}C and – 2 ^{0}C**, to permit **colloidal stabilisation**

- **Clarification:**

  ☞ the operation that **gives** the **beer** its **clear limpid quality**, **eliminating** the last **remaining traces** of **clouding** still **in suspension**

  ☞ it consists of **pumping** the **liquid** through a **suitable filter, t**hen filtered beer is **stored in tanks**, and ready to be **bottled**

- **Bottling/Package**

  - ☞ **final stage** of the beer production process which is **transferring the beer** into **different kind** of containers (**bottles, barrels, cans etc**) where it need to be biologically stabilised before or after bottling

  - ☞ **biological stabilisation** may be carried out **cold** (sterilising filtration) or **hot** (using pasteurisation, either immediately before - **flash pasteurization** - or after the **drink is introduced** into its container - **tunnel pasteurisation**)

  - ☞ at the **bottling stage**, the beer is **inserted** into different forms (**bottle**, **barrel**, **can** etc) to enable it to be appreciated with **moderation**

Manufacture of wines

- The **major difference** between **making red wine** and **white wine** is that the **juice** is **fermented without** the grape's **skins** when making white wine

Alcoholic Beverages

- **fermentation** of juices for the preparation of **alcoholic beverages** is being practiced for the last many centuries
- **wine** is a fermented beverages produced from **grape** and has a large acceptability across the world and has immense potential for local marketing as well as export
- these are the beverages which are prepared **after alcoholic fermentation** of **sugars by yeast**, contain varying amounts of **ethyl alcohol** (**5 – 42 %**), and are **consumed directly** or after **dilution** in water
- **wine product** made by alcoholic **fermentation of grapes** or **grape juice** unless otherwise specified, by **yeast** (**Saccharomyces cerevisiae** and a subsequent **ageing process,** where alcohol content is **11 - 14 %**, but may be as low as **7 %**

Process for preparation of wine

Grape

↓

Sorting and Washing

↓

Crushing and Pressing

↓

Grape Juice

↓ ← SO_2 @ 100 ppm)

↓ ← Add sugar to raise TSS to 22-24 Brix and pH to 3.2-3.3 (by using tartaric acid if available pH is high and sodium bicarbonate is available pH is lower than desired)

Grape Must (TSS 20-24° Brix)

↓ ← *Saccharomyces cerevisae* culture @ 5%

Fermentation (at temp. 20-25°C for 8-10 days)
(TSS reaches 8 °Brix)

↓

Straining through cheese cloth

↓

Siphoning

↓

Clarification

↓

Bottling

↓

Grape Wine

Wine Making Problems

- the major cause of **wine failures** is a **lack of proper sterilization** procedures and practices, problems encountered are:

1. Corkiness

☞ Symptoms: An **unpleasant flavor** in wine

☞ Possible Causes:

a. bottling with a **defective cork**

b. not a complete **seal** and the **outside air allowed** to **enter** into the bottle

c. Inferior cork

2. Soapiness

☞ Symptoms: **soapy taste** in favorite wine.

☞ Possible Causes:

a. equipment, **carboy**s and **Fermenters** not properly **cleaned** and **rinsed**

Manufacture of Spirit

- **distilled spirit**, also called **distilled liquor**, **alcoholic beverage** (such as **brandy**, **whisky**, **rum**, or **arrack**) that is obtained by **distillation** from **wine** or other **fermented fruit** or **plant juice** or from a **starchy material** (such as **various grains**) that has **first been brewed**
- **alcoholic** content of **distilled** liquor is **higher than** that of **beer** or **wine**

Manufacture of Spirit

- **all spirits** go through at least **two** procedures - **fermentation** and **distillation**.
  - ☞ **fermentation** is where **all alcohol** is **created**, **distillation** is where the **alcohol** is **separated** and **removed**
  - ☞ In order for f**ermentation** to occur, **two** things are needed: a **raw material** in **liquid form** that **contains sugar**, followed by the **addition** of **yeast**.
  - ☞ **yeast** is a **living organism** that **feeds on sugar**; the **bi-product** of this **consumption** is **alcohol** and **carbon dioxide** (**CO_2**)

Manufacture of Spirit

- **Distilling** is essential process where a liquid made of **two** or **more parts** is separated into **smaller parts** of desired purity by the **addition** and **subtraction** of **heat** from the mixture
- vapours/liquids distilled will be richer in content than any of their ingredients that have **lower boiling points**
- **distilled spirits** are produced from **agricultural raw materials** such as **grapes**, other **fruit**, **sugar-cane**, **molasses**, **potatoes**, **cereals**, etc
- there are many subtleties involved in the creation of different spirits drinks, the process for a cereal-based spirits is as follows:

Distillation Process Spirit

Step 1 Milling:

- the raw material is ground into a **coarse meal**
- the process breaks down the protective hull covering the raw material and frees starch

Step 2 Mashing:

- the **starch** is **converted** to **sugar**, which is mixed with **pure water** and **cooked**
- this produces a **mash**

Step 3 Fermentation:

- the **sugar** is converted to **alcohol** and **carbon dioxide** by the addition of **yeast**
- with the **addition** of **yeast** to the **sugar**, the **yeast multiplies producing carbon dioxide** which **bubbles away** and a mixture of **alcohol**, **particles** and **congeners**, or the elements which create **flavour** to each drink

Step 4 Distillation:

- ☞ the **alcohol**, **grain particles**, **water** and **congeners** are **heated**
- ☞ the **alcohol vaporizes first**, leaving the **water**, the **grain** particles and some of the **congeners** in the **boiling vessel**
- ☞ **vaporised** alcohol is then **cooled** or **condensed**, to **form clear drops** of **distilled spirits**
- ☞ **two** additional **steps** are often taken in making some **distilled spirits**

Step 5 Ageing:

- ☞ certain **distilled spirits** (e.g. **rum**, **brandy**, **whiskey**) are **matured** in **wooden casks** where they **gradually develop** a distinctive **taste**, **aroma** and **colour**

Step 6 Blending:

- ☞ some spirits go through a **blending process** whereby **two** or **more spirits** of the **same category** are c**ombined**
- ☞ this process is **distinctive** from **mixing** since the **blended spirit remains** of the **same specific category** as its components

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Thank You

Muchas Gracias

Muito Obrigado