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**End Products:**

**a. Polymers:**

Macromolecule which contains large number of building blocks or molecule joined

together.

Building units: monomers =or repeating unit.

Homopolymer: polymer formed from same monomer. ex: polyamide, polyester.

Copolymer: polymer formed from more than one monomer. ex :Styrene-BD

copolymer.

**Polymer Composition:**

Most polymers are hydrocarbons

– i.e. made up of H and C

\_ Saturated hydrocarbons

\_ Each carbon bonded to four other atoms

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**Polymer chemistry**

\_ In polyethylene (PE) synthesis, the monomer is ethylene

\_ Turns out one can use many different monomers

\_ Different functional groups/chemical composition – polymers have very

different properties

Note: polyethylene is just a long HC

- paraffin is short polyethylene

**Classification of polymer according to type of utilization:**

1-Thermoplastic . 2- Thermoset.

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3-Elastomer. 4-Fibers 5-Adhesive.

**Classification of polymer according to end use:**

**1-Plastic.**

1-Tough substance with H.Mwt.

2-Softening when heated –moulded plastic.

a-Thermoplastic:PE,PP. b-Thermoset:PF,Polyester.

**2-Fibers.**

1-Low elongation

2- Lighter weight

3-High tensile strength.

4-High resistance to deformation.

5-Low moisture absorption.

6-Highly crystalline due to secondary forces.

**3-Elastomers:**

1-H.Mwt unsat. HCS.

2-Has long flexible chains.

3-Weak intermolecular forces.

4- Amorphous with certain degree of cross linking

To prevent them from slipping over each other.

**Polymer classification according to reaction:**

1-Addition polymerization

2-Condensation polymerization

**Addition**

1-used in preparation of PE,PP,PS.

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2-initiated by a-free radical b-cationic ,anionic, cationic .coordination catalyst.

3-reaction occurs by self addition of unsat. molecule .

4-H.Mwt polymer formed at once even at low conversion.

**Condensation**

1-Produced by reaction between two molecule with elimination of small

molecule such as water .

M+M→M-M

M-OH+M-COOH→M-M+H2O

2-H.Mwt is not observed until the end of polymerization.

3-Long reaction times are needed for high conversion .

4- PF,UF.

5- Insulator (electrical and thermal)

**1-Polyethylene:**

**PE** :The most commodity polymers ,and PCs final products(widely used) Why PE is

widely used?

1‐Easly in producing monomer (E) from NG or petroleum fractions or Naphtha.

2‐Low cost 3‐ PE posses especial properties such as resistance to corrosion and

plastering.

**Classification of PE;**

**1-**Low density PE **:LDPE**

Density:0.915‐0.935 gm/cm3**.**

Mwt=30000‐50000.

Branched chain polymer .

Degree of crystallization is low.

Low ability to absorb water.

High resistance to chemicals(acids and bases)

Resistances to impact and electricity thus it is used in insulating.

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**2**-High density PE **:HDPE**

a‐Density=0.95‐0.96gm/cm3.

b‐ Linear polymer(no branches).

c‐Highly crystalline.

d‐Highly packed molecule, less permeable to gases.

**3**‐Linear low density :**LLDPE**

It posses good physical and mechanical properties

**1-LDPE: low density poly ethylene:-**

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**Description:** Ethylene, initiator and, if applicable comonomers are fed to the process

and compressed to pressure up to 3100 bar before entering the tubular reactor. In the TS

mode, the complete feed enters the reactor at the inlet after the preheater; in the TM

mode, part of the gas is cooled and quenches the reactor content at various points of

injection. The polymer properties are controlled by the initiator, pressure, temperature

profile and comonomer content. After the reactor, excess ethylene is recovered and

recycled to the reactor feed stream. The polymer melt is mixed with additives in an

extruder to yield the final product A range of products can be obtained using the

*Lupotech* T process, ranging from standard LDPE grades to EVA copolymers or

N-butyl-acrylate modified copolymer. The products can be applied in (shrink)

film extrusion, injection molding, extrusion blow molding, pipe extrusion, pipe

coating, tapes and monofilaments. There is no limit to the number of reactor

grades that can be produced. The product mix can be adjusted to match market

demand and economical product ranges. Advantages for the tubular reactor

design with low residence time are easy and quick transitions, startup and

shutdown.

**Note:** When **tubular reactor** is used LDPE produced is used for production of

films while when **Autoclaves reactor** used LDPE produced is used for

coatings.

**2-HDPE:High density polyethylene:**

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**Description**: A wide range of polyethylene is made in a gas-phase fluidized bed reactor

using proprietary solid and slurry catalysts. The product is in a dry, free-flowing

granular form substantially free of fines as it leaves the reactor and is converted to pellet

form for sale. Melt index and molecular weight distribution are controlled by selecting

the proper catalyst type and adjusting operating conditions. Polymer density is

controlled by adjusting comonomer content of the product. High productivity of

conventional and metallocene catalysts eliminates the need for catalyst removal

The simple and direct nature of this process results in low investment and

operating costs, low levels of environmental pollution, minimal potential fire and

explosion hazards, and easy operation and maintenance. Gaseous ethylene,

comonomer and catalyst are fed to a reactor (1) containing a fluidized bed of

growing polymer particles and operating near 25 kg / cm2 and approximately

100°C. A conventional, single-stage, centrifugal compressor (2) circulates

reaction gas, which fluidizes the reaction bed, provides raw material for the

polymerization reaction, and removes the heat of reaction from the bed.

Circulating gas is cooled in a conventional heat exchanger (3). The granular

product flows intermittently into product discharge tanks (4) where un reacted

gas is separated from the product and returned to the reactor. Hydrocarbons

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remaining with the product are removed by purging with nitrogen. The granular

product is subsequently pelletized in a low-energy system (5) with the

appropriate additives for each application.

**Products**: Polymer density is easily controlled from 0.915 to 0.970 g/cm.

Depending on catalyst type, molecular weight distribution is either narrow or broad.

Melt index may be varied from less than 0.1 to greater than 200. Grades suitable for

film, blow-molding, pipe, roto-molding and extrusion applications are produced.

**PVC Poly(vinylchloride) (suspension)**:

**Application:** A process to produce polyvinyl chloride (PVC) from vinylchloride

monomer (VCM) using suspension polymerization. Many types of PVC grades are

produced including: commodity, high K-value, low K-value, matted type and copolymer

PVC. The PVC possesses excellent product qualities such as easy

processability and good heat stability.

**Description:** PVC is produced by batch polymerization of VCM dispersed in

water. Standard reactor sizes are 60, 80, 100 or 130 m3. The stirred reactor (1)

is charged with water, additives and VCM. During polymerization reaction, the

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temperature is controlled at a defined temperature depending on the grade by

cooling water or chilled water. At the end of the reaction, the contents are

discharged into a blowdown tank

(2) where most of the un reacted VCM is flashed off. The reactor is rinsed and

sprayed with an anti-fouling agent, and is ready for the following batch. The

PVC slurry containing VCM is continuously fed to the stripping column(3). The

column has a proprietary design and effectively recovers VCM from the PVC

slurry without any deterioration of PVC quality. After stripping, the slurry is dewatered

(4), and dried effectively by the proprietary dryer (5). It is then passed

to storage silos for tanker loading or bagging. Recovered VCM is held in a gas

holder (6), then compressed, cooled and condensed to be reused for the

following polymerization batch.

**Polypropylene:PP**:-

**Description:** In the process homopolymer and random copolymer polymerization takes

place in liquid propylene within a tubular loop reactor (1). Heterophasic impact

copolymerization can be achieved by adding a gas-phase reactor (3) in series.

Removal of catalyst residue and amorphous polymer is not required. Unreacted

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monomer is flashed in a two-stage pressure system (2, 4) and recycled back to

the reactors. This improves yield and minimizes energy consumption. Dissolved

monomer is removed from the polymer by a steam sparge (5). The process can

use lower-assay chemical-grade propylene (94%) or the typical polymerizationgrade

(99.5%).

**Yields:** Polymer yields of 40,000 – 60,000 kg / kg of supported catalyst are

obtained. The polymer has a controlled particle size distribution.

**Products:** The process can produce a broad range of propylene-based polymers,

including homopolymer PP, various families of random copolymers and terpolymers,

hetero phasic impact and speciality impact copolymers(up to 25% bonded ethylene), as

well as high-stiffness, high clarity copolymers.

**Polystyrene,PS: general purpose (GPPS):**

**Description:** Styrene monomer, a small amount of solvent and additives are fed to the

specially designed reactor (1) where the polymerization is carried out. The

polymerization temperature of the reactor is carefully controlled at a constant level to

keep the desired conversion rate. The heat of polymerization is easily removed by a

specially designed heat transfer system. At the exit of the reactor, the polymerization is

essentially complete. The mixture is then preheated (2) and transferred to the

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devolatilizers (3) where volatile components are separated from the polymer solution by

evaporation under vacuum. The residuals are condensed (4) and recycled back to the

process. The molten polymer is pumped through a die (5) and cut into pellets by a

pelletizer (6)

**Synthetic fibers**:

Fibers":Length/diameter>100:

(1)Textiles are main use.

1-Must have high tensile strength.

2-Usually highly crystalline and highly polar.

(2)Formed by spinning: ex. extrude polymer through a spinneret:

Pt plate with 1000"s of holes for nylon. Melt spinning

Ex. Rayon-dissolved in solvent then pumped through die head to make fibers.Solution

spinning

(3) The fibers are drawn .

(4) Lead to a highly aligned chains-febrile

**1-Polyesters (polyethylene terephthalate)**

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**Application:** To produce polyesters for resin and textile applications from terephthalic

acid (PTA) or dimethyl terephthalate (DMT) and diols [ethylene glycol (EG) or others],

using the UIF‐proprietary four‐reactor(4R)‐ process including DISCAGE‐finisher.

**Description:** A slurry composed of PTA and EG, or molten DMT and EG is fed to the

first esterification/ester-interchange reactor (1) in which main reaction occurs at

elevated pressure and temperatures (200°C–270°C). Reaction vapors—water or

methanol— are sent to a low/high boiler separation column. High boilers are

reused as feedstock. The oligomer is sent to a second cascaded, stirred reactor

(2) operating at a lower pressure and a higher temperature. The reaction

conversion continues to more than 97%. Catalyst and additives may be added.

Reaction vapors are sent to the process column (5). The oligomer is then

prepolymerized by a third cascaded reactor (3) under sub atmospheric pressure

and increased temperature to obtain a degree of polycondensation >20. Final

polycondensation up to intrinsic viscosities of i. V. = 0.9 is done in the

DISCAGE-finisher (4). Pelletizing or direct melt conversion usage is optional.

EG is recovered by condensing process vapors at vacuum conditions. Vacuum

generation may be done either by water vapor as a motive stream or by the diol

(EG). The average product yield exceeds 99%.

**2-Nylon 6 :**

Is a polyamide contain –CONH

Raw material: Caprolactum.

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**3-Nylon 66:**

Polymer is produced from hexamethylene adipamide which produced from

condensation polymerization of adipic acid and hexamethylenediamine.

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**4-Acrylic :**

**Uses**: Wool replacement

Production: Copolymerization of acrylonitrile with comonomer in presence of

reaction initiators either free radicals or anionic at low temperature.

Polymerization on industrial scale:

1-Suspnsion polymerization: in presence of water.

2-Solution polymerization: in presence of suitable solvent : DMF or DMSO.

**Acetic acid CH3COOH**

CH3OH + CO →CH3COOH

**Feed:**. Methanol and carbon monoxide (CO) are reacted with the carbonylation

reaction using a heterogeneous Rh **catalyst**



**Description:** Fresh methanol from absorber(7) & (8)., mixed with the recycle liquid

from the recycle surge drum (6). This stream is charged to a unique bubble column

reactor (1).

Carbon monoxide is compressed and sparged into the reactor riser. **Catalyst** is an

immobilized Rh complex catalyst on solid support, which offers higher activity and

operates under less water conditions in the system due to heterogeneous system, and

therefore, the system has much less corrosivity. Reactor effluent liquid is withdrawn and

flash-vaporized in the Flasher (2).

The vaporized crude acetic acid is sent to the dehydration column (3) to remove water

and any light gases. Dried acetic acid is routed to the finishing column (4).

**Ethylene Derivatives:**

**Ethylene oxide**



**Application:** To produce ethylene oxide (EO) from the direct oxidation of ethylene

using the Dow Meteor process.

**Description:** The Meteor Process, a technology first commercialized in1994

1- is a simpler 2- safer process for the production of EO 3- having lower capital

investment requirements and 4- lower operating costs. Meteor Process

**A**-ethylene and oxygen are mixed and passed through a single-train, multi tubular

catalytic reactor (1) to selectively process is a simpler, safer technology with lower

facility investment costs. **B**- Heat is recovered from the reactor outlet gas before it

enters the EO absorber (2) where EO is scrubbed from the gas by water. The EOcontaining

water from the EO absorber is concentrated by stripping (3). the EO reactor,

is removed via activated, hot The cycle gas exiting the absorber is fed to the CO2

removal section (4,5) where CO2, which is co-produced in potassium carbonate

treatment. The CO2 lean cycle gas is recycled by compression back to the EO reactor.

**Advantages:**

Plant with one reactor work with high selectivity with low conversion for each

cycle. Reactants used with high concentration which reduced the capital cost.

**Disadvantages:**

1- The demand for additional units e.g. oxygen separation unit (high purity).

2- The need of CO2removal from recycle gas.

3- N2 must be removed from recycle gas; additional units.

However oxidation by O2 is more economic when high capacity production

is used.

**EO Uses:**

1-In production of ethylene glycol(anti freeze agent).

2-Used as surfactant. 3-In production of polyester.

4-In manufacture of Hydraulic fluid.

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Other old method utilized air for oxidation:

Two reactors and two absorber to complete oxidation of E to produce EO.

T=260-290OC, P=10-13 atm.

Cata: Ag/Al2O3 + Promotor: Ba, K + Inhibitor AgCl ,NaI ,used as

sphere to reduce pressure drop.

**Ethylene glycol :**



**Application:** To produce ethylene glycols (MEG, DEG, TEG) from ethylene oxide

(EO) using Dow’s Meteor process.

**Description:** In the Meteor Process, an EO/water mixture is preheated and fed

directly to an adiabatic reactor (1), which can operate with or without a catalyst. An

excess of water is provided to achieve high selectivities to monoethylene glycol (MEG).

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Diethylene (DEG) and triethylene (TEG) glycols are produced as co products. In a

catalyzed mode, higher selectivities to MEG can be obtained, thereby reducing DEG

production to one-half that produced in the uncatalyzed mode. Excess water from the

reactor effluent is efficiently removed in a multi effect evaporation system (2). The

concentrated water/glycols stream from the evaporation system is fed to the water

column (3) where the remaining water and light ends are stripped from the crude

glycols. The water-free crude

glycol stream is fed to the MEG refining column (3) where polyester-grade MEG,

suitable for polyester fiber and PET production, is recovered. DEG and TEG exiting the

base of the MEG refining column can be recovered as high-purity products by

subsequent fractionation.

**Uses:**

1-Polyester(fibers and films). 2- PET .3-Anti freeze agent. 4-Gas drying

**Vinyl chloride:**

**Vinylchloride monomer VCM CH(Cl)=CH2** :



**Description:** PVC slurry discharged from reactors contains significant amounts of

VCM ( >30,000 ppm) even after initial flashing. This process effectively removes the

remaining VCM so that the monomer is recovered and reused.

-The PVC slurry, containing VCM, is continuously fed to the stripping column (1). The

slurry passes counter-currently to steam, which is fed into the base of the column. All

process operations, including grade change, are automatically done in a completely

closed system.