Introduction to Polymer Chemistry

EXERCISE [PAGES 337 - 339]

Exercise | Q 1.01 | Page 337

Choose the correct option from the given alternatives.

Nylon fibres are _____

1. semisynthetic fibres
2. **polyamide fibres**
3. polyester fibres
4. cellulose fibres

Solution: Nylon fibres are **polyamide fibres.**

Exercise | Q 1.02 | Page 337

Choose the correct option from the given alternatives.

Which of the following is naturally occurring polymer?

1. Teflon
2. Polyethylene
3. PVC
4. **Protein**

Solution: Protein

Exercise | Q 1.03 | Page 337

Choose the correct option from the given alternatives.

Silk is a kind of _____ fibre.

1. Semisynthetic
2. Synthetic
3. **Animal**
4. Vegetable

Solution: Silk is a kind of **animal** fibre.

Exercise | Q 1.04 | Page 337

Choose the correct option from the given alternatives.

Dacron is another name of _____.

1. Nylon 6
2. Orlon
3. Novolac
4. **Terylene**

Solution: Dacron is another name of **terylene**.

Exercise | Q 1.05 | Page 337

Choose the correct option from the given alternatives.

Which of the following is made up of polyamides?

1. Dacron
2. Rayon
3. **Nylon**
4. Jute

Solution: Nylon

Exercise | Q 1.06 | Page 337

Choose the correct option from the given alternatives.

The number of carbon atoms present in the ring of ε-caprolactam is

1. Five
2. Two
3. Seven
4. **Six**

Solution: Six

Exercise | Q 1.07 | Page 337

Choose the correct option from the given alternatives.

Terylene is _____.

1. polyamide fibre
2. **polyester fibre**
3. vegetable fibre
4. protein fibre

Solution: Terylene is **polyester fibre**.

Exercise | Q 1.08 | Page 337

Choose the correct option from the given alternatives.

PET is formed by _____.

1. addition
2. **condensation**
3. alkylation
4. hydration

Solution: PET is formed by **condensation**.

Exercise | Q 1.09 | Page 337

Choose the correct option from the given alternatives.

Chemically pure cotton is _____.

1. acetate rayon
2. viscose rayon
3. cellulose nitrate
4. **cellulose**

Solution: Chemically pure cotton is **cellulose**.

Exercise | Q 1.1 | Page 337

Choose the correct option from the given alternatives.

Teflon is chemically inert, due to presence of _____.

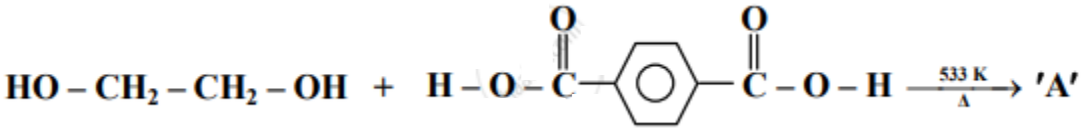
1. C-H bond
2. **C-F bond**
3. H- bond
4. C=C bond

Solution: Teflon is chemically inert, due to presence of **C-F bond**.

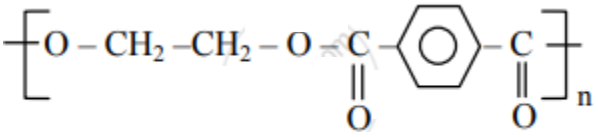
Exercise | Q 2.1 | Page 337

Answer the following in one sentence.

Identify 'A' and 'B' in the following reaction ___.



Solution: Polymer 'A' is:



Terylene or dacron

Exercise | Q 2.1 | Page 337

Answer the following in one sentence.

Identify 'A' and 'B' in the following reaction ___.

$$H_2N-(CH_2)_6-NH_2 + HOOC-(CH_2)_4-COOH \xrightarrow[533\ K]{N_2} \text{'B'}$$

Solution:

Polymer 'B' is:

$$[-HN-(CH_2)_6-\underset{\text{Nylon 6,6}}{NH-C-(CH_2)_4-C-}]_n$$

Exercise | Q 2.2 | Page 337

Complete the following statement.

Caprolactam is used to prepare _____.

Solution: Caprolactam is used to prepare **Nylon 6**.

Exercise | Q 2.2 | Page 337

Complete the following statement.

Novolac is a copolymer of _____ and _____.

Solution: Novolac is a copolymer of **Phenol** and **formaldehyde**.

Exercise | Q 2.2 | Page 337

Complete the following statement.

Terylene is _____ polymer of terephthalic acid and ethylene glycol

Solution: Terylene is **condensation** polymer of terephthalic acid and ethylene glycol.

Exercise | Q 2.2 | Page 337

Complete the following statement.

Benzoyl peroxide used in addition polymerisation acts as _____.

Solution: Benzoyl peroxide used in addition polymerisation acts as **initiator**.

Exercise | Q 2.2 | Page 337

Complete the following statement.

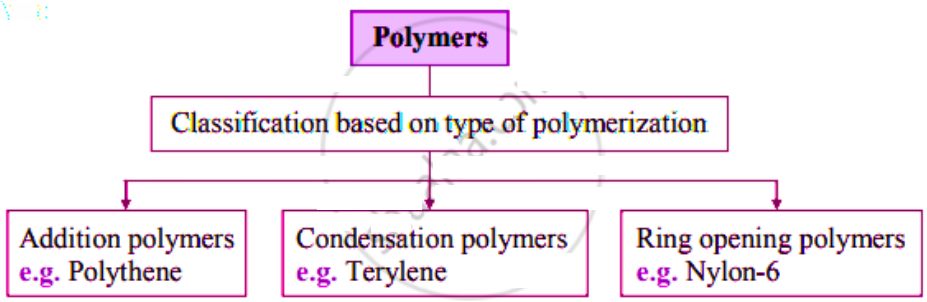
Polythene consists of polymerized_____.

Solution: Polythene consists of polymerized **ethene.**

Exercise | Q 2.3 | Page 338

Draw the flow chart diagram to show the classification of polymers based on the type of polymerization.

Solution:



Exercise | Q 2.4 | Page 338

Answer the following in one sentence.

Write examples of addition polymers and condensation polymers.

Solution:

1. **Addition polymers:**
   Polythene, Teflon, Polyacrylonitrile, Polyvinylchloride (PVC), etc.
2. **Condensation polymers:**
   Terylene, Nylon-6,6, Bakelite, Novolac, etc.

Exercise | Q 2.5 | Page 338

Answer the following in one sentence.

Name some chain-growth polymers.

Solution:

Chain growth polymers are. polyacrylonitrile, polyvinylchloride, polythene, etc

Exercise | Q 2.6 | Page 338

Answer the following in one sentence.

Define the term: Monomer

Solution:

Small molecules that are interlinked together to form polymers are called as monomers.

Exercise | Q 2.6 | Page 338

Answer the following in one sentence.

Define the term: Vulcanization

Solution:

The process by which a network of cross-links is introduced into an elastomer is called vulcanization.

Exercise | Q 2.6 | Page 338

Answer the following in one sentence.

Define the term: Synthetic fibres

Solution:

Man-made polymeric solids which form threads are called synthetic fibres.

Exercise | Q 2.7 | Page 338

Answer the following in one sentence.

What type of intermolecular force leads to high-density polythene?

Solution:

Van der Waals forces between closely packed linear polymeric chains are responsible for high-density polythene.

Exercise | Q 2.8 | Page 338

Answer the following in one sentence.

Give one example each of copolymer and homopolymer.

Solution:

1. **Copolymer:** Buna-S.
2. **Homopolymer:** Polythene.

Exercise | Q 2.9 | Page 338

Answer the following in one sentence.

Identify thermoplastic and thermosetting plastic from the following:

1. PET
2. Urea formaldehyde resin
3. Polythene
4. Phenol formaldehyde resin

Solution:

1. **Thermoplastic:** Polythene, PET

2. **Thermosetting plastic:** Urea formaldehyde resin, Phenol formaldehyde resin

Exercise | Q 3.01 | Page 338

Answer the following.

Write the names of classes of polymers formed according to intermolecular forces and describe briefly their structural characteristics.

Solution:

1. Polymers are classified into various categories on the basis of intermolecular forces as follows:

- Elastomers
- Fibres
- Thermoplastic polymers
- Thermosetting polymers

2. Their structural characteristics are as follows:

i. Elastomers:

- Elastomers have the property of elasticity in which a substance gets stretched by external force and restores its original shape on the release of that force.
- Elastomers, the elastic polymers, have weak van der Waals type of intermolecular forces that permit the polymer to be stretched.
- A few crosslinks between the chains help the stretched polymer to retract to its original position on removal of applied force.
  e.g. Vulcanized rubber, Buna-S, Buna-N, neoprene, etc.

ii. Fibres:

- Polymeric solids which form threads are called fibres.
- The fibres possess high tensile strength which is a property to have resistance to breaking under tension.
- High tensile strength is due to the strong intermolecular forces like hydrogen bonding and strong dipole-dipole forces. Due to these strong intermolecular forces, the fibres are crystalline in nature.
  e.g. Polyamides (nylon 6,6), polyesters (terylene), etc.

iii. Thermoplastic polymers:

- Thermoplastic polymers have the property of plasticity, that is, these polymers can be easily shaped or moulded.
- They are capable of repeated softening on heating and hardening on cooling.
- These polymers possess moderately strong intermolecular forces that are intermediate between elastomers and fibres.
  e.g. Polythene, polystyrene, polyvinyls, etc.

iv. Thermosetting polymers:

- Thermosetting polymers are rigid polymers.

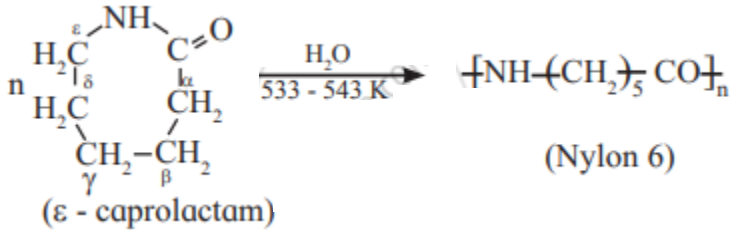
- During their formation, they have the property of being shaped on heating; but they get hardened while hot. Once hardened, they cannot be softened by heating and therefore cannot be remoulded.
- This characteristic is the result of extensive cross-linking by covalent bonds formed in the moulds during hardening/setting process while hot.
  e.g. Bakelite, urea-formaldehyde resin, etc.

Exercise | Q 3.02 | Page 338

Answer the following.

Write the reaction of the formation of Nylon 6.

Solution:



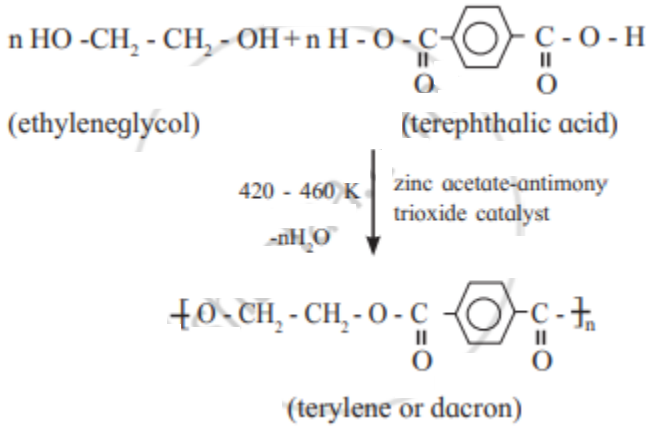
(ε - caprolactam) (Nylon 6)

Exercise | Q 3.02 | Page 338

Answer the following.

Write the reaction of the formation of Terylene.

Solution:



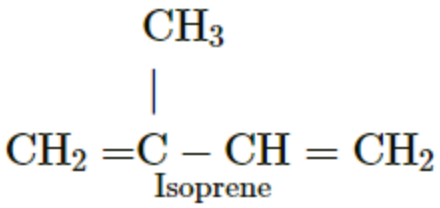
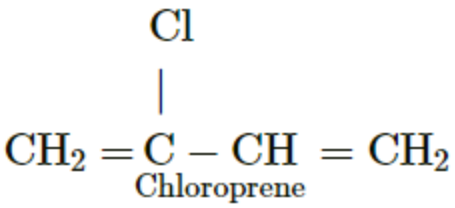
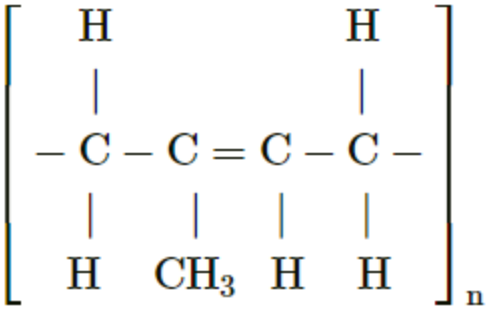
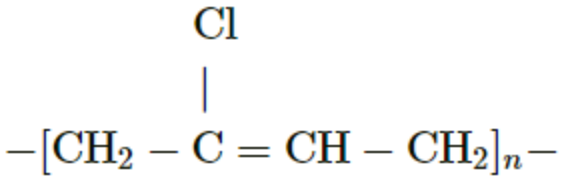
(terylene or dacron)

Exercise | Q 3.03 | Page 338

Answer the following.

Write structure of natural rubber and neoprene rubber along with the name and structure of their monomers.

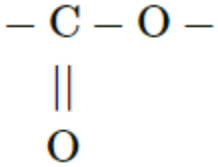
Solution:

Natural rubber	Neoprene
Monomer:  Isoprene	**Monomer:**  Chloroprene
Structure of natural rubber: 	**Structure of neoprene:** 

Exercise | Q 3.04 | Page 338

Answer the following.

Name the polymer type in which following linkage is present.



Solution:

The polymer containing ester linkage is called polyester.

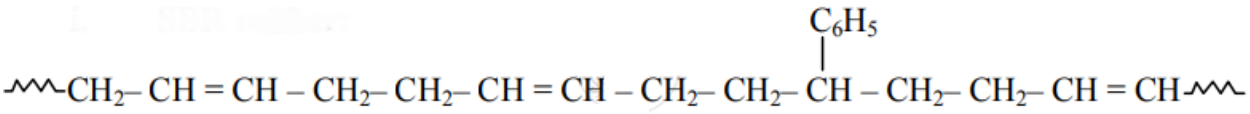
Exercise | Q 3.05 | Page 338

Answer the following.

Write structural formula of the following synthetic rubbers:

SBR rubbe

Solution:



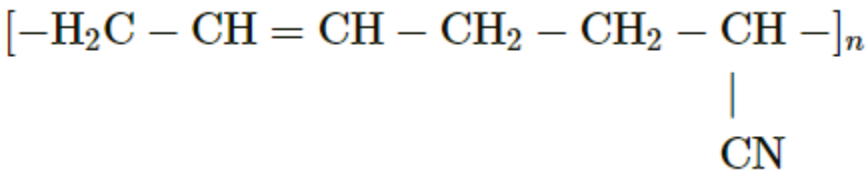
Exercise | Q 3.05 | Page 338

Answer the following.

Write structural formula of the following synthetic rubbers:

Buna-N rubber

Solution:



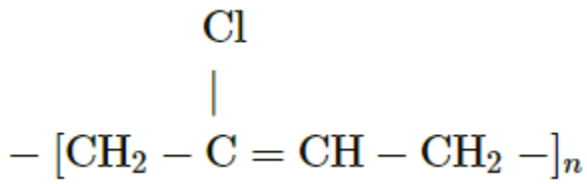
Exercise | Q 3.05 | Page 338

Answer the following.

Write structural formula of the following synthetic rubbers:

Neoprene rubber

Solution:



Exercise | Q 3.06 | Page 338

Answer the following.

Match the following pairs:

Name of polymer	Monomer
1. Teflon	a. $CH_2 = CH_2$
2. PVC	b. $CF_2 = CF_2$
3. Polyester	c. $CH_2 = CHCl$
4. Polythene	d. C_6H_5OH and HCHO
5. Bakelite	e. Dicarboxylic acid and polyhydoxyglycol

Solution:

Name of polymer	Monomer
1. Teflon	b. $CF_2 = CF_2$
2. PVC	c. $CH_2 = CHCl$
3. Polyester	e. Dicarboxylic acid and polyhydoxyglycol
4. Polythene	a. $CH_2 = CH_2$
5. Bakelite	d. C_6H_5OH and HCHO

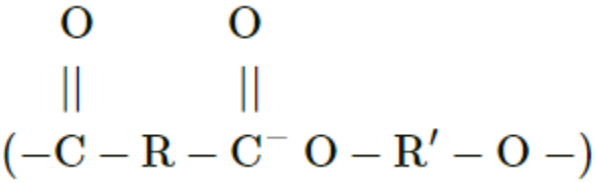
Exercise | Q 3.07 | Page 338

Answer the following.

Draw the structures of polymers formed from the following monomers

n HOOC–R–COOH + n HO–R'–OH

Solution:



Exercise | Q 3.07 | Page 338

Answer the following.

Draw the structures of polymers formed from the following monomers

$H_2N–(CH_2)_5$ – COOH

Solution:

[- NH - $(CH_2)_5$ - CO-]$_n$

Exercise | Q 3.08 | Page 338

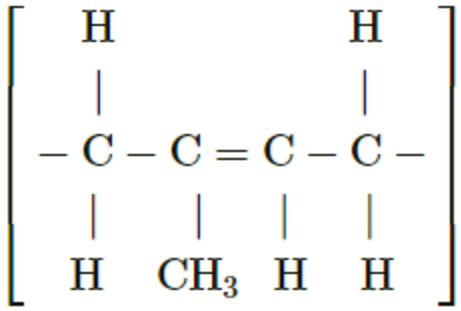
Answer the following.

Name and draw structure of the repeating unit in natural rubber.

Solution:

Repeating unit in natural rubber is obtained from the monomer isoprene.

Structure of repeating unit is:



Exercise | Q 3.09 | Page 338

Answer the following.

Classify the following polymers as natural and synthetic polymers

a. Cellulose
b. Polystyrene
c. Terylene
d. Starch
e. Protein
f. Silicones
g. Orlon (Polyacrylonitrle)
h. Phenol-formedehyde resins

Solution:

Polymer	Type of polymer
a. Cellulose	Natural
b. Polystyrene	Synthetic
c. Terylene	Synthetic
d. Starch	Natural
e. Protein	Natural
f. Silicones	Synthetic
g. Orlon (polyacrylonitrile)	Synthetic
h. Phenol-formaldehyde resins	Synthetic

Exercise | Q 3.1 | Page 338

Answer the following.

What are synthetic resins? Name some natural and synthetic resins.

Solution:

- **Synthetic resins:**

  These polymers are artificially prepared by polymerization of one monomer or copolymerization of two or more monomers.
  e.g. nylon and terylene.
  Synthetic polymers are further divided into three subtypes: fibres, synthetic rubbers, and plastics.

- **Natural resins:** Natural rubber, silk, wool, etc.
- **Synthetic resins:** Nylon, terylene, neoprene, etc.

Exercise | Q 3.11 | Page 338

Answer the following.

Distinguish between thermosetting and thermoplastic resins. Write example of both the classes.

Solution:

Thermosetting resin	Thermoplastic resin
They do not soften on heating	They soften on heating and harden on cooling
They cannot be remoulded or reshaped.	These can be remoulded or reshaped.
They possess extensive cross-linking formed by covalent bonds.	They possess moderately strong intermolecular forces that are intermediate between elastomers and fibres.
They are rigid polymers.	They are not rigid polymers.
e.g. Bakelite, urea-formaldehyde resins, etc.	e.g. PVC, polythene, polystyrene, etc.

Exercise | Q 3.12 | Page 338

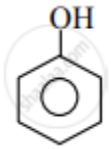
Answer the following.

Write name and formula of raw material from which bake lite is made.

Solution:

Bakelite is made by condensation of two different monomers:

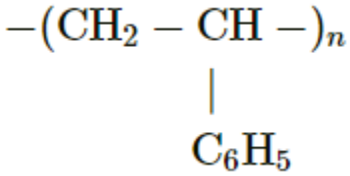
a. Phenol:



b. Formaldehyde: CH_2O

Exercise | Q 4.1 | Page 338

Identify condensation polymers and addition polymers from the following.



Solution: It is an Addition polymer.

Exercise | Q 4.1 | Page 338

Identify condensation polymers and addition polymers from the following.

$-(CH_2 - CH = CH - CH_2 -)_n$

Solution: It is an Addition polymer.

Exercise | Q 4.1 | Page 338

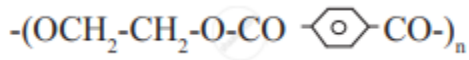
Identify condensation polymers and addition polymers from the following.

$-(CO(CH_2)_4 - CONH(CH_2)_6NH-)_n$

Solution: It is a Condensation polymer.

Exercise | Q 4.1 | Page 338

Identify condensation polymers and addition polymers from the following.



Solution:

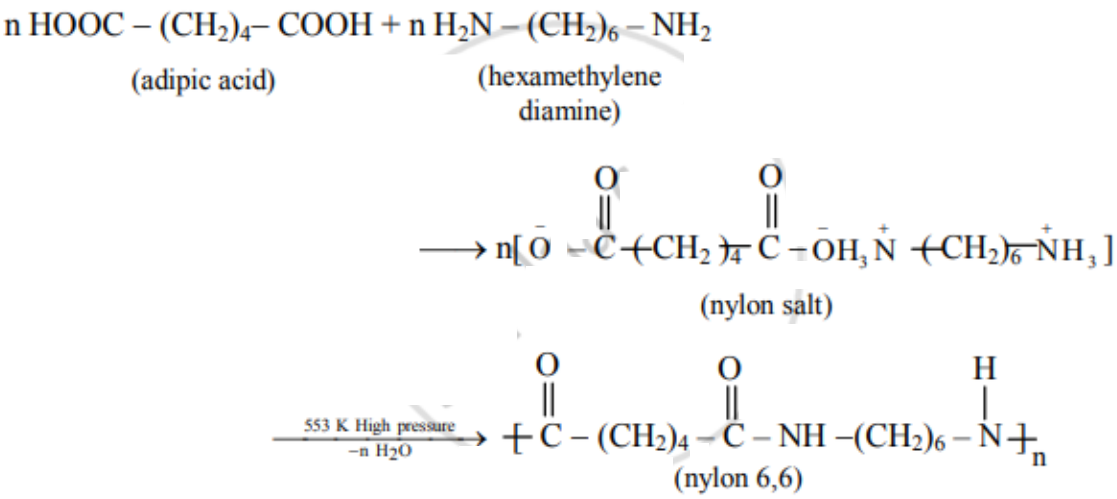
It is a Condensation polymer.

Exercise | Q 4.2 | Page 339

Attempt the following:

Write the chemical reactions involved in the manufacture of Nylon 6,6.

Solution:



Exercise | Q 4.3 | Page 339

Attempt the following:

Explain the vulcanisation of rubber. Which vulcanizing agents are used for the following synthetic rubber.
a. Neoprene
b. Buna-N

Solution:

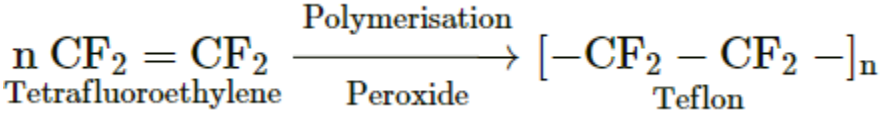
a. Neoprene: MgO is used to vulcanize neoprene.

b. Buna-N: Sulfur is used to vulcanize Buna-N.

Exercise | Q 4.4 | Page 339

Write chemical reaction to prepare the following polymer: **Teflon**

Solution:



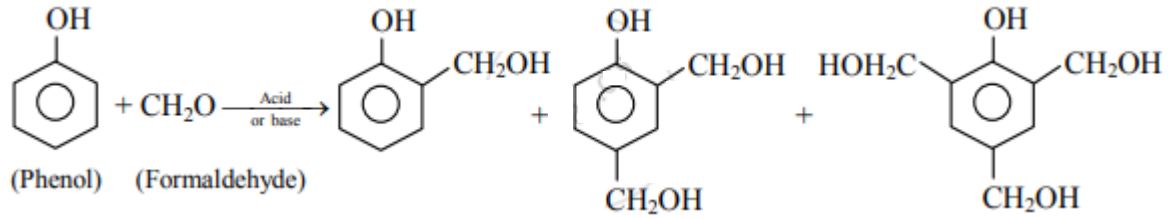
Exercise | Q 4.4 | Page 339

Write the reaction involved in the formation of:

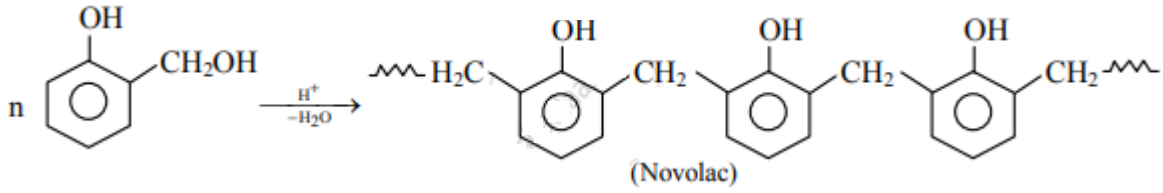
Bakelite

Solution:

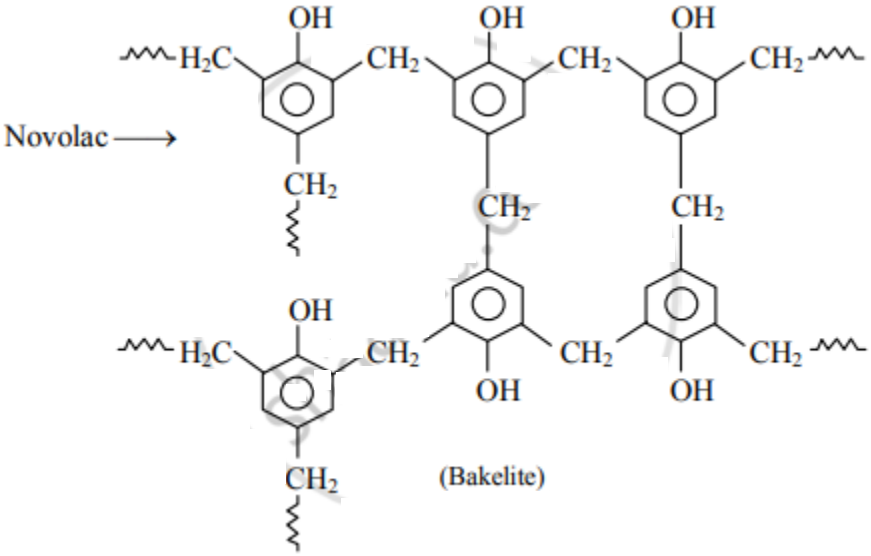
Step 1:



Step 2:



Step 3:



Exercise | Q 4.5 | Page 339

Attempt the following:

What is meant by LDP and HDP? Mention the basic difference between the same with suitable examples.

Solution:

1. What is meant by LDP and HDP? Mention the basic difference between the same with suitable examples.
2. LDP is a branched polymer of ethene with polymeric chains loosely held. Hence, even though it is tough, it is extremely flexible. Therefore, LDP is used in producing extruded

films, sheets, mainly for packaging and household uses like in preparation of squeeze bottles, attractive containers, etc. where low tensile strength and flexibility is required. On the other hand, HDP is a linear polymer of ethene with closely packed polymeric chains. Hence, it is much stiffer than LDP and has high tensile strength and hardness. Therefore, HDP is used in the manufacture of toys and other household articles like buckets, dustbins, bottles, pipes, laboratory wares and other objects where high tensile strength and stiffness is required.

Exercise | Q 4.6 | Page 339

Attempt the following:

Write preparation, properties and uses of Teflon.

Solution:

- **Preparation of teflon:**

1. The monomer used in preparation of teflon is tetrafluoroethylene, ($CF_2 = CF_2$), which is a gas at room temperature.

2. Tetrafluoroethylene is polymerized by using free-radical initiators such as hydrogen peroxide or ammonium persulphate at high pressure to produce polytetrafluoroethylene (teflon).

$$\underset{\text{Tetrafluoroethylene}}{n\ CF_2 = CF_2} \xrightarrow[\text{Peroxide}]{\text{Polymerization}} \underset{\text{Teflon}}{[-CF_2 - CF_2 -]_n}$$

- **Properties of teflon:**

1. Teflon is tough, chemically inert and resistant to heat and attack by corrosive reagents.

2. C - F bond is very difficult to break and remains unaffected by corrosive alkali, organic solvents.

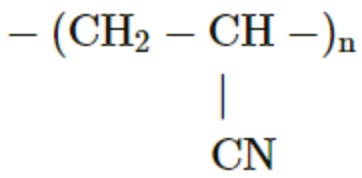
- **Uses:**

Teflon is used in making non-stick cookware, oil seals, gaskets, etc.

Exercise | Q 4.7 | Page 339

Attempt the following:

Classify the following polymer as straight-chain, branched-chain and cross-linked polymers.



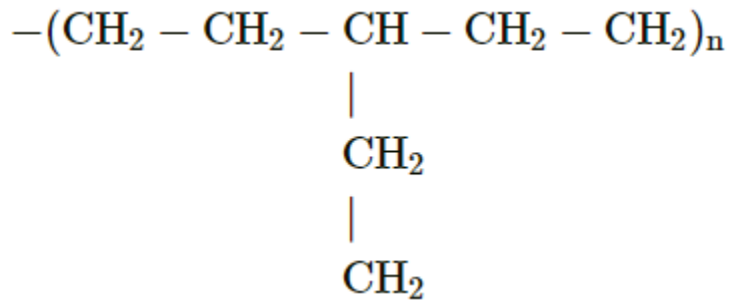
Solution:

Straight chain polymer

Exercise | Q 4.7 | Page 339

Attempt the following:

Classify the following polymer as straight-chain, branched-chain and cross-linked polymers.



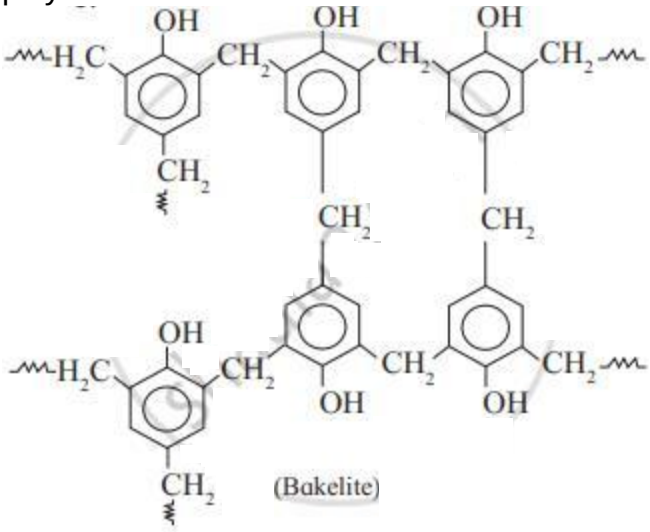
Solution:

Branched-chain polymer

Exercise | Q 4.7 | Page 339

Attempt the following:

Classify the following polymer as straight-chain, branched-chain and cross-linked polymers.



Solution: Crosslinked polymer

Exercise | Q 5.1 | Page 339

Answer the following

How is polythene manufactured? Give their properties and uses.

Solution:

i. LDP is prepared by polymerization of ethylene under high pressure (1000 - 2000 atm) and temperature (350 - 570 K) in presence of traces of O_2 or peroxide as initiator.

$$n\ CH_2 = CH_2 \xrightarrow[\text{peroxide at} 350-570\ K,\ 1000-2000\ atm]{\text{Traces of } O_2 \text{ or}} LDP$$

ii. The mechanism of this reaction involves free radical addition and H-atom abstraction. The latter results in branching.

iii. Polymeric chains are loosely held due to branching and the polymer has low density.

iv. **Properties of low-density polyethylene:**

a. LDP films are extremely flexible but tough, chemically inert, and moisture resistant. b. It is a poor conductor of electricity with a melting point 110 °C.

v. **Uses of low-density polyethylene:**

a. It is mainly used in the preparation of pipes for agriculture, irrigation, domestic water line connections as well as insulation to electric cables.

b. It is also used in submarine cable insulation.

c. It is used in producing extruded films, sheets, mainly for packaging and household uses like in preparation of squeeze bottles, attractive containers, etc.

vi. HDP is a linear polymer with high density due to close packing.

vii. It is obtained by polymerization of ethene in presence of Zieglar-Natta catalyst, which is a combination of triethyl aluminium with titanium tetrachloride.

viii. Polymerization of ethene is carried out at a temperature of 333 K to 343 K and a pressure of 6-7 atm.

$$n\ CH_2 = CH_2 \xrightarrow[6-7\ atm,\ catalyst]{333\ K-343\ K} HDP$$

ix. **Properties of high-density polyethylene:**

a. HDP is crystalline, melting point in the range of 144 - 150 °C.

b. It is much stiffer than LDP and has high tensile strength and hardness.

c. It is more resistant to chemicals than LDP.

x. **Uses of high-density polyethylene:**

a. HDP is used in the manufacture of toys and other household articles like buckets, dustbins, bottles, pipes, etc.

b. It is used to prepare laboratory wares and other objects where high tensile strength and stiffness is required.

Exercise | Q 5.2 | Page 339

Answer the following.

Is synthetic rubber better than natural rubber? If so, in what respect?

Solution:

Yes, synthetic rubber is superior to natural rubber.

1. Synthetic rubber has high mechanical strength.

2. It has high abrasion resistance.

3. It is resistant to petroleum, vegetable oils, light as well as heat.

Exercise | Q 5.3 | Page 339

Answer the following.

Write main specialities of Buna-S, Neoprene rubber?

Solution:

1. **Buna-S:**
   It has mechanical strength and has abrasion resistance. Hence, it is used in tyre industry.
2. **Neoprene:**

- Neoprene is particularly resistant to petroleum, vegetable oils, light as well as heat.
- Hence, it is used in making hose pipes for the transport of gasoline and making gaskets.
- It is used for manufacturing insulator cable, jackets, belts for power transmission and conveying.

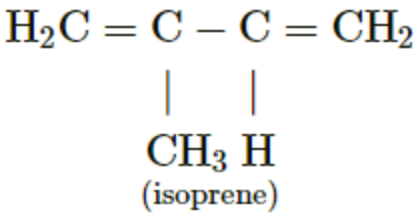
Exercise | Q 5.4 | Page 339

Answer the following.

Write the structure of isoprene and the polymer obtained from it.

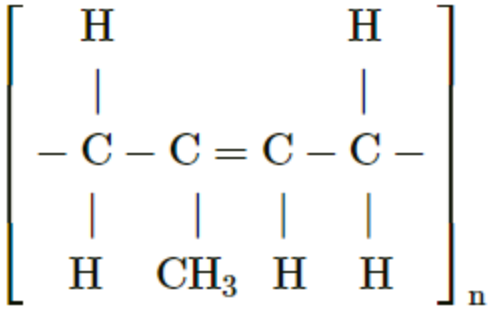
Solution:

1) Isoprene:



(isoprene)

2) Polymer of isoprene (polyisoprene or natural rubber):



(polyisoprene/rubber)

Exercise | Q 5.5 | Page 339

Answer the following.

Explain in detail free radical mechanism involved during preparation of addition polymer.

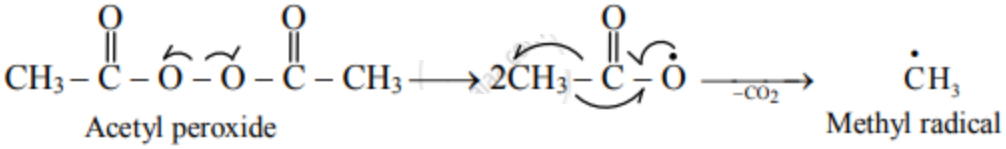
Solution:

The free radical mechanism is most common in addition to polymerization. It is also called a chain reaction which involves three distinct steps. These are as follows:

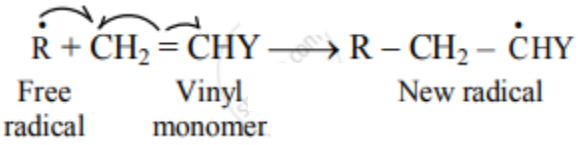
i) Step 1: Chain initiation:

a. The chain reaction is initiated by a free radical which is formed from an initiator (catalyst) such as benzoyl peroxide, acetyl peroxide, tert-butyl peroxide, etc.

b. For example, acetyl peroxide generates methyl radical as shown below:



c. The free radical (say R•) so formed attaches itself to the olefin (vinyl monomer) and produces a new radical, made up of two parts, namely, the attached radical and the monomer unit.



ii. Step 2: Chain propagation:

a. The new radical formed in the initiation step reacts with another molecule of vinyl monomer, forming another still bigger sized radical, which in turn reacts with another monomer molecule.

b. The repetition of this sequence takes place very rapidly. It is called chain propagation.

c. This step is very rapid and leads to high molecular mass radical.

iii. Step 3: Chain termination:

a. At some stage, termination of the growing chain takes place. It may occur by several processes.

b. One mode of termination is by combination of two growing chain radicals.