UNIT 15

POLYMERS

1. Polymer : It is a very large molecule having molecular mass 10^3-10^7 g mol^{-1}. They are formed by joining together repeating structural units, called monomers.

2. Classification of Polymers :

(a) Based on Source :

(i) Natural : Found in plants and animals, e.g., Proteins, cellulose, natural rubber, silk, wool.

(ii) Synthetic : Man-made, e.g., Nylon, polyster, neoprene, bakelite, teflon, PVC, polystyrene.

(b) Based on Structure :

(i) Linear polymers : This consist of long and straight chain repeating units, e.g., Polythene (HDPE), PVC, nylon, polyester.

(ii) Branched polymers : This contain linear chains having some branches, e.g., amylopectin, glycogen etc.

(iii) Cross-linked polymers : Strong covalent bonds are present between various linear polymer chains, e.g., Bakelite, urea-formaldehyde polymer, melamine, formaldehyde polymer etc.

(c) Based on mode of polymerization :

(i) Addition polymers : These are formed by the repeated addition of monomer molecules possessing multiple bonds, e.g., polythene, polypropene, polystyrene, PMMA (polymethyl metha crylate).

(ii) Condensation polymers : These are formed by the repeated condensation reaction of different bifunctional or trifunctional monomers with the elimination of small molecules like water, HCl, NH_3, alcohol, etc., e.g., Bakelite, nylon, polyster, urea-formaldehyde resin.

(d) Based on molecular forces :

(i) Elastomers : Forces of interaction between polymer chains is weakest, e.g., natural rubber, neoprene, vulcanized rubber.

(ii) Fibers : Strong hydrogen bonds are present between the polymer chains. They have high tensie strength, e.g., Nylon, polyster, silk, wool, orlon, rayon etc.

(iii) Thermoplastics : They are linear/slightly branched chains molecules capable of repeated softening on heating and hardening on cooling, e.g., Polythene, PVC, polystyrene, polypropene.

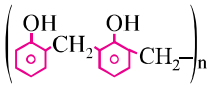
(iv) Thermosetting plastics : They are cross-linked or heavily branched molecules, which on heating undergo extensive cross-linkages and become infusible, e.g., Bakelite, urea-formaldehyde resin.

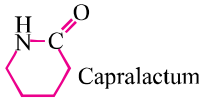
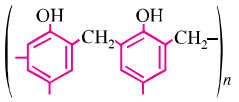
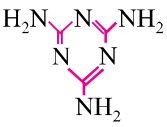
(e) Based on growth of polymerization : Depending upon the mechanism of polymerization, polymers are classified as :

(i) Addition polymers or Chain growth polymers : They follow mostly free radical mechanism.

(ii) Condensation polymers or Step growth polymers : Because they are formed in gradual steps.

Polymers and Their Monomers

S. No.	Name of Polymer	Structure	Monomer	Uses
1.	Polythene	$(-CH_2-CH_2-)_n$	$CH_2=CH_2$ Z	As insulator, anticorrosive, packing material, household and laboratory wares.
2.	Polystyrene	$CH_2 = CH_2$ C_6H_5 Styren	$CH_2 = CH_2$ C_6H_5 Styrene	As insulator, wrapping material, manufacture of toys and household articles.
3.	Polyvinylchloride (PVC)	$(-CH_2-\underset{Cl}{CH}-)_n$	$CH_2 = CHCl$ Vinyl chloride	In manufacture of raincoats, hand bags, vinyl flooring and leather clothes.
4.	Polytetrafluoro ethylene (PTFE) or Teflon	$(-CF_2-CF_2-)_n$	$CF_2 = CF_2$ TFE	As lubricant, insulator and making cooking wares.
5.	NOVOLAC		(a) HCHO (b) C_6H_5OH	In making bonding give varnishes, lacquers etc.
6.	Polyacrylonitrile (Orion) (Acrilian)	$(-CH_2-\underset{CN}{CH}-)_n$	$CH_2 = CHCN$ Acrylonitrile	In making synthetic fibres and synthetic wool.
7.	Styrene butadiene rubber (SBR or Buna-S)	$(-CH_2-CH-CH-\underset{C_6H_5}{CH}-CH_2-CH-CH_2-)$	(a) $CH_2 = CH - CH = CH_2$ (b) $\underset{C_6H_5}{CH = CH_2}$	In making automobile tyres and footwear.

8.	Nitrile rubber (Buna-N)	$(-CH_2-CH=CH-CH_2-CH-CH_2-)$ CN	(a) $CH_2 = CH - CH = CH_2$ (b) $CH = CH_2$ CN	In making oil seals, manufacture of hoses and tank linings.
9.	Neoprene	$(-CH_2-C=CH-CH_2-)_n$ Cl	$CH_2 = C - CH = CH_2$ Cl Chloroprene	As insulator, making conveyor belts and printing rollers.
10.	Natural rubber (NR)	$\left(\begin{matrix}CH_2 & & CH_2\\ & C=C & \\ CH_3 & & H\end{matrix}\right)_n$ is form	$CH_2 = C - CH = CH_2$ CH_3 Isoprene	In making erasers, tyres, tubes, valcanised rubber etc.
11.	Terylene (Dacron)	$(-OOC-COO-C_6H_4-CH_2-CH_2-)_n$	(a) HOOC – C_6H_4 – COOH (b) $HO-CH_2-CH_2-OH$	For making fibres, safety belts, tyre cords, tents etc.
12	Polypropene = P Propene	$(-CH_2-\underset{CH_3}{CH}-)_n$	Propen $H_3 - CH = CH_2$	Ropes, toys, pipes, fibre etc. strings.
13.	Glyptal	$(-OCH_2-CH_2OOC-C_6H_4-COO)_n$	HOOC – C_6H_4 – COOH	As binding material in preparation of mixed plastics and plants.
14.	Nylon 6	$(NH-[CH_2]_5-\overset{O}{\overset{\|}{C}}-)_n$	 Capralactum	In making fibres, plastics, tyre cords and ropes.
15.	Nylon 66	$(NH-[CH_2]_4NHCO[CH_2]_4CO-)_n$	(a) $HOOC-(CH_2)_4-COOH$ (b) $H_2N-(CH_2)_6-NH_2$	In making brushes, synthetic fibres, parachutes, ropes and carpets.
16.	Bakellite		(a) HCHO (b) C_6H_5OH	For making gears, protective coating and electrical fittings.
17.	Urea formaldehyde resin	$(-NH-CO-NH-CH_2-)_n$	(a) HCHO (b) NH_2CONH_2	For making unbreakable cups and laminated sheets.
18.	Melamine formaldehyde resin		 (a) 2 HCHO (b) HCHO	In making plastic crockery, unbreakable cups and plates.
19.	Poly-β-hydroxy butyrate-co-β-hydroxy valerate [PHBV]	$(-O-CH-CH_2-CO-)_n$ R O $R = CH_3C_2H_5$	OH $CH_3-CH-CH_2-COOH$ OH $CH_3 + CH_2-CH-CH_2-COOH$	As packaging, orthopaedic devices and in controlled drug release.

VERY SHORT ANSWER TYPE QUESTIONS (1 Mark)

Q. 1. Define the term 'homopolymerisation' giving an example.

Ans. The polymer formed by the polymerization of single/same monomeric species is known as homopolymerisation. E.g., Polythene/PVC/Polypropene.

Q. 2. Give an example of elastomer.

Ans. Natural rubber or Buna-S or Buna-N or Neoprene.

Q. 3. Why is bakelite a thermosetting polymer ?

Ans. Because bakelite have three dimensional network of covalent bonds with cross-linking between chains.

Q. 4. Write the monomers of Buna-N.

Ans. $H_2C = CH - CH = CH_2$ + $H_2C = \underset{\displaystyle CN}{\underset{|}{CH}}$

1,3 Butadiene

Acrylonitrile

Q. 5. Is $\left[H_2C\,CH(C_6H_5)\right]_n$ a homopolymer or copolymer ? Why ?

Ans. Homopolymer, because it is formed by polymerization of one kind of monomer species.

Q. 6. Write the structure and one use of urea formaldehyde resin.

Ans. $\left[HNCONHCH_2\right]_n$

It is used in unbreakable crockery.

Q. 7. Is $\left[H_2C-\underset{\displaystyle Cl}{\underset{|}{CH}}\right]_n$ a homopolymer or a copolymer ?

Ans. Homopolymer.

Q. 8. Which of the following is natural polymer ?

Buna-S, Proteins, PVC

Ans. Proteins.

Q. 9. Based on molecular forces what type of polymer is neoprene ?

Ans. Elastomer.

Q. 10. Which of the following is a fibre ?

Nylon, Neoprene, PVC

Ans. Nylon

Q. 11. Name a natural elastomer.

Ans. Natural rubber.

Q. 12. Write name of a synthetic polymer which is an ester.

Ans. Terylene.

Q. 13. Name of monomer of Nylon 6.

Ans. Aminocaproic acid

Q. 14. Write the monomer units of bakelite.

Ans. Phenol and formaldehyde.

Q. 15. Define a copolymer.

Ans. The polymers made by addition polymerisation from two different monomers are termed as copolymers. E.g., Buna-S, Buna-N etc.

Q. 16. Write one use of PVC.

Ans. In manufacture of raincoats and vinyl flooring.

Q. 17. Define polymer.

Ans. Polymer is defined as very large molecules having molecular mass (10^3-10^7 u). These are also referred to as macromolecules.

Q. 18. Give an example of thermoplastics.

Ans. Thermoplastics are polythene, polystyrene, polyvinyls etc.

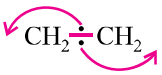
Q. 19. To which class of polymers does Nylon-66 belong ?

Ans. Polyamides.

Q. 20. Name the type of monomers in terylene.

Ans. Ethylene glycol and terephthalic acid.

Q. 21. How do you explain the functionality of a monomer ?

Ans. Functionality means the number of bonding sites in a molecule. E.g., 

Q. 22. Give chemical name of teflon.

Ans. Polytetrafluoroethene.

Q. 23. The Ziegler-Natta catalyst is used for polymerisation of..... .

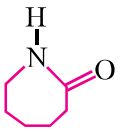
Ans. Triethylaluminium + Titanium tetrachloride

SHORT ANSWER-I TYPE QUESTIONS (2 Marks)

Q. 1. Draw the structure of monomers of each of the polymers :

(i) PVC **(ii) Nylon-6**

Ans. (i) $H_2C = \underset{Cl}{CH}$ Vinyl chloride

(ii)  Caprolactum

Q. 2. What is the repeating unit in the condensation polymer obtained by combining $HOOCCH_2CH_2COOH$ (succinic acid) and $H_2NCH_2CH_2NH_2$ (ethylene diamine) ?

Ans. $nHOOC–CH_2CH_2COOH + nH_2NCH_2CH_2NH_2 \longrightarrow \left(\overset{O}{\overset{\|}{C}} – CH_2CH_2\overset{O}{\overset{\|}{C}} – \overset{H}{\underset{|}{N}} – CH_2CH_2\overset{H}{\underset{|}{N}}\right)_n$

Q. 3. Draw the structure of monomers of the following polymers :

(i) Teflon **(ii) Polythene**

Ans. (i) $F_2C = CF_2$ Tetrafluoroethene

(ii) $H_2C = CH_2$ Ethene

Q. 4. Name the two groups into which polymers are classified on the basis of magnitude of intermolecular forces.

Ans. (i) Elastomers

(ii) Fibres

(iii) Thermoplastic polymers

(iv) Thermosetting polymers

Q. 5. Mention two important uses of each of the following :

(i) Bakelite **(ii) Nylon-6**

Ans. (i) Bakelite : For making combs, electrical switches, handles of utensils, computer disc etc.

(ii) Nylon-6 : For making tyre cords, fabrics, ropes etc.

Q. 6. Distinguish between homopolymers and copolymers with an example of each.

Ans. Homopolymers : Polymers whose repeating structural units are derived from only one type of monomer units are called homopolymers. For example, Polythene.

Copolymers : Polymers whose repeating structural units are derived from two or more types of monomer units are called copolymers. For example, Nylon-6, 6.

Q. 7. What is step growth polymerisation ? Explain with an example.

Ans. Step growth polymerisation involves condensation between monomers having multifunctional groups. It is also known as condensation polymerisation. E.g.,

$$nHOOC{-}(CH_2)_4{-}COOH + nH_2N{-}(CH_2)_6NH_2$$

$$\rightarrow \underset{\text{Nylon 6, 6}}{+C-(CH_2)_4-\overset{O}{\overset{\|}{C}}-\overset{H}{\overset{|}{N}}-(CH_2)_6-\overset{H}{\overset{|}{N}}+_n} + (2n-1)H_2O$$

Q. 8. What is the difference between elastomers and fibres ? Give one example of each.

Ans. Elastomers : Polymers in which the intermolecular forces of attraction between the polymer chains are weakest are called elastomers. E.g., Natural rubber.

Fibres : Polymers in which intermolecular forces of attraction are the strongest are called fibres. E.g., Nylon-6, 6.

Q. 9. Mention the important uses of each :

(i) Nylon-6, 6 **(ii) PVC**

Ans. (i) Uses of Nylon-6, 6 :

(a) It is used in making carpets, textile fibres etc.

(b) It is used for making elastic hosiery.

(ii) Uses of PVC :

(a) It is used for making raincoats, hand bags etc.

(b) It is used in making water pipes.

Q. 10.Arrange the following polymers in the order of increasing intermolecular forces :

(i) Nylon-6, Buna-S, Polythene

(ii) Nylon-6, Neoprene, Polyvinyl chloride

Ans. (i) Buna-S < Polythene < Nylon-6

(ii) Neoprene < Polyvinyl chloride < Nylon-6

Q. 11.Define thermoplastic and thermosetting polymers. Give one example of each.

Ans. Thermoplastics : Polymers in which the intermolecular forces of attraction are in between those of elastomers and fibres are called thermoplastics. E.g., Nylon-6, PVC, etc.

Thermosetting polymers : These are semi-fluid substances with low molecular masses which when heated in a mould undergo a permanent change in chemical composition to give hard, infusible and insoluble mass. E.g., Bakelite.

Q. 12.What is biodegradable polymer ? Give an example of a biodegradable polymer.

Ans. Biodegradable polymers are those which are decomposed by micro organisms. E.g., PHBV (Poly-B-hydroxybutyrate – Co – B – hydroxyl valerate).

Q. 13.How does vulcanization change the character of natural rubber ?

Ans. It introduce sulphur bridge or cross-link between polymer chain.

Q. 14.Name a polymer each for the following applications :

(i) Insulation of electrical switches

(ii) Making laminated sheets

Ans. (i) Bakelite (ii) Urea formaldehyde resin

Q. 15. How does the presence of double bonds in rubber influence their structure and reactivity ?

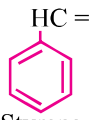
Ans. Natural rubber is a cis-polyisoprene. These cis- double bonds do not allow to polymer unit to come close for effective interaction. Hence rubber show elasticity.

SHORT ANSWER-II TYPE QUESTIONS (3 Marks)

Q. 1. Write the names and structure of the monomers of the following polymers :

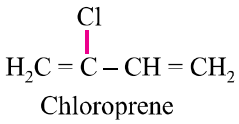
(i) Buna-S **(ii) Neoprene** **(iii) Nylon-6**

Ans. (i) Buna-S :

$H_2C = CH - CH - CH_2$ and 

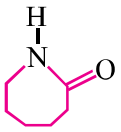
1, 3-Butadiene Styrene

(ii) Neoprene :



Chloroprene

(iii) Nylon-6 :



Caprolactum

Q. 2. Differentiate between thermoplastics and thermosetting polymers. Give one example of each.

Ans. Same as Q. 11 (Two marks questions)

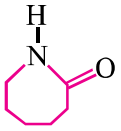
Q. 3. Write names and structure of monomers of following polymers :

(i) Bakelite (ii) Nylon-6 (iii) Polythene

Ans. (i) Phenol and formaldehyde

$C_6H_5OH + HCHO$

(ii) Caprolactum



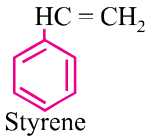
(iii) Ethene

$H_2C = CH_2$

Q. 4. Write names and structure of monomers of following polymers :

(i) Polystyrene (ii) Dacron (iii) Teflon

Ans. (i) Styrene



Styrene

(ii) Ethylene glycol + Terephthalic acid

$HOH_2C - CH_2OH$ + HOOC–C$_6$H$_4$–COOH

(iii) Tetrafluoroethene

$F_2C = CF_2$

Q. 5. (i) What is the role of t-butyl peroxide in the polymerisation of ethane ?

(ii) Identify the monomers in the following polymer :

$$+ HN(CH_2)_6NHCO(CH_2)_4CO +$$

(iii) Arrange the following polymers in the increasing order of their intermolecular forces :

Polystyrene, Terylene, Buna-S

Ans. (i) Catalyst/initiator of free radical

(ii) Hexamethylenediamine and adipic acid

(iii) Buna-S < Polystyrene < Terylene

Q. 6. Write the mechanism of free radical polymerisation of ethane.

Ans. (i) Chain initiation step

$C_6H_5\overset{O}{\overset{\|}{C}}-O-O-\overset{O}{\overset{\|}{C}}-C_6H_5 \longrightarrow 2C_6H_5-\overset{O}{\overset{\|}{C}}-O^{\bullet} \longrightarrow 2C_6H_5^{\bullet}$

Benzoyl peroxide — Phenylradical

$C_6H_5^{\bullet} + H_2C = CH_2 \rightarrow C_6H_5CH_2\dot{C}H_2$

(ii) Chain propagating step

$C_6H_5CH_2\dot{C}H_2 + H_2C = CH_2 \longrightarrow C_6H_5CH_2CH_2\dot{C}H_2$

$\downarrow$

$C_6H_5(CH_2CH_2)_nCH_2CH_2$

(iii) Chain terminating step

$C_6H_5(CH_2CH_2)_nCH_2\dot{C}H_2$

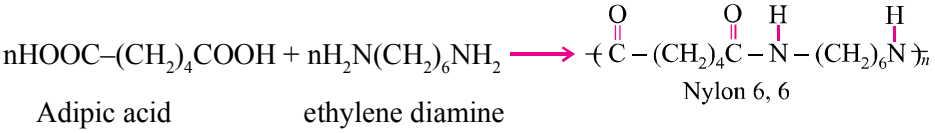
$\longrightarrow C_6H_5(CH_2CH_2)_nCH_2CH_2CH_2(CH_2CH_2)_nC_6H_5$

$C_6H_5(CH_2CH_2)_nCH_2\dot{C}H_2$

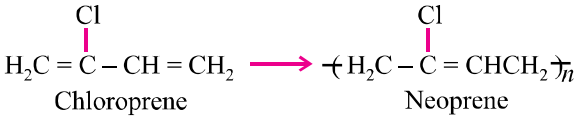
Q. 7. Write chemical equation for the synthesis of :

(i) Nylon-6, 6 (ii) Neoprene (iii) Terylene

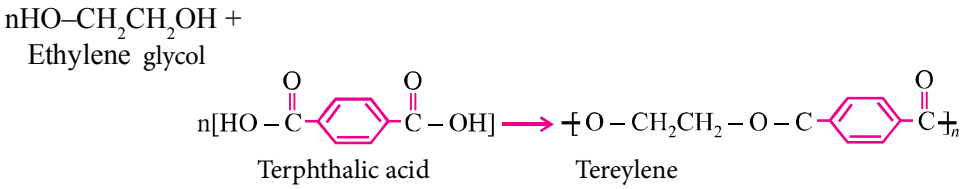
Ans. (i) Nylon-6, 6 :



(ii) Neoprene :



(iii) Terylene :



Q. 8. Write the monomers which are used for the synthesis of following polymers :

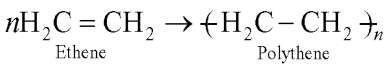
(i) Terylene (ii) Polythene (iii) Bakelite

Indicate the type of polymerisation for each which forms polymers.

Ans.	**Monomers**	**Type of polymerisation**
(i)	Ethylene glycol + Terephthalic acid	Condensation
(ii)	Ethene	Addition
(iii)	Phenol + Formaldehyde	Condensation

Q. 9. How are polymers classified on the basis of mode of polymerisation ? Explain with examples.

Ans. Addition polymers : Are formed by repeated addition of a large number of same or different monomers possessing double or triple bonds. E.g., Polythene.



Condensation polymers : Are formed by repeated condensation reaction between two bifunctional or trifunctional monomer units usually with the elimination of small molecules like water, alcohol, ammonia, etc. E.g., Nylon-6, 6.

$$nHOOC(CH_2)_4COOH + nH_2N(CH_2)_6NH_2 \longrightarrow$$

$$+C-(CH_2)_4-C-N-(CH_2)_6-N+_n + (2n-1)H_2O$$

Nylon 6, 6

Q. 10.A monomer of a polymer on ozonolysis gives two moles of CH_2O and one mol of $CH_3-\overset{O}{\overset{\|}{C}}-CHO$. Write the structure of monomer and polymer and each step of reaction.

Ans. Structure of monomer :

$$CH_2O + O=\overset{CH_3}{\overset{|}{C}}-CHO + OCH_2 \longrightarrow CH_2=\overset{CH_3}{\overset{|}{C}}-CH=CH_2$$

Structure of polymer :

$$+CH_2-\underset{H_3C}{\overset{|}{C}}=\underset{H}{\overset{|}{C}}-CH_2+$$

Q. 11.Can a copolymer be formed in both addition and condensation polymerisation ? Explain with examples.

Ans. Yes. Buna-S, Buna-N : Addition polymer

Nylon-6, 6, terylene : Condensation

LONG ANSWER TYPE QUESTIONS (5 Marks)

Q. 1. How are following polymers obtained ? Write the names and structures of monomers and structure of respective polymers :

(i) Dacron **(ii) Nylon-6** **(iii) Buna-N**

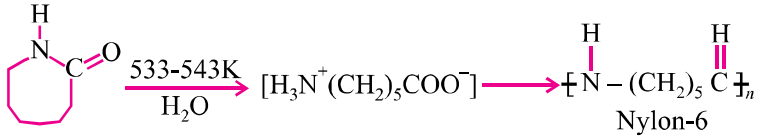
(iv) Glyptal **(v) PHBV**

Ans. (i) Dacron : By condensation polymerisation.

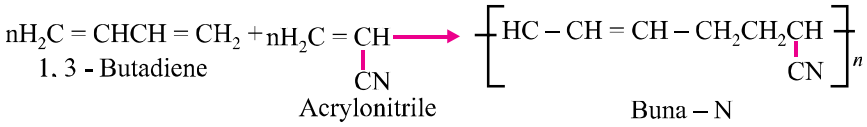
$$nHOH_2C-CH_2OH + nHO-\overset{O}{\overset{\|}{C}}-C_6H_4-\overset{O}{\overset{\|}{C}}-OH \longrightarrow +O-CH_2CH_2-O-\overset{O}{\overset{\|}{C}}-C_6H_4-\overset{O}{\overset{\|}{C}}+_n$$

Terephthlic acid Dacron

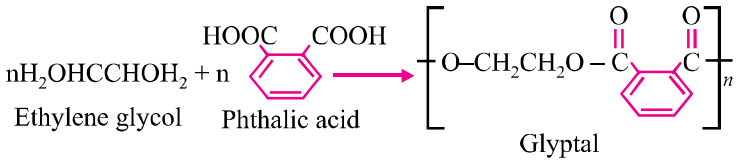
(ii) Nylon-6 : By condensation polymerisation.



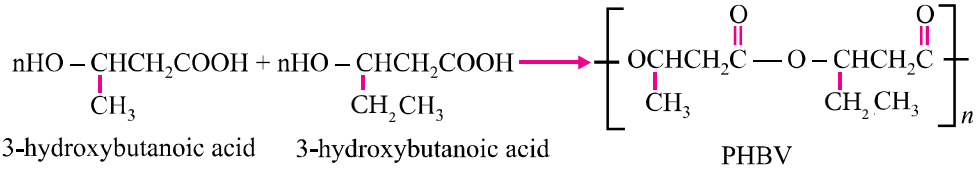
(iii) Buna-N : By addition polymerisation.



(iv) Glyptal : By condensation polymerisation.



(v) PHBV : By condensation polymerisation.



VALUE BASED QUESTIONS (4 Marks)

Q. 1. In school, lot of emphasis is given to 3R principle to Reduce, Refuse and Recycle. Two shopkeepers, Naresh Jain is using bags made up of jute, a polymer of cellulose while Rakesh Gupta using polythene as packing material. Abdul Kadir, a science student told Rakesh Gupta not to use polythene bags for packing but to use jute bags.

(i) Why is jute preferred over polythene as packing material by Abdul Kadir ?

(ii) Give monomers of jute and polythene.

(iii) Is polythene an addition polymer or a condensation polymer ?

(iv) Mention the values associated with the use of jute.

Q. 2. During war or accidents people get deep injuries which require stitching of wounds. Rohit told his friend, Avi, that earlier these wounds were used to be stitched by nylon-6 thread but nowadays instead of it Nylon-2-Nylon-6 fibre is used.

(i) Why should Nylon-2-Nylon-6 be used for stitching of wounds instead of Nylon-6 thread ?

(ii) Give monomers of Nylon-6 and Nylon-2-Nylon-6.

(iii) Is this polymer an addition polymer or a condensation polymer ?

(iv) Mention the values associated with use of Nylon-2-Nylon-6.

Q. 3. Two shopkeepers are using LDP (low density polythene) and HDP (high density polythene) polymers for packing of materials.

(i) Name the polyethene preferred for packaging.

(ii) Name the catalyst used in synthesis of HDP.

(iii) HDP has high density. Why ?

(iv) Mention the value associated with the use of a specific polymer.

Q. 4. PHBV (poly-β-hydroxybutyrate-co-β-hydroxyvalerate) is a biodegradable polymer. It is a co-polymer of 3-hydroxybutanoic acid and 3-hydroxy pentanoic acid.

(i) How has PHBV found utility in medicines as capsule ?

(ii) Write the name of polymer used in artificial limb popularly known as Jaipur foot.

(iii) Is this polymer an addition polymer or condensation polymer ?

(iv) Write the values associated with the use of PHBV.

Q. 5. Vidhi's mother followed a very traditional way of cooking using earthenwares, copper utensils etc. Her daughter replaced all the kitchen steel utensils with teflon coated ones.

(i) In your opinion, who is correct in present situation ?

(ii) Give monomer of teflon. Is it an addition or a condensation polymer ?

(iii) Write the structure of teflon.

(iv) Mention the values shown by Vidhi.