

UNIT 6



Polymers

Unit Outcomes

After completing this unit, you will be able to:

- *understand the processes of addition polymerization and condensation polymerization ;*
- *list a variety of synthetic polymers and natural polymers and explain their differences;*
- *classify synthetic polymers as addition polymers or condensation polymers and identify their monomers;*
- *describe monomers, properties and uses of plastics, rubbers, carbohydrates and proteins;*
- *analyze the risks and benefits of the development of and application of synthetic polymers (example, plastics) and suggest possible methods of control;*
- *demonstrate scientific enquiry including classifying, comparing and contrasting, communicating, asking questions, applying concepts and making generalizations.*

MAIN CONTENTS

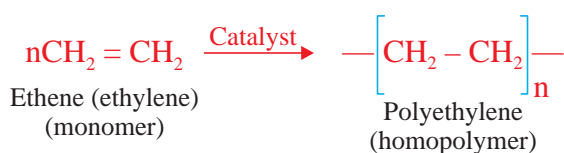
- 6.1 Introduction to Polymers
- 6.2 Polymerization
- 6.3 Synthetic Polymers
- 6.4 Natural Polymers
 - *Unit Summary*
 - *Review Exercise*

6.1 INTRODUCTION TO POLYMERS

After completing this subunit, you will be able to:

- define the terms monomer and polymer;
- classify polymers into synthetic and natural polymers; and
- give examples of synthetic and natural polymers.

Polymers are *macro (large) molecules* made from smaller repeating units called **monomers**. Hence, monomers are the building blocks of polymers. A polymer might be made from identical monomers or different types of monomers. Homopolymers are made from only one type of monomer. For example, polyethylene is synthesized by the polymerization of one type monomer, ethene (ethylene).

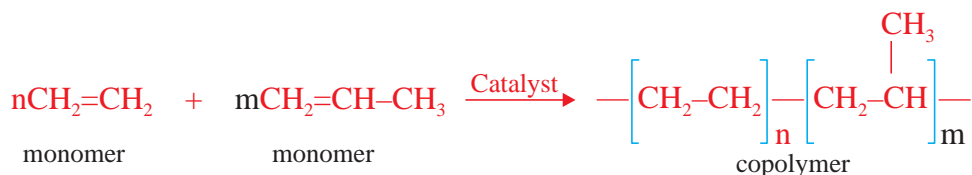


Activity 6.1



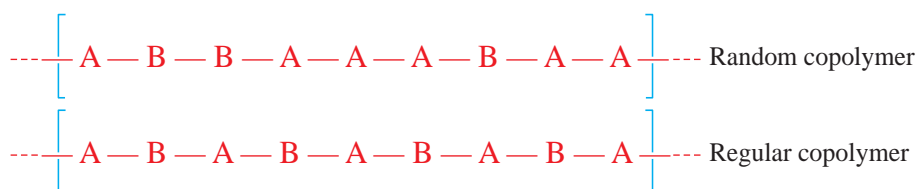
Assume that 2000 students are standing in the school play ground and each student is treated as a monomer unit of polyethylene. The students are asked to hold the hands of each other in a linear fashion. In this way, the students will form a linear chain of polyethylene molecule. Calculate the molecular mass of the polyethylene molecule, using this analogy.

Copolymers are prepared by polymerizing more than one kind of monomer unit. For instance, ethene ($\text{H}_2\text{C}=\text{CH}_2$) and propene ($\text{H}_2\text{C}=\text{CH}-\text{CH}_3$) can be copolymerized to produce a polymer that has two kinds of repeating units:



Copolymers are classified as random or regular, based on the way the monomers are arranged along the polymer chain (Figure 6.1).

Random polymers contain repeating units arranged in a random fashion. Regular polymers contain a sequence of monomers in regular alternating repeating units.



where, **A** and **B** represent monomer units.

Figure 6.1 Random and regular copolymers.

On the basis of their source, polymers are classified as synthetic and natural. Natural polymers, as their name indicates, are found in nature. For example, proteins, carbohydrates, nucleic acids and natural rubber are natural polymers. You will study them in the last section of this unit.

Synthetic polymers are man-made polymers. Most synthetic polymers are organic compounds. Some of the examples are nylon, polyester (Dacron), Teflon, Bakelite, polyethylene, and polyvinyl chloride.

Can you list more examples of synthetic and natural polymers?

Exercise 6.1

- Define each of the following terms:

a monomer	d copolymer
b polymer	e natural polymer
c homopolymer	f synthetic polymer
- List examples of natural and synthetic polymers in daily life.
- Classify each of the following polymers as natural or synthetic:

a wool	f polyvinyl chloride
b dacron	g bakelite
c insulin	h glycogen
d teflon	i DNA
e cellulose	
- Draw the structure of the copolymer of:
 $\text{HO}-\text{CH}_2\text{CH}_2-\text{OH}$ and $\text{HOOC}-\text{CH}_2\text{CH}_2-\text{COOH}$.

6.2 POLYMERIZATION

After completing this subunit, you will be able to:

- explain polymerization;
- mention the two types of polymerization;
- explain how addition polymerization takes place; and
- explain how condensation polymerization takes place.

Polymerization is the process by which monomer units combine together to form polymers. Polymerization can be carried out either through addition polymerization or condensation polymerization.

Activity 6.2



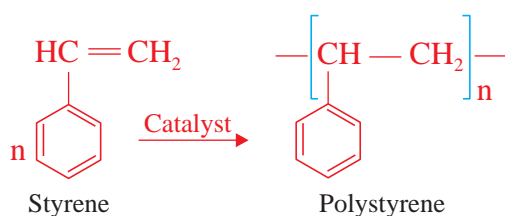
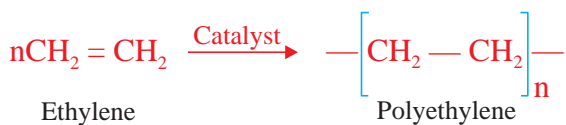
Perform the following activity. Then, share your ideas with the rest of the class.

- Distinguish between addition and condensation reactions.
- Prepare list of monomers used in polymerization and have a look at their structures and functional groups. Explain their special features that allow them to form large molecules.

6.2.1 Addition Polymerization

Addition polymerization requires a large number of monomer molecules which can be polymerized by addition reactions. This type of polymerization is also known as **chain-growth polymerization**.

For example, the addition polymerization of many ethylene molecules yields polyethylene and that of styrene molecules gives polystyrene.



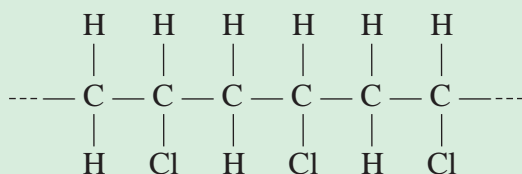
Note that the molecular formula of a polymer is n times that of the monomer and upon polymerization, the double bond is converted to a single bond.



Note also that, if a polymer is given, you can identify the monomer unit that is repeated in it.

Example 6.1

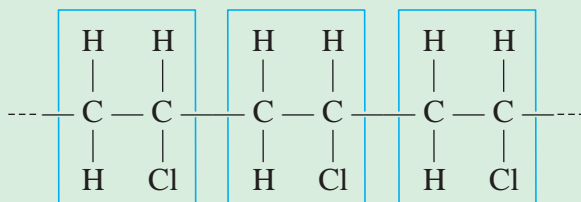
The addition polymer polyvinyl chloride (PVC) has the structure



- Draw the structure of the monomer from which PVC is made.
- How many monomer units are in a PVC polymer that has a molar mass of 1.33×10^5 g/mol?

Solution:

- We need to find the repeating unit from which this polymer chain is constructed



The repeating unit is $\begin{array}{c} \text{H} & \text{H} \\ | & | \\ \text{---C} & \text{---C} \text{---} \\ | & | \\ \text{H} & \text{Cl} \end{array}$, and the monomer has carbon-carbon double bond.

- b To find the number of monomer units, we have to divide the molar mass of the polymer (PVC) by the molar mass of monomer.

The molar mass of the monomer CH_2CHCl is calculated as follows:

$$\text{Number of monomer units} = \frac{\text{Molar mass of the polymer}}{\text{Molar mass of the monomer}}$$

$$= \frac{1.33 \times 10^5 \text{ g/mol}}{62.5 \text{ g/mol}} = 2128$$

$$\text{C} = 12 \times 2 = 24$$

$$\text{H} = 1 \times 3 = 3$$

$$\text{Cl} = 35.5 \times 1 = 35.5 = 62.5 \text{ g/mol}$$

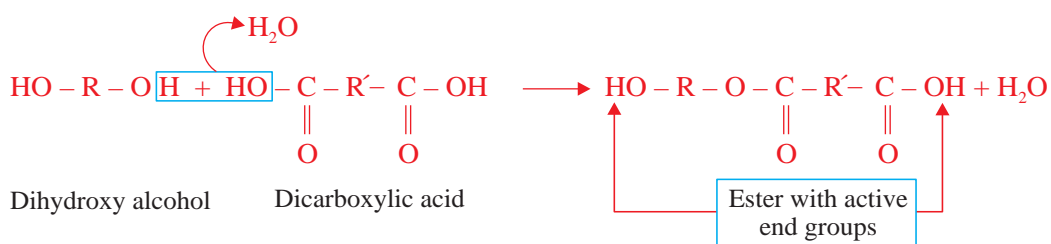
Which means that 2128 vinyl chloride molecules combine to form the polymer.

6.2.2 Condensation Polymerization

Condensation polymerization involves the combination of monomer molecules, with the elimination of simple molecules like water. This polymerization is also known as step growth polymerization. In order to produce a condensation polymer, the monomers involved must have two or more functional groups.

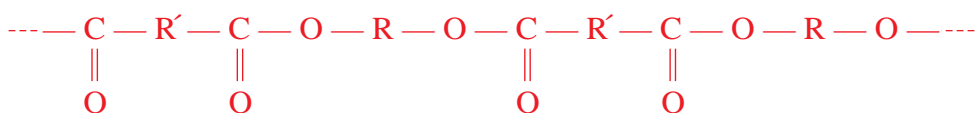
Can you give examples of condensation polymers?

Consider what happens when an alcohol with two $-\text{OH}$ groups, $\text{HO}-\text{R}-\text{OH}$, reacts with a dicarboxylic acid, $\text{HOOC}-\text{R}'-\text{COOH}$. In this case the ester formed still has a reactive group at both ends of the molecule.



The COOH group at one end of the ester molecule can react with another alcohol molecule. This process can continue, leading eventually to a long-chain polymer containing large number of ester groups.

The general structure of the polyester can be represented as



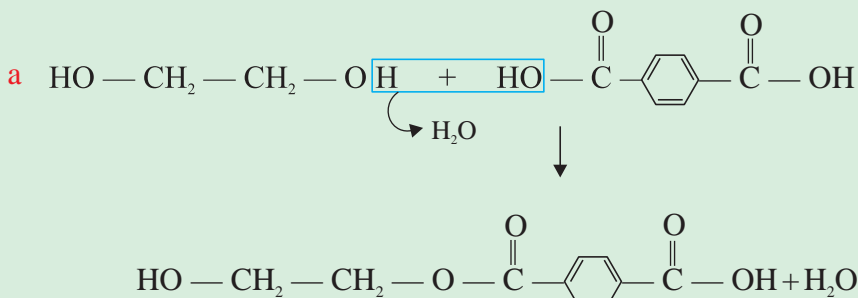
Section of the polyester

Example 6.2

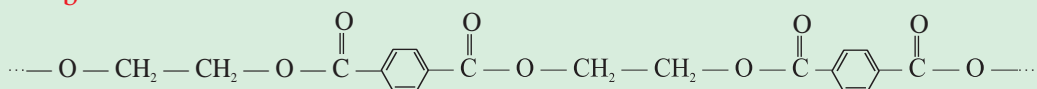
Polyethylene terephthalate or Dacron is prepared from ethylene glycol (HO-CH₂-CH₂-OH) and terephthalic acid.

- Write the structural formula of the ester that formed when one molecule of ethylene glycol reacts with one molecule of terephthalic acid.
- Draw a section of polyethylene terephthalate.

Solution :

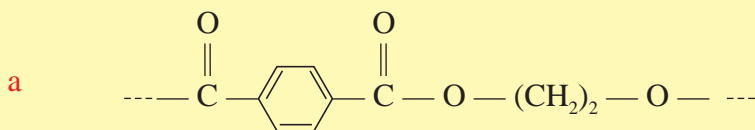


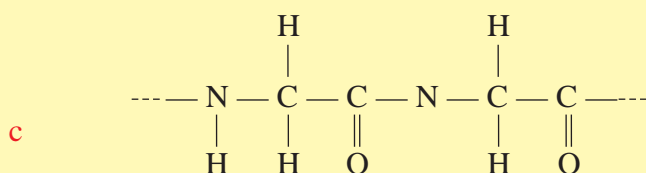
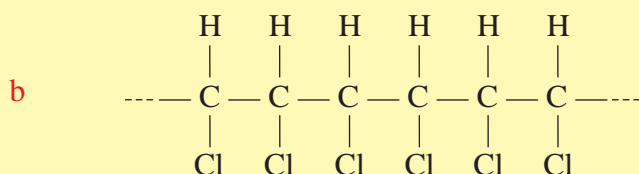
b



Exercise 6.2

- Draw the structures of the monomers that would be used to make the following polymers.





2. Consider a polymer made from tetrachloroethylene.
- Draw a portion of the polymer chain.
 - What is the molar mass of the polymer if it contains 3.2×10^3 tetrachloroethylene?
 - Calculate the percentage of C and Cl in the polymer?

6.3 SYNTHETIC POLYMERS

After completing this subunit, you will be able to:

- give examples of addition polymers;
- tell the monomers of each of the given addition polymers;
- explain common uses of addition polymers;
- give examples of condensation polymers;
- tell the monomers of each of the given condensation polymers;
- explain the uses of these condensation polymers: nylon, polyester and Bakelite;
- describe thermoplastics and thermosetting polymers; and
- give examples of thermoplastics and thermosetting polymers.

During the 1800s, scientists began to chemically modify natural polymers to produce new substances. The first semi-synthetic polymer produced was Bakelite in 1909. You will study the preparation and uses of Bakelite in this subunit. In 1911, Bakelite was followed by rayon, the first synthetic fiber. Despite these important developments, it was not until World War II that significant changes took place in the polymer industry. Since then, the polymer industry has continued to evolve as one of the fastest growing industries in the world.

6.3.1 Addition Polymers

Activity 6.3



Form a group and discuss each of the following questions:

1. What problems do you think are arising with the rapid development of synthetic polymers?
2. What necessary steps should be taken to protect the environment from synthetic polymers?

After the discussion, share your ideas with the rest of the class.

Discuss the following question in a group:

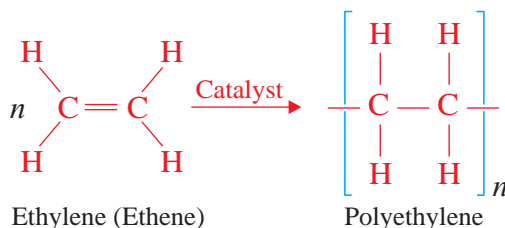
Usually ethene is obtained from petroleum by cracking. An alternative source of ethene is to make it from ethanol, which is obtained by fermentation. Why do you think that this is a feasible alternative in Ethiopia at the moment? Write an equation to show the synthesis of ethene from ethanol.

After the discussion, share your ideas with the rest of the class.

Polyethylene

Have you observed polyethylene materials in your surrounding?

Polyethylene is a polymer made by the addition polymerization of ethylene.



where, **n** is a very large number.

Polyethylene has no taste or odour and is lightweight, nontoxic and relatively cheap. Some of its primary uses are in making squeeze bottles, plastic wrapping, garment bags, trash bags and electrical insulation.



Polyethylene trash bags



Squeeze bottle (wash bottle)

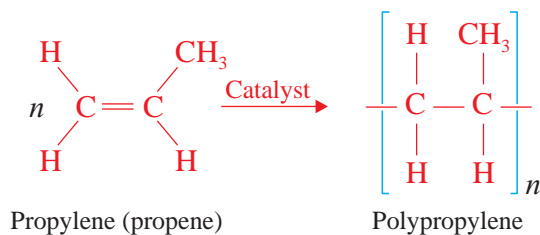


Polyethylene tube

Figure 6.2 Some polyethylene materials.

Polypropylene

The monomer of polypropylene is propylene (propene). It is produced by the addition polymerization of propylene.



Polypropylene is stronger than polyethylene. It is used for making food containers that can safely be washed in a dishwasher. It can also be used for making ropes, fishing nets, carpets, and bottles.



Polypropylene rope



Polypropylene carpet



Polypropylene bottles

Figure 6.3 Some polypropylene products.

Polyvinyl Chloride (PVC)

Activity 6.4



Form a group. Discuss the following questions. After the discussion, share your ideas with other groups.

1. Draw the structure of vinyl chloride.
2. Write a chemical equation that shows the preparation of vinyl chloride from acetylene and hydrogen chloride.
3. Write a chemical equation that indicates the polymerization of vinyl chloride to polyvinyl chloride.

Polyvinyl chloride is the third most widely produced plastic, after polyethylene and polypropylene. It is commonly used for making pipes, leather-like materials, shoes, raincoats, aprons, wallpaper, floor tile, and phonograph records.



PVC pipes



PVC floor tile

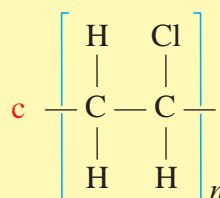
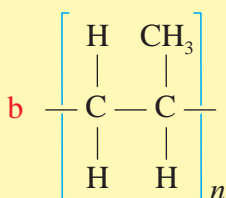
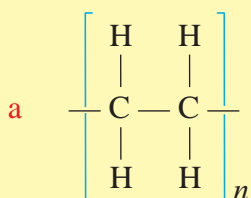


PVC raincoat

Figure 6.4 Some polyvinyl chloride products.

Exercise 6.3

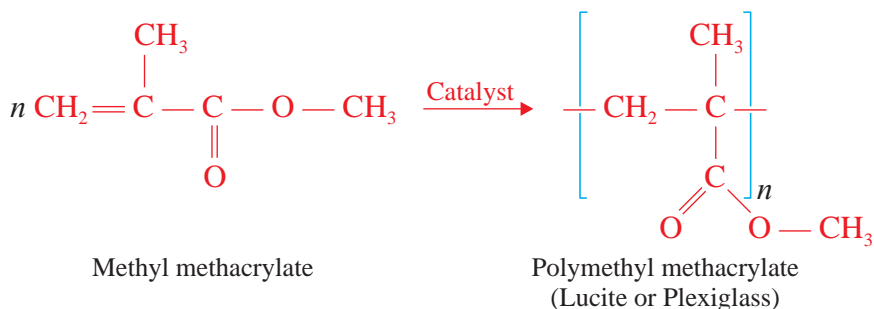
- Write the molecular formula and structure of monomers of each of the following polymers.



- Describe major uses of:
 - polyethylene
 - polypropylene
 - polyvinyl chloride
- Make a list of materials in your home made of PVC.
- What is the basic structural difference between low density polyethylene (LDPE) and high density polyethylene (HDPE)?

Polymethyl methacrylate (Perspex)

Polymethyl methacrylate, PMMA, is sold under the trade name Lucite or plexiglass. It is prepared by the polymerization of methyl methacrylate.

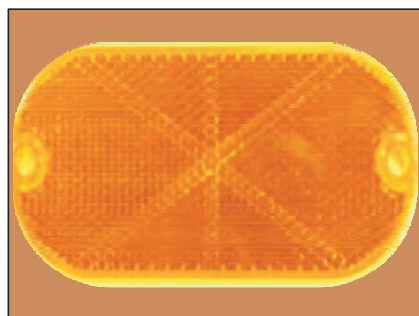


Note that acrylic acid is the common name of 2-propenoic acid, $\text{CH}_2=\text{CHCOOH}$

PMMA is a lightweight glass-like polymer used as a glass substitute for example, in airplane windows and streetlights.



PMMA as airplane window

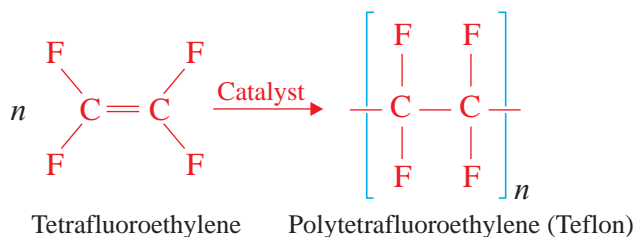


PMMA as reflector in streetlight

Figure 6.5 Some polymethyl methacrylate materials.

Polytetrafluoroethylene, PTFE, Teflon

Teflon is prepared by the addition polymerization of tetrafluoroethylene.



Teflon has good resistance to chemical attack, and it can be used at any temperature between -73°C and 260°C with no effect on its properties. It also has a very low

coefficient of friction, which makes it waxy or slippery to touch. As a result, it is particularly suited to applications in food preparation. For example, bread dough does not stick to a Teflon-coated surface. Teflon is used for coating cooking utensils and for making electrical insulation.



Teflon coated dish



Teflon tape

Figure 6.6 Some Teflon materials.

Polystyrene

Activity 6.5



Make a list of some materials made of polystyrene. Discuss with your classmates, the physical and chemical behaviour of polystyrene and PVC.

Polystyrene is produced by the addition polymerization of styrene. It is one of the most widely used polymers. For example, it is used for making packing materials especially for impact-absorbent. Its other uses include preparing CD and DVD cases, toys, flowerpots and architectural models.



Polystyrene used for packing a cup



Polystyrene CD case



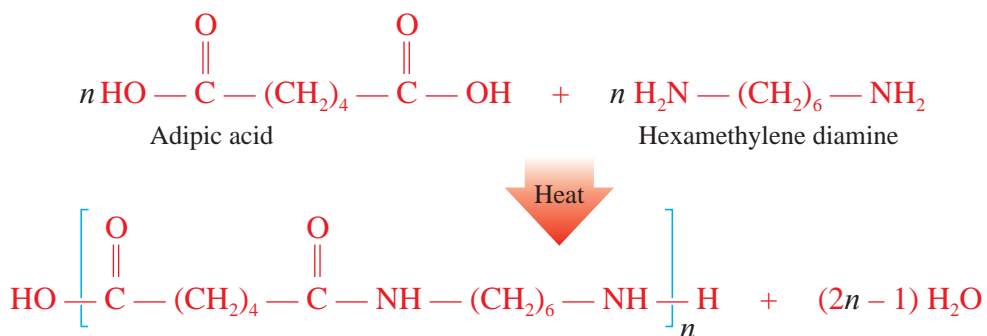
Architectural model of building, using Styrene

Figure 6.7 Some Polystyrene Materials.

6.3.2 Condensation Polymers

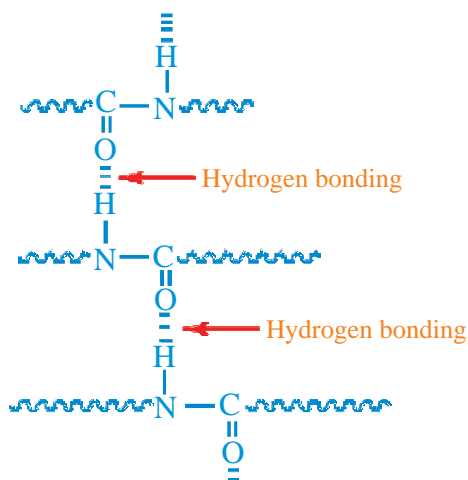
Nylons

Nylons are polyamides. They can be produced by the condensation reaction of diacids and diamines. One of the most common polyamides is nylon 66. It is a copolymer and is prepared by the condensation of 1,6-diaminohexane (hexamethylene diamine) and 1,6-hexanedioic acid (adipic acid). The basic amine reacts with the acid to form a salt. Heating removes water and forms the amide bonds.



Nylon 66 (the numbers indicate there are six carbon atoms each in hexamethylene diamine and adipic acid).

There are hydrogen bondings between the polymer chains.



Uses of nylon include making parachutes, ropes, clothes, stockings, hair combs, and rugs. They are also used to reinforce automobiles tires.



Nylon cloth



Nylon rug

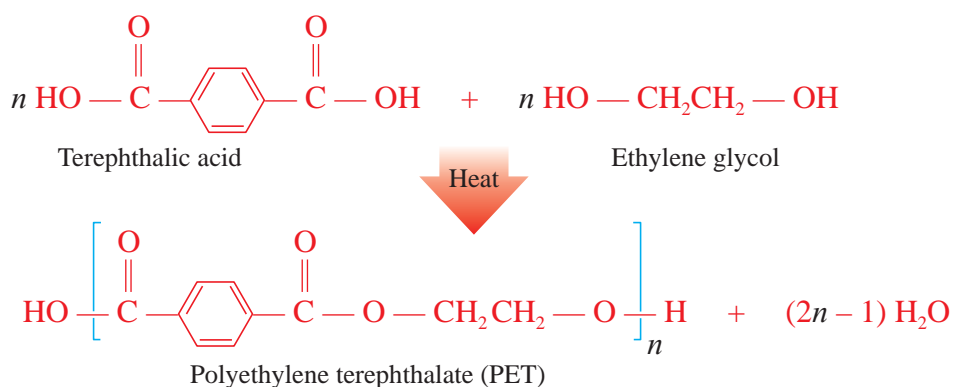


Stockings

Figure 6.8 Some nylon materials.

Polyester (Polyethylene terephthalate or Dacron)

Dacron is a copolymer and is formed when equimolar amounts of 1, 4-benzene dicarboxylic acid (terephthalic acid) and 1, 2-ethanediol (ethylene glycol) react.



Dacron is a strong and impact resistant. It is colourless and has high transparency. It is mainly used for synthetic fibers. Mixing it with various amounts of cotton gives fabrics that are durable, easily dyed and crease-resistant. It is also used for making bottles and packaging materials.



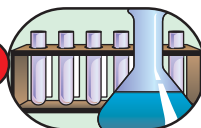
Dacron cloth (Polyester)



Dacron wrap

Figure 6.9 Some Dacron materials.

Experiment 6.1



Synthesis of Nylon

Objective: To prepare nylon and study its properties.

Apparatus and Chemicals: 250 ml beakers, dropping funnel, glass rod, forceps or copper wire hooks, 0.5 M basic solution of hexamethylenediamine, 0.5 M NaOH solution and adipoyl chloride.

Caution: Wear gloves while doing this experiment.

Procedure:

1. Place 5 mL of Solution A in a small beaker.

Solution A: Prepare a 0.5 M basic solution of hexamethylenediamine (or 2,6 – diaminohexane, $\text{H}_2\text{N}(\text{CH}_2)_6(\text{NH}_2)$) as follows: weigh 6 g of hexamethylene diamine in a large beaker and dilute to 100 mL with 0.5 M NaOH solution.

2. Place 5 mL of Solution B in a second beaker.

Solution B: Weigh 5 g of adipoyl chloride and dissolve in 100 mL of cyclohexane.

3. Slowly add **solution B** to **solution A** using dropping funnel, pouring it down the side of the slanted beaker. Do not stir the mixture of solution A and solution B.
4. Nylon will form at the interface of the two solutions.
5. Draw a thread out of the interface using a forceps or a copper wire hook, and draw the thread out of the beaker using glass rod as a pool and slowly windup the thread as you draw it out.
6. After nylon has been collected, wash it thoroughly with water, dry it superficially with towel then let it dry.

Results and discussion

1. Why the two solutions are not able to mix?
2. Why is adipoyl chloride used instead of adipic acid?

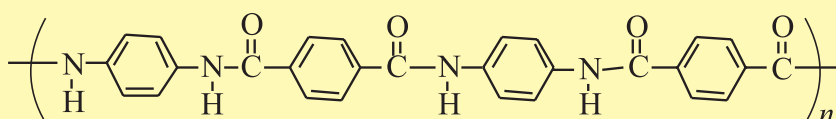
Exercise 6.4

- Write the structure of the following polymers and also indicate the monomer units involved in the formation of these polymers.

a Nylon 66

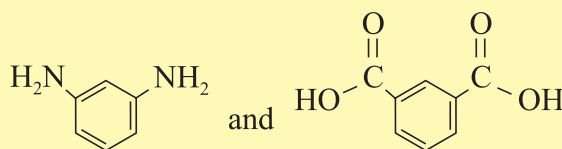
b Dacron

- Describe the major uses of nylons and polyethylene terephthalate.
- Kevlar is used in bulletproof vests. The structure of Kevlar is:



Which monomers are used to make Kevlar?

- Nomex is used in fire-resistant clothing. It is a copolymer of:



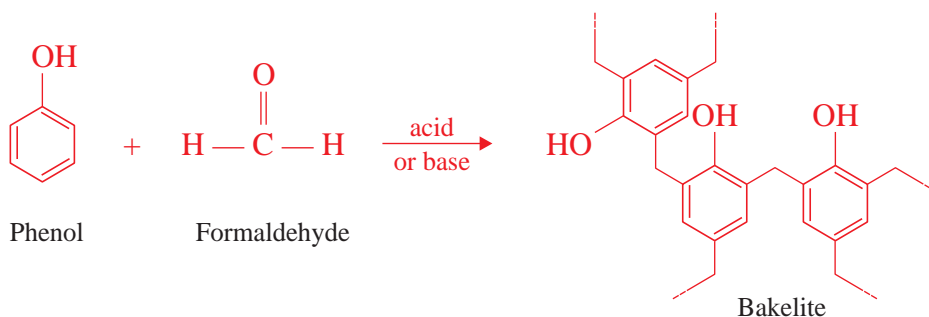
draw the structure of the Nomex polymer.

- How do Kevlar and Nomex differ in their structure?

Bakelite

The monomers of Bakelite are phenol and formaldehyde. The reaction between phenol and formaldehyde is not a simple reaction. The reaction takes place in the presence of an acid or a base as a catalyst.

The chemical representation of the reaction is:



Bakelite has been used for making rotary-dial telephones, whistles, billiard balls, dominos, chess, checkers, porcelain etc.



Bakelite chess pieces



Bakelite phone



Bakelite purses

Figure 6.10 Bakelite products.

Thermoplastics and Thermosetting Polymers

What is the basic difference between thermoplastics and thermosetting polymers?

Based on their response to heat, polymers can be divided into two groups: **thermoplastics** and **thermosetting** plastics.

Thermoplastics soften on heating and can be moulded into different shapes. They become hard on cooling. The process of heating and cooling can be repeated many times without causing any change in their properties. For example, polyethylene, polypropylene, polyvinyl chloride, Teflon, polymethyl methacrylate, nylon and polyester (Dacron) are thermoplastics.

Thermosetting plastics can be moulded into different shapes by heating and they become hard when cooled. However, once solidified and set they cannot be softened or remoulded by heating. For example, Bakelite is a thermosetting plastic.

What makes this difference?

Thermoplastics consist of linear or slightly branched molecules which do not chemically bond with each other when heated. Instead, the polymer molecules are held together by weak **Van der Waals** forces. In contrast, thermosetting plastics consist of chain molecules that chemically bond, or cross-link, with each other when heated.

Which forces are stronger, Van der Waals forces or covalent bonds? Why?

Thermoplastic materials can be recycled, whereas thermosetting cannot.

What are the advantages of recycling?

Table 6.1 Difference between thermoplastics and thermosetting plastics.

Thermoplastics	Thermosetting plastics
<ul style="list-style-type: none"> • On heating, they do not soften and can be reshaped and reused several times. • They are generally long chain linear polymers. • They are generally weak, soft and less brittle. • They can be recycled. 	<ul style="list-style-type: none"> • On heating, they soften readily and once shaped cannot be remoulded again. • They have three dimensional cross-linked structure • Thermosetting plastics are hard, strong, and brittle • They cannot be recycled.

Exercise 6.5

1. What are the monomers of Bakelite?
2. Write the major uses of Bakelite.
3. Explain the difference between thermoplastics and thermosetting polymers, using examples.
4. What makes thermoplastic materials recyclable, whereas thermosetting ones are not?

Impacts of Synthetic Polymers on Environment

Activity 6.6



1. Collect some discarded plastic materials and identify the materials of which these items are made. Discuss the impact of these materials on the environment. Share your ideas with the rest of your classmates.
2. What should be done to alleviate the problems caused by plastics?



It is common to use plastic bags to carry materials that we buy from supermarkets or shops.

If you discarded plastic materials to the environment, what problems would they cause to the environment?

Synthetic polymers or plastics are extensively used throughout the world. Although they are very important for humans, there are many environmental concerns about their use. Study of fields like environmental science and environmental chemistry are mainly concerned with protecting the environment.

The production of plastic produces substantial amounts of toxic chemicals (e.g. ethylene oxide, benzene and xylenes) to air and water. Many of the toxic chemicals released in plastic production can cause cancer and birth defects and damage the nervous system, blood, kidneys and immune systems. These chemicals can also cause serious damage to environment.

Direct disposal (littering or dumping) and incineration (burning) of these wastes is a common practice. Each is harmful to the health of people and the environment. For example, dumping plastic wastes in urban drainage systems pollutes water courses and causes flooding. When these water bodies are contaminated, they carry disease into the household. The burning of plastics encourages airborne pollution, the majority of which is extremely toxic and can cause a host of health problems (cancer, asthma, etc.). Although landfilling and recycling reduce the waste problem, each has considerably negative consequences: landfills leak and often contaminate the ground water with toxic liquids and residues. Recycling of plastic is associated with skin and respiratory problems, resulting from exposure to and inhalation of toxic fumes, especially hydrocarbons and residues released during the process.

One of the features that we value in plastics, their durability, is also a problem for us. When plastics are disposed into the environment, they remain there for a very long time, degrading very slowly, and continue to pollute our environment.



Figure 6.11 Plastics discarded to the environment.

Exercise 6.6

1. What are the major problems caused by plastics?
2. Is there any relationship between durability of plastics and pollution? Explain your answer.

6.4 NATURAL POLYMERS

After completing this subunit, you will be able to:

- give examples of addition polymers;
- describe natural rubber;
- tell the monomer of natural rubber;
- explain vulcanization;

- explain the use of natural rubber;
- give three examples of synthetic rubber;
- explain the uses of synthetic rubbers;
- compare and contrast synthetic and natural rubber;
- define the term carbohydrate;
- describe monosaccharide;
- draw the structures of monosaccharides;
- give examples of monosaccharides and disaccharides;
- describe disaccharides;
- draw the structures of disaccharides;
- describe polysaccharides;
- draw the structure of starch and cellulose;
- explain the difference between starch, glycogen and cellulose;
- define the terms amino acid, peptide and protein;
- describe the structure of amino acids;
- explain how proteins are formed; and
- list types of proteins.

Natural polymers are found in nature. They are mainly produced by plants and animals.

Activity 6.7



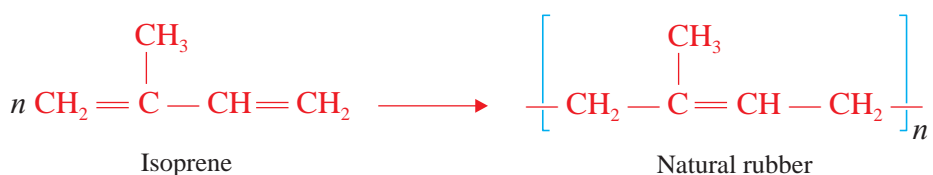
Prepare a list of natural polymers found in the environment and in human body. Classify them as condensation polymer or addition polymer. Then, share your ideas with your classmates.

Note that most synthetic polymers have been made only since 1909. However, natural polymers appeared on the earth about a million years ago. In addition, the number of

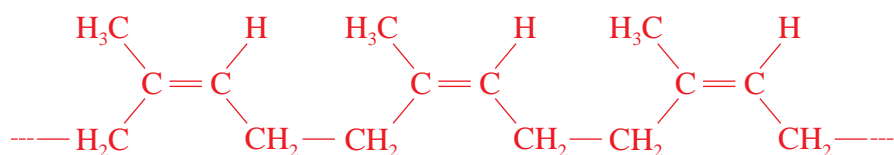
natural polymers is almost constant, but number of new synthetic polymers is growing very fast.

6.4.1 Natural Rubber

Natural rubber is obtained from rubber tree. The monomer of natural rubber is isoprene or 2-methyl-1,3-butadiene.



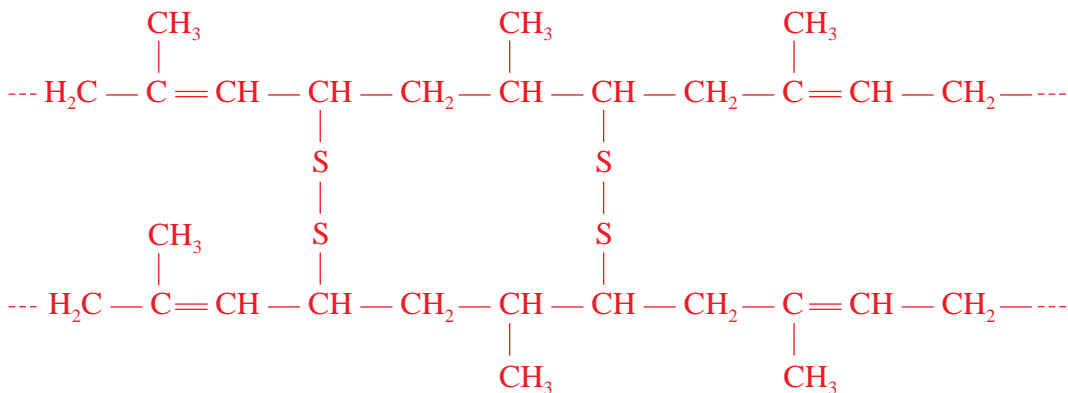
Since isoprene has two double bonds, it retains one of the double bonds after polymerization reaction. Natural rubber has the cis-configuration of methyl groups.



Rubber is an example of elastomer type of polymer, in which the polymer can return to its original shape after being stretched. Natural rubber is a soft and sticky solid.

Rubber softens in hot weather and gets hard in cold weather. It is soluble in organic solvents such as carbon disulfide, petrol, ether and so on.

The properties of natural rubber are improved by introducing cross linkages between its polymer chains. This can be achieved by heating natural rubber with sulphur. This process is known as vulcanization. Vulcanization establishes cross-links between linear polymer chains.



Vulcanized rubber has the following properties.

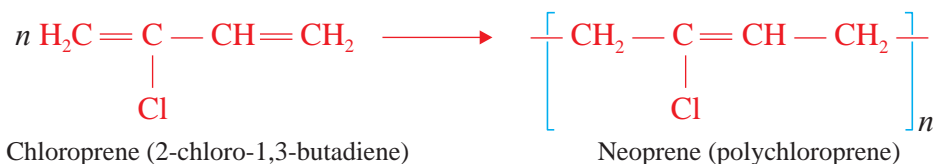
- * It is hard and nonsticky.
- * It has higher elasticity, which occurs over a higher range of temperature.
- * It has high tensile strength.
- * It is insoluble in solvents.
- * It is not oxidized readily .

6.4.2 Synthetic Rubber

Synthetic rubber is produced either by the polymerization of conjugated dienes in the presence of a catalyst or by copolymerization of conjugated dienes with other olefinic compounds.

Neoprene

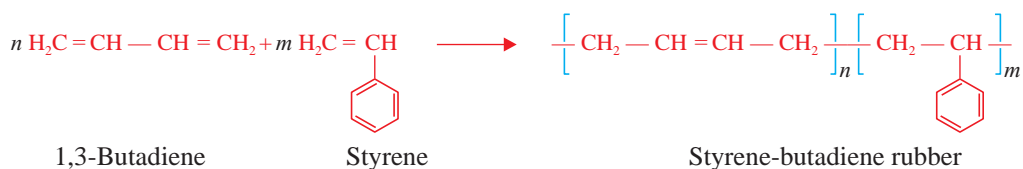
Neoprene is a polymer of 2-chloro-1,3-butadiene and is obtained by addition polymerization.



Neoprene is a linear thermoplastic polymer. Because of its resistance to chemicals, it is used for making hoses for chemicals, petrols, and oils.

Styrene Butadiene Rubber (SBR)

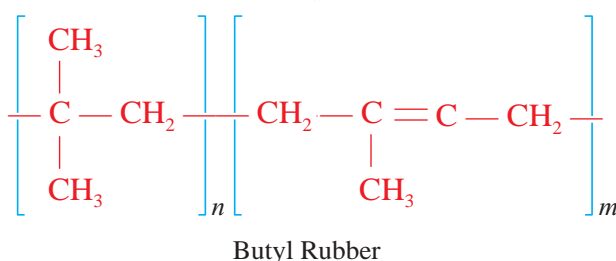
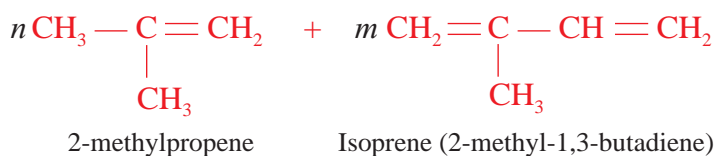
It is a copolymer of styrene with butadiene.



It is vulcanized in a similar manner as natural rubber. This rubber is superior to natural rubber with regard to mechanical strength. Its primary application is in the manufacture of tires and other mechanical goods.

Butyl Rubber

Butyl rubber is a polymer made by the polymerization of 2-methylpropene (isobutylene) with 1-2% of 2-methyl-1,3-butadiene (isoprene).

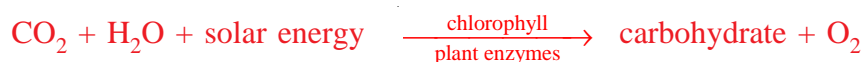


Exercise 6.7

- What are the monomers of
 - natural rubber?
 - neoprene?
 - SBR?
 - butyl rubber?
- What is vulcanization of rubber and how does it affect the properties of rubber?
- What are the major uses of neoprene and SBR ?

6.4.3 Carbohydrates

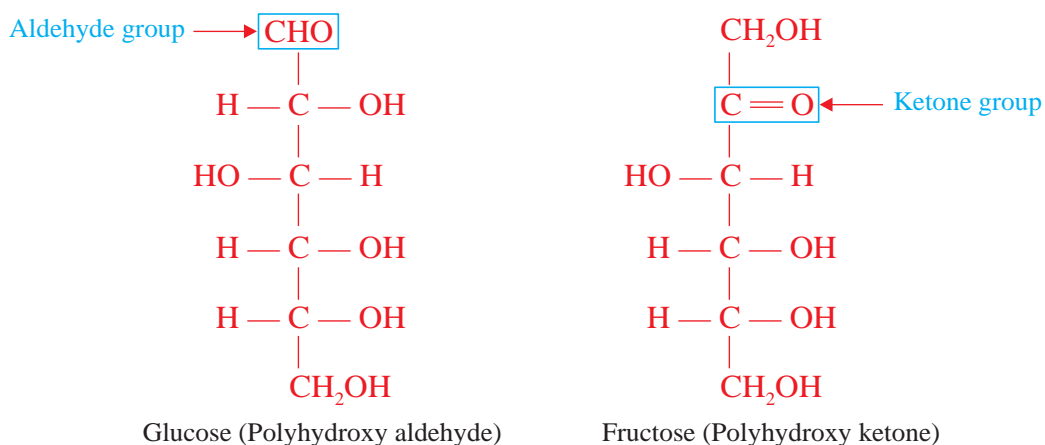
Carbohydrates are compounds that contain carbon, hydrogen and oxygen. Green plants produce carbohydrates by photosynthesis. In this process, carbon dioxide from air and water from the soil are the reactants and sunlight absorbed by chlorophyll is the energy source.



Earlier, carbohydrates that were purified and analysed had molecular formulas that corresponds to $\text{C}_n\text{H}_{2n}\text{O}_n$ or $\text{C}_n(\text{H}_2\text{O})_n$. As a result, they were considered to be "hydrates of carbon" or carbohydrates. However, examination of the structures of

carbohydrates shows that this view is inaccurate. Even though this definition is no more used, the name carbohydrate is still used.

Today, carbohydrates are defined as polyhydroxy aldehydes, polyhydroxy ketones or compounds that yield such substance upon hydrolysis. For example, glucose is a polyhydroxy aldehyde, and fructose is a polyhydroxy ketones.



Carbohydrates are classified on the basis of their acid-catalyzed hydrolysis products as monosaccharide, disaccharides and polysaccharides.

a *Monosaccharides*

Monosaccharides, or simple sugars, are carbohydrates that cannot be hydrolyzed into smaller compounds. Monosaccharides with three to seven carbon atoms are found in nature. A three-carbon monosaccharides is called a triose, and those that contain four, five and six carbon atoms are called tetroses, pentoses, and hexoses, respectively.

Monosaccharides are classified as aldoses and ketoses based on the carbonyl group present.

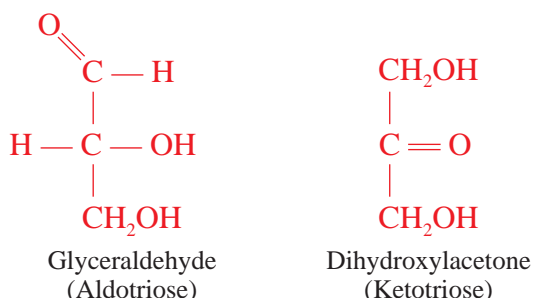
Aldoses are monosaccharides that contain an aldehyde functional group. Ketoses are monosaccharides that contain a ketone functional group.

Monosaccharides are often classified by both their number of carbon atoms and their functional group.

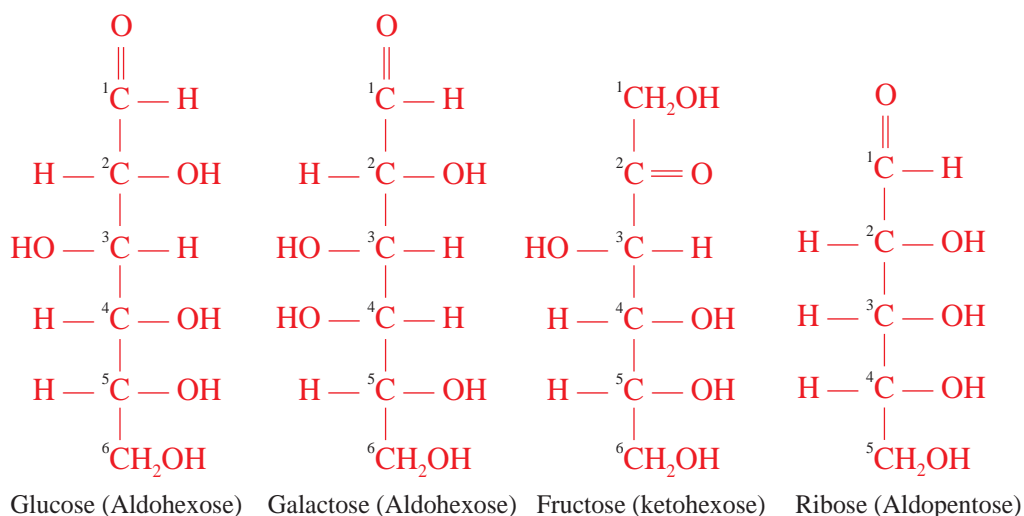
A six-carbon monosaccharide with an aldehyde functional group is an *aldohexose*. A five-carbon monosaccharide with a ketone functional group is a *ketopentose*.

Monosaccharides are also often called sugars. The word sugar is associated with “sweetness” and most monosaccharides have a sweet taste. Both monosaccharides and disaccharides are called sugars.

The simplest aldotriose and ketotriose are glyceraldehyde and dihydroxyacetone.



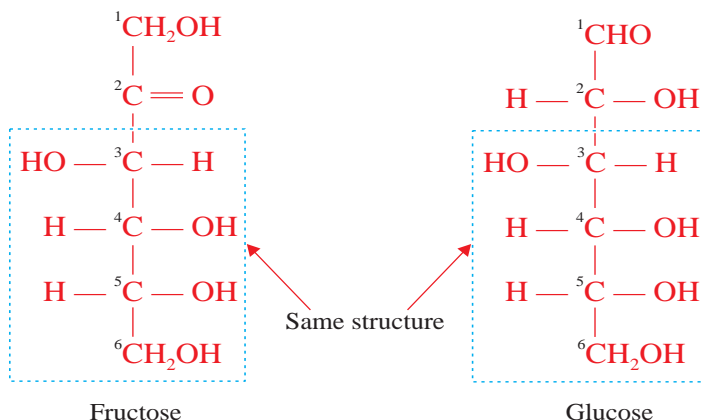
The most common monosaccharides are glucose, galactose, fructose and ribose. Glucose and galactose are aldohexoses, fructose is a ketohexose, and ribose is aldopentose. All four of these monosaccharides are water soluble, white and crystalline solids.



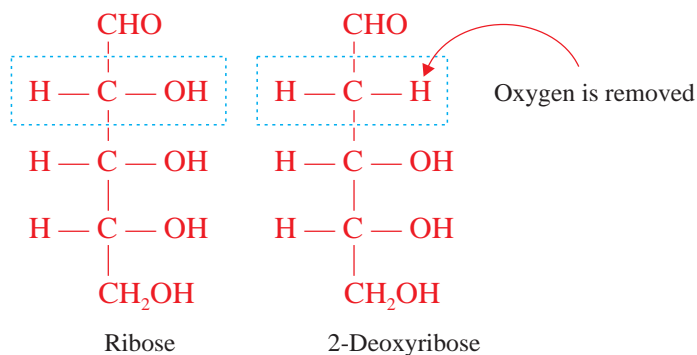
Note that glucose and galactose differ only in the configuration of the $-\text{OH}$ group and $-\text{H}$ group on carbon-4. Glucose is the most abundant monosaccharide in nature. It is called blood sugar because blood contains dissolved glucose. Its concentration in the blood ranges from 70-100 mg per 100 ml of blood. Cells use this glucose as a primary energy source.

In the human body, galactose is synthesized from glucose in the mammary glands for use in lactose (*milk sugar*). Fructose is the sweetest-tasting of all sugars and is found in many fruits. It is also present in honey, in equal amounts with glucose.

From the third to the sixth carbon the structure of fructose is identical to that of glucose. Differences at carbons 1 and 2 are related to the presence of a ketone functional group in fructose and of an aldehyde functional group in glucose.



Ribose is a component of ribonucleic acid (RNA) and adenosine triphosphate (ATP). The compound 2-deoxyribose is a component of deoxyribonucleic acid molecules (DNA). The prefix deoxy indicates that the oxygen at carbon-2 is removed.

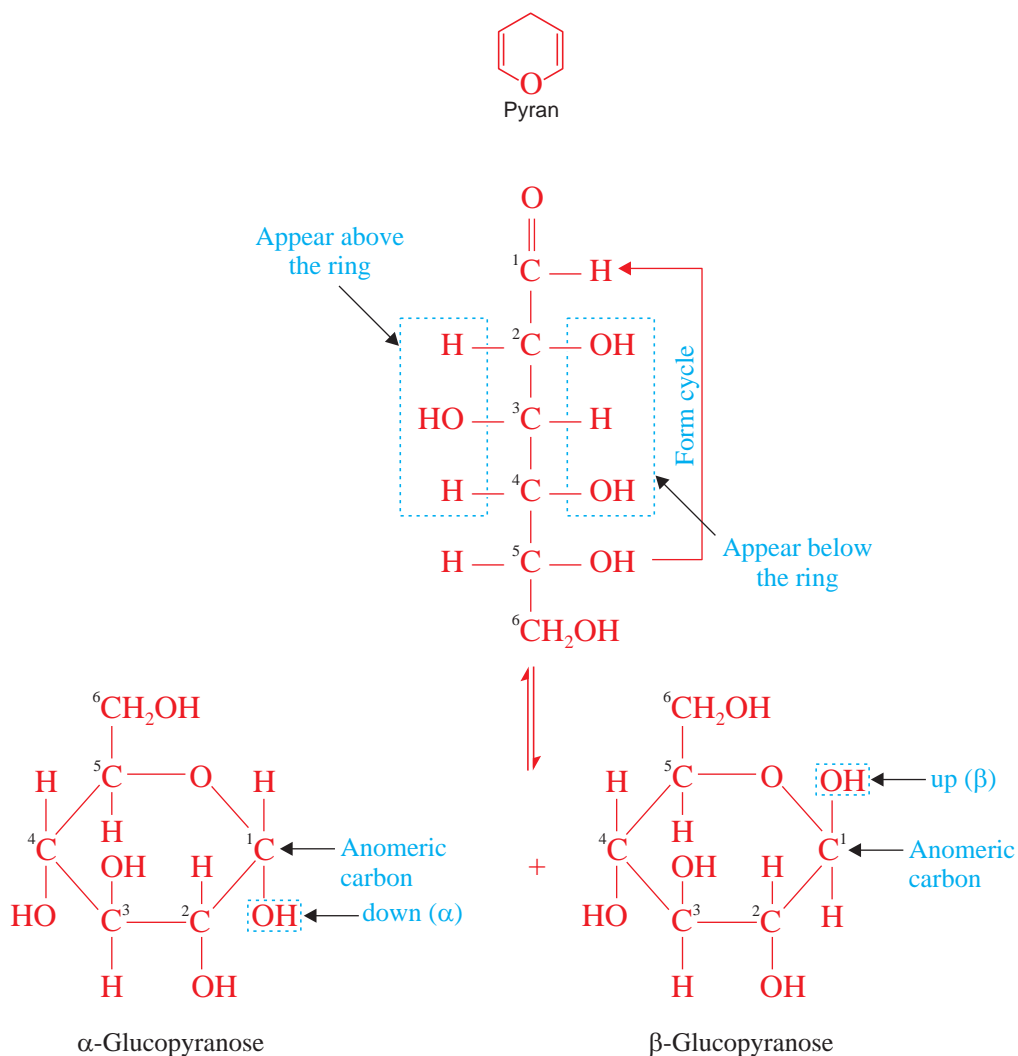


Experimental evidence indicates that, for monosaccharides containing five or more carbon atoms, their open-chain structures are in equilibrium with two cyclic structures and the cyclic structures are the dominant forms at equilibrium. The cyclic forms of monosaccharides result from the ability of their carbonyl group to react intramolecularly (*within the molecule*) with the hydroxyl group. The result is a cyclic hemi-acetal or cyclic hemi-ketal.

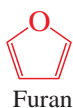
If a six member ring is formed, it is called **pyranose**. The pyranose ring is formed by the reaction of the $-\text{OH}$ group on carbon-5 with the carbonyl group on carbon-1.

Is there any structural similarity between Pyran and Pyranose?

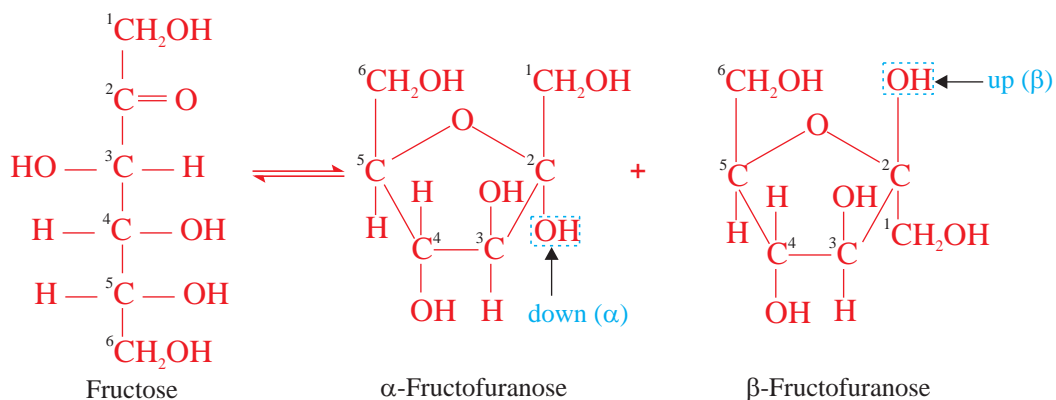
The name pyranose is derived from pyran, which is the name of the six-member heterocyclic ether.



If the -OH attached to anomeric carbon is below the ring or down, we use α and when -OH is above the ring, we use β . Galactose, like glucose, forms a six membered ring, but both fructose and ribose form a five-member ring sugar called **furanose**. This name derived from furan, which is the name of five-member heterocyclic ether.

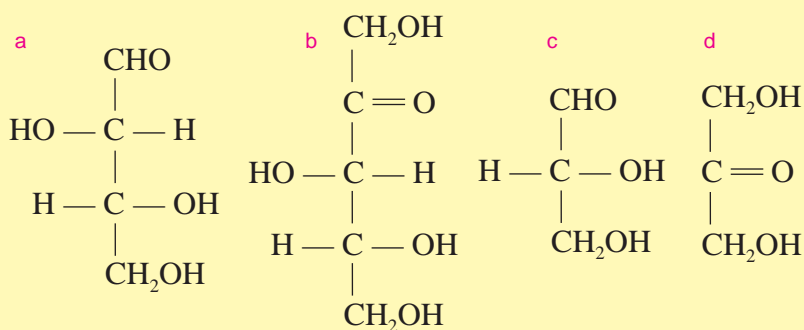


The furanose ring is formed by the reaction of the -OH group on C-5 with the carbonyl group on C-2 .



Exercise 6.8

- Are carbohydrates “hydrates of carbon”? Explain your answer.
- Classify each of the following monosaccharides by its number of carbon atoms and its type of carbonyl group.



- Write the cyclic forms of galactose and ribose.
- Write the molecular formula of ribose, glucose, galactose and fructose.
- What are reducing sugars? Which of the following monosaccharides behave as reducing sugars?

- | | |
|------------|-------------|
| a Glucose | c Galactose |
| b Fructose | d Ribose |

b Disaccharides

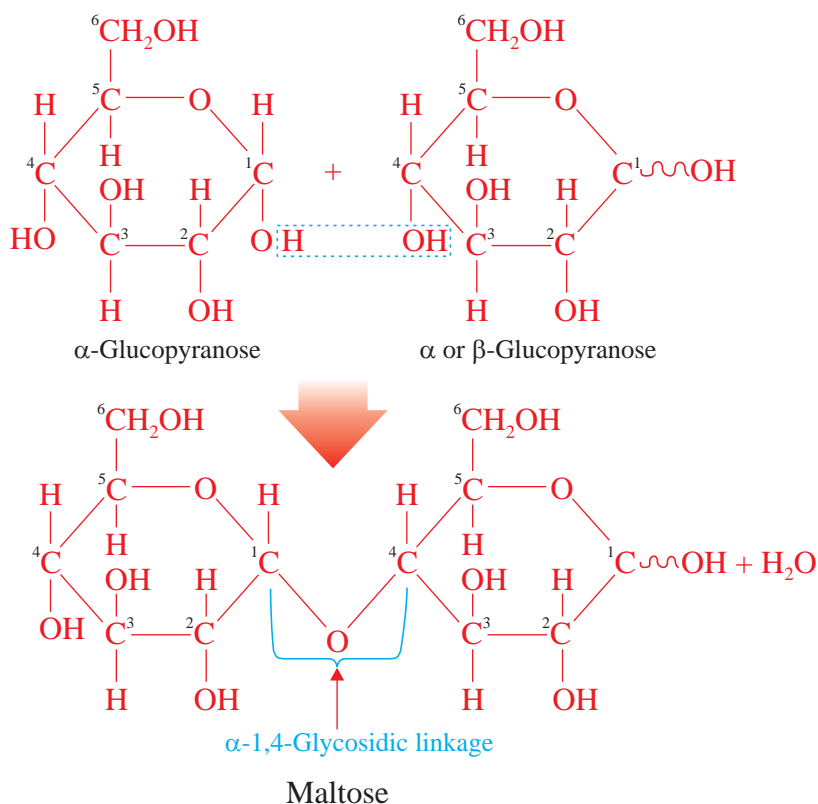
They are dimers made up of two monosaccharide molecules. The monosaccharides may be either the same or different. The monosaccharides are joined by glycosidic linkage between anomeric carbon of one monosaccharide and the $-OH$ group of the other.

The most glycosidic linkage is between the 4-hydroxyl group of one monosaccharide and the α or β position of the anomeric carbon. This kind of linkage is called α -1,4- or β -1,4-glycosidic linkage or bond depending on the configuration at the anomeric carbon atom.

Maltose

Maltose, often called malt sugar, is produced whenever the polysaccharide starch breaks down. This happens when seed germinates in plants and during starch digestion in human beings.

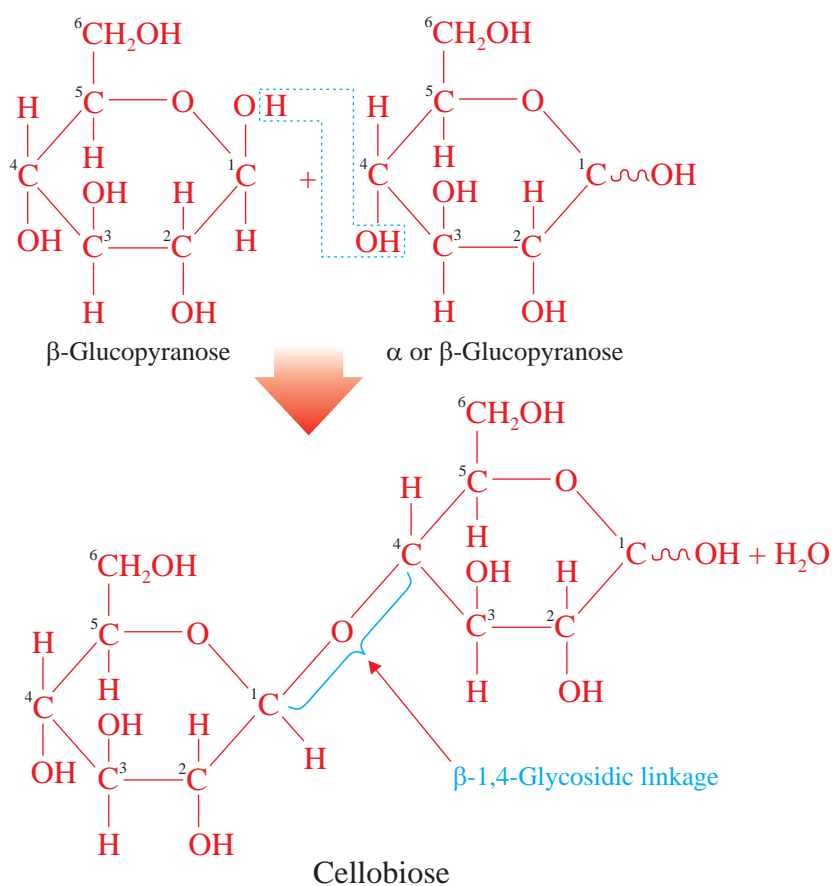
Maltose is made of two glucose units, one of which must be α -glucose and the other can be α or β glucose. Note that since the orientation of OH at carbon-1 is either α or β , we represent it by ($\sim OH$).



The glycosidic linkage between the two glucose units is called an α -1, 4- linkage. The two -OH groups that form the linkage are attached, respectively, to carbon-1 of the first glucose unit (*in the α -configuration*) and to carbon-4 of the second glucose unit.

Cellobiose

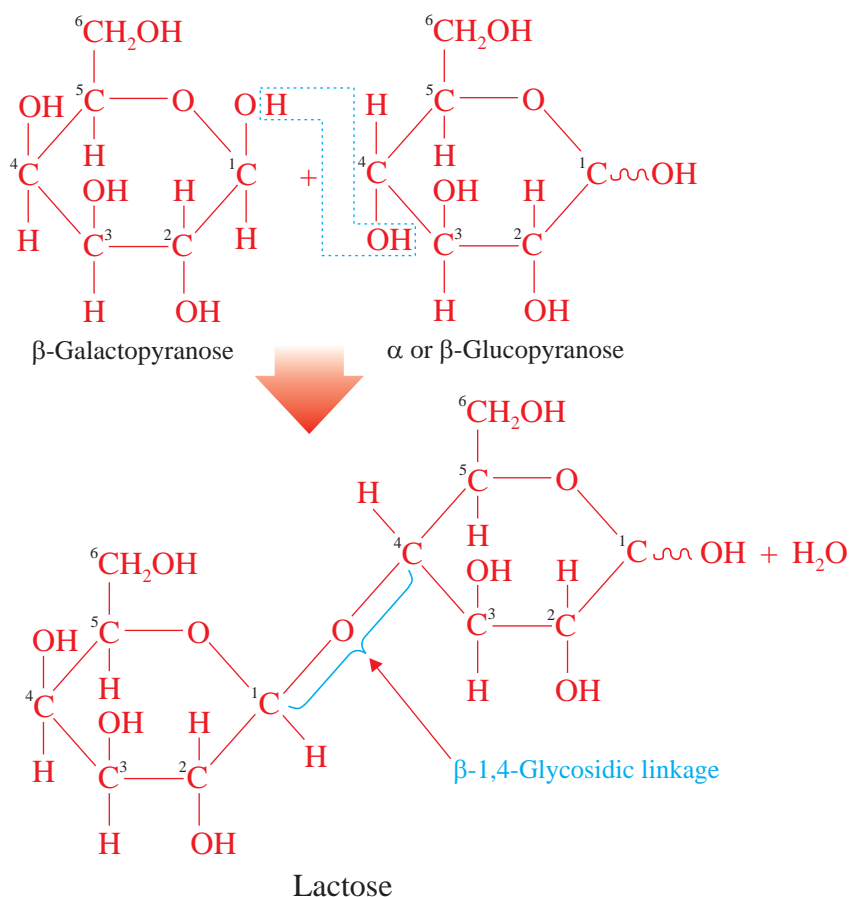
Like maltose, cellobiose contains two glucose units. It differs from maltose in that the glycosidic linkage is β -1,4-linkage.



Maltose and cellobiose have different biological behaviors. Maltase, the enzyme that breaks the glucose-glucose α -1,4-linkage present in maltose, is found both in the human body and yeast. As a result, maltose is digested easily by humans and is readily fermented by yeast. Both the human body and yeast lack the enzyme cellobiase needed to break the glucose-glucose β -1,4-linkage of cellobiose. Therefore, cellobiose cannot be digested by humans or fermented by yeast.

Lactose

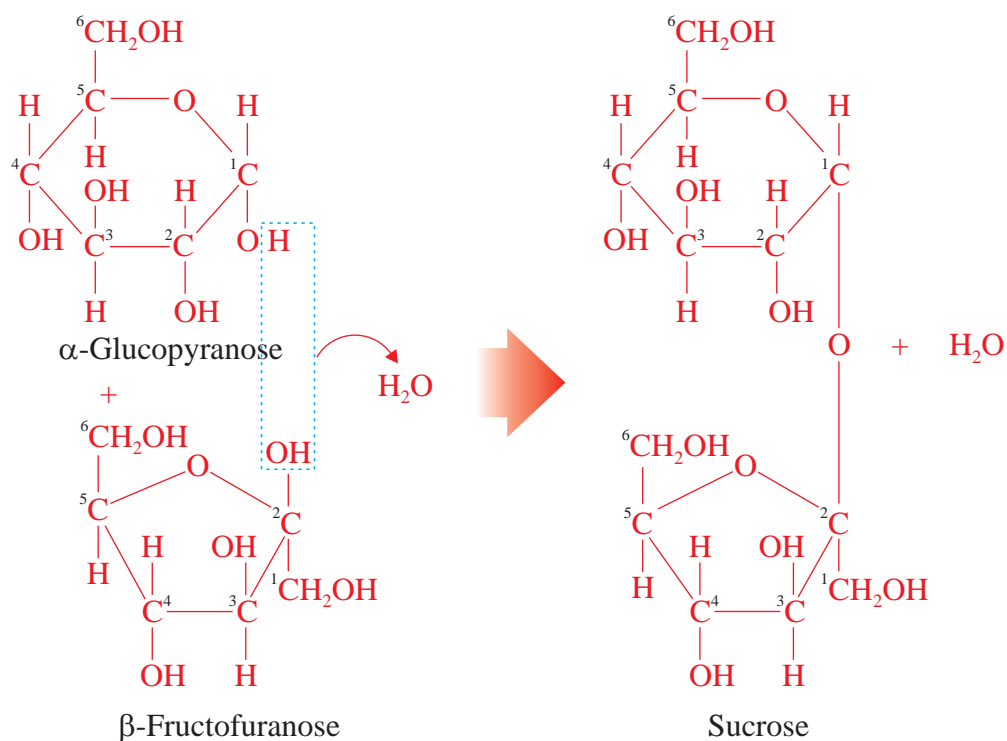
Lactose is made up of a β -galactose unit and an α or β glucose unit joined by a β -1,4-linkage.



Lactose is the major sugar found in milk. The souring of milk is caused by conversion of lactose to lactic acid by bacteria in the milk.

Sucrose

Sucrose, common table sugar, is the most abundant of all the disaccharides. The two monosaccharide units in sucrose molecule are α -glucose and β -fructose. The glycosidic linkage is α , β -1,2-linkage. The $-\text{OH}$ group on carbon-2 of β -fructose reacts with the $-\text{OH}$ group on carbon-1 of α -glucose.



Sucrose is commercially produced from the juice of sugar cane and sugar beets.

Exercise 6.9

- What monosaccharides are produced from the hydrolysis of the following disaccharides?

a sucrose	c lactose
b maltose	d cellobiose
- What type of glycosidic linkage is present in the following disaccharides?

a sucrose	c lactose
b maltose	d cellobiose
- Write the molecular formula of:

a sucrose	c lactose
b maltose	d cellobiose
- In making candy, sucrose is boiled in water with little acid, such as lemon juice.
 - What is the purpose of adding the lemon juice?
 - Why does the product mixture taste sweeter than the starting sucrose solution?

c Polysaccharides

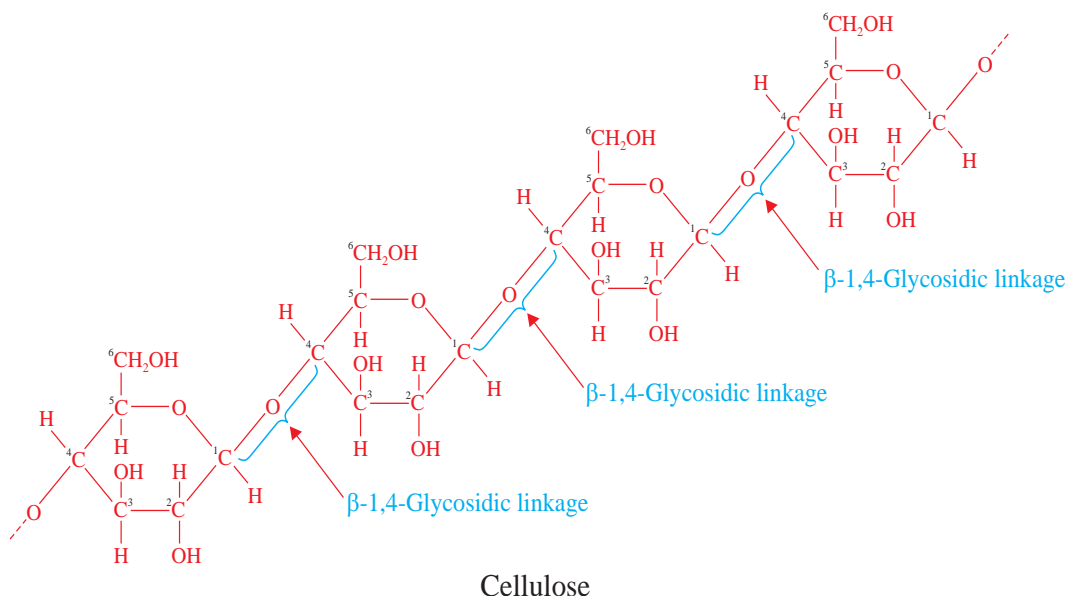
Are polysaccharides condensation polymers or addition polymers?

Polysaccharides are polymers. They consist of a large number of monosaccharide units bonded together by glycosidic bonds. The three important polysaccharides, all made up of glucose units, are cellulose, starch and glycogen.

Are polysaccharides homopolymers or copolymers?

Cellulose

Cellulose is the most abundant polysaccharide. It is the structural component of the cell walls of plants. Structurally, cellulose is a linear (unbranched) glucose polymer in which the glucose units are linked by β -1,4-glycosidic bonds.



Cellulose is not a source of nutrition for humans because humans lack the enzyme cellulase which can hydrolyze the β -1,4-glycosidic bonds and produce free glucose from cellulose.

However, animals such as horses, cows and sheep contain bacteria in their intestine that produce cellulase and produce free glucose from cellulose. Thus, grasses and other plant materials are sources of nutrition for these animals. Cotton is composed of pure cellulose. The cotton fibre forms around the seeds of the cotton plant as indicated in [Figure 6.12](#) and is designed to help carry the seeds long distances on the

wind so that the plant can distribute itself. It is the most widely used natural-fibre for clothing.



Figure 6.12 Cotton.

Activity 6.8



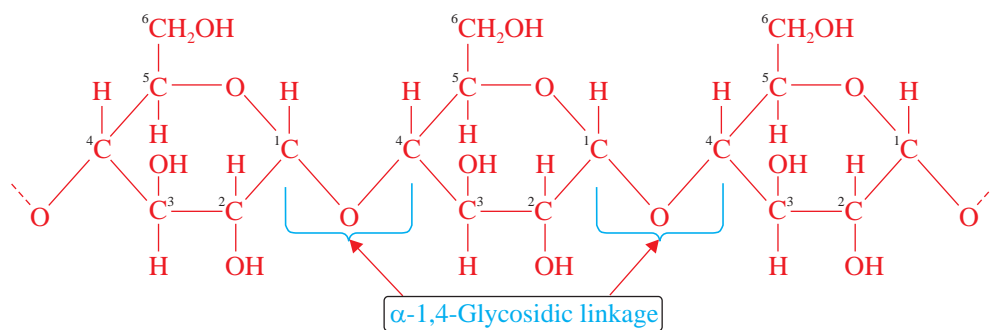
1. Give examples of synthetic fibres used for clothing that were developed on principles learned from carbohydrates.
2. What is the simplest method to differentiate woollen fibre from a cotton fibre?

Starch

Starch is used for energy storage in plants. If excess glucose enters a plant cell, it is converted to starch and stored for later use.

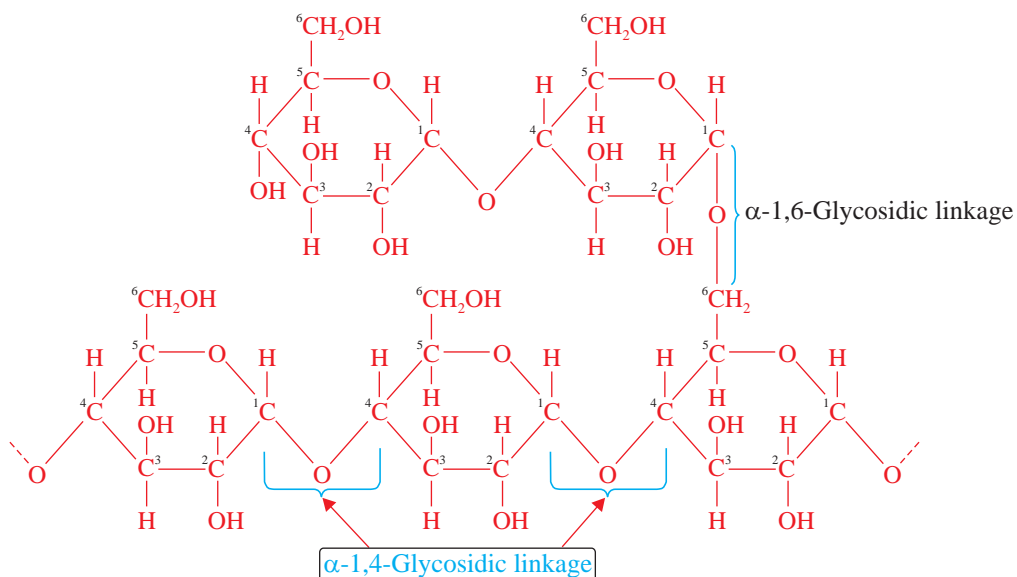
Starch can be separated into two principal polysaccharides, amylose and amylopectin.

Amylose is a straight-chain glucose polymer and accounts for 20-25% of starch. The glucose units in amylose are connected by α -1,4-glycosidic bonds. The number of glucose units present in amylose chain depends on the source of the starch.



Starch (Amylose)

Amylopectin is a highly branched glucose polymer, which accounts for 75-80% of starch. Similar to the case in amylose, all the linkages in amylopectin are α -linkages. A branch occurs in amylopectin about once in every 25-30 glucose units. The branch points involve α -1,6-linkages. Because of the branching, amylopectin has a large average molecular mass than the linear amylose.



Starch (Amylopectin)

Note that all of the glycosidic linkages in starch (*both amylose and amylopectin*) are of the α -type. In amylose, they are all α -1,4-linkages and in amylopectin both α -1,4 and α -1,6-linkages are present.

Glycogen

It is a glucose storage polysaccharide in humans and animals. It is called animal starch. Liver cells and muscle cells are the storage sites for glycogen in humans.

Like amylopectin, glycogen units are joined by α -1,4- and α -1,6-glycosidic bonds. However, glycogen is about three times more highly branched than amylopectin.

When excess glucose is present in the blood, the liver and muscle tissues convert the excess glucose to glycogen, which is then stored in these tissues. If the glucose blood level decreases, some stored glycogen is hydrolyzed back to glucose.

Exercise 6.10

- Describe the structural differences and similarities between the following pairs of polysaccharides:
 - glycogen and amylopectin
 - amylose and amylopectin
 - amylose and cellulose
 - amylose and glycogen
- Match each of the following structural characteristics to the polysaccharides. You can use the characteristics in column B more than once.

Column A	Column B
i Amylopectin	A Contains both α -1,4- and α -1,6-glycosidic linkages
ii Amylose	B Composed of glucose monosaccharide units
iii Glycogen	C Composed of unbranched glucose chains
iv Cellulose	D Contains only β -1,4-glycosidic linkage

- Humans can digest starch but not cellulose. Why?

6.4.4 Proteins

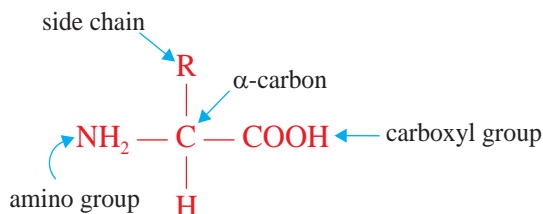
What are proteins?

The name protein comes from the Greek word “*proteios*” which means “*primary*”. This indicates the relative importance of these compounds. All proteins contain carbon, hydrogen, oxygen and nitrogen. Many proteins also contain sulphur.

Proteins are made by the polymerization of the twenty naturally occurring amino acids. An amino acid is a compound that contains both an amino ($-\text{NH}_2$) group and a carboxylic acid ($-\text{COOH}$) group.

The amino acids found in proteins are always α -amino acids (*the amino group is attached to the carbon atom adjacent to the carboxyl group*).

The structural formula for an α -amino acid is:

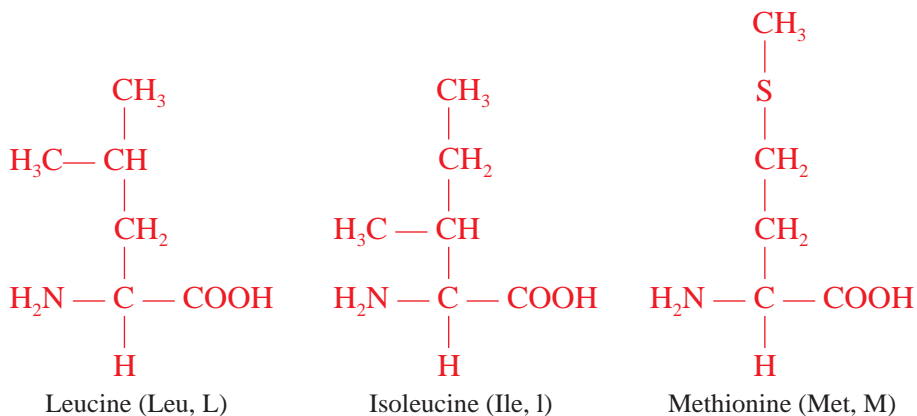
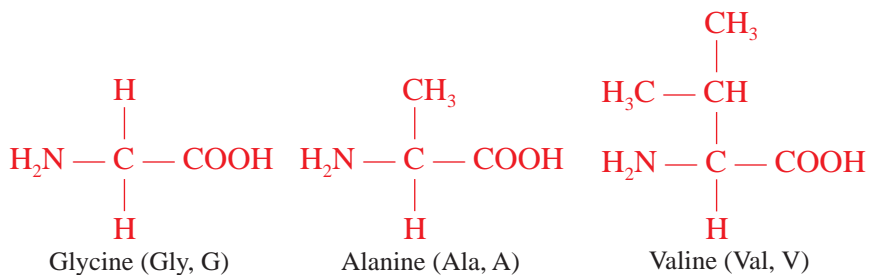


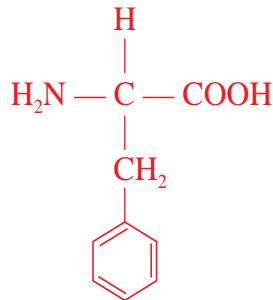
The R group present in an α -amino acid is called the amino acid side chain. The nature of this side chain distinguishes α -amino acids from each other. Based on the side chain polarity, amino acids can be grouped into four categories:

1. Nonpolar amino acids;
2. Polar neutral amino acids;
3. Polar acidic amino acids; and
4. Polar basic amino acids.

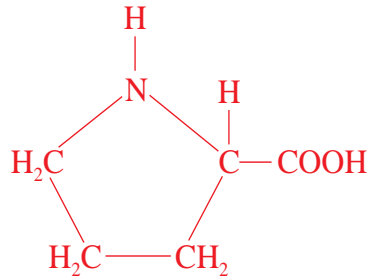
Nonpolar amino acids

Nonpolar amino acids contain one amino group, one carboxyl group, and a nonpolar side chain. When they are incorporated into a protein, these amino acids are hydrophobic or “*water-fearing*” and are not attracted to water molecules. They are generally found on the interior of proteins, where there is limited contact with water. There are eight nonpolar amino acids.





Phenylalanine (Phe, F)



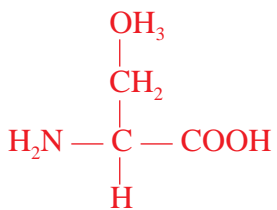
Proline (Pro, P)

Note that either three letters or one letter can represent each amino acid.

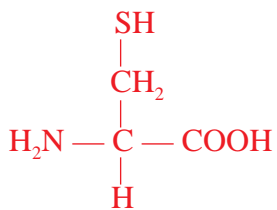
Polar neutral amino acids

What will happen if polar neutral amino acids are incorporated into a protein?

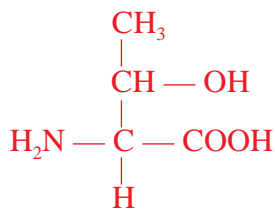
Polar neutral amino acids contain one amino group, one carboxyl group, and a side chain that is polar but neutral. There are seven polar neutral amino acids.



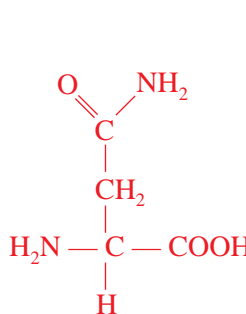
Serine (Ser, S)



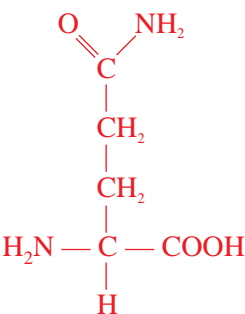
Cysteine (Cyst, C)



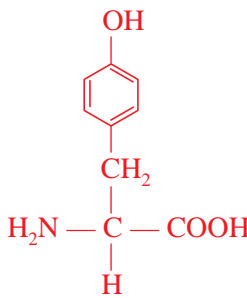
Threonine (Thr, T)



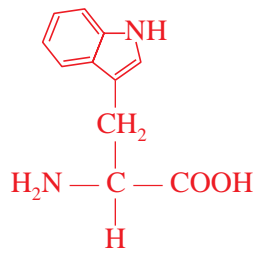
Asparagine (Asn, N)



Glutamine (Gln, Q)



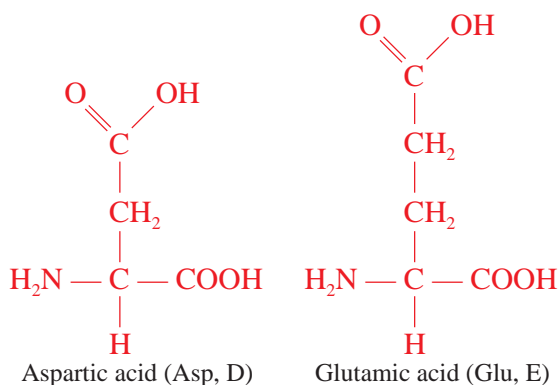
Tyrosine (Tyr, Y)



Tryptophan (Trp, W)

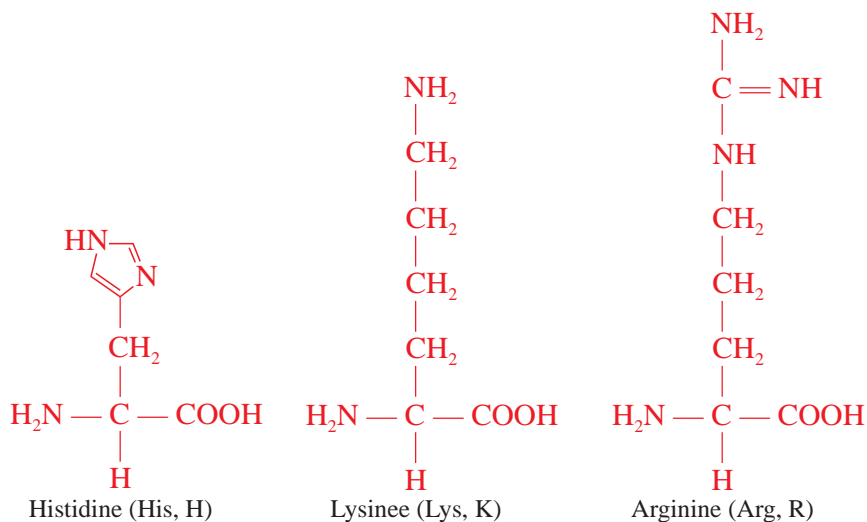
Polar acidic amino acids

Polar acidic amino acids contain one amino group and two carboxyl groups. The second carboxyl group is part of the side chain. There are two polar acidic amino acids.



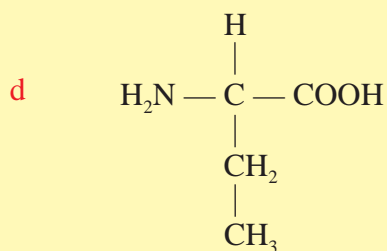
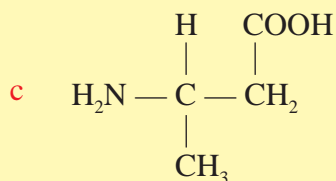
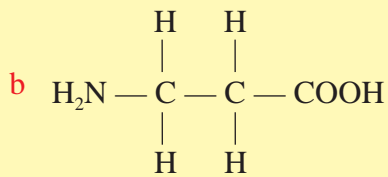
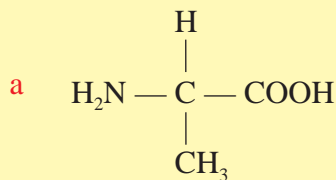
Polar basic amino acids

Polar basic amino acids contain two amino groups and one carboxyl group. The second amino group is part of the side chain. There are three polar basic amino acids.



Exercise 6.11

1. Which of the following structures represents α -amino acids?



2. Give two examples for each of the following amino acids, together with their structures.

- a Nonpolar amino acids c Polar acidic amino acids
b Polar neutral amino acids d Polar basic amino acids

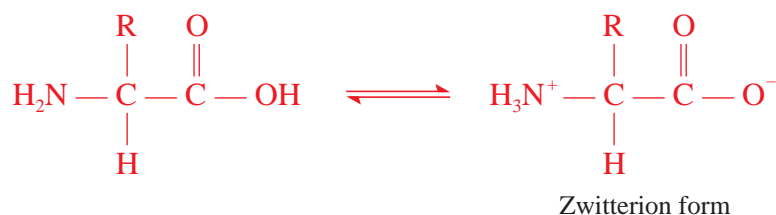
Physical Properties of Amino Acids

Amino acids have the following properties.

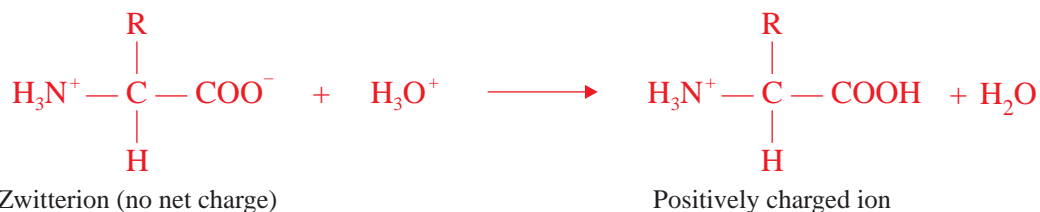
- i) They have high melting points.
- ii) They are colourless crystalline substances.
- iii) They are soluble in water but insoluble in nonpolar solvents.

Thus, they resemble ionic compounds. This occurs due to the fact that amino acids contain both an acid ($-\text{COOH}$) and a base ($-\text{NH}_2$) functional groups. These acids and basic groups react with each other to form a dipolar ion or internal salt. The dipolar ion of an amino acid is called zwitterion.

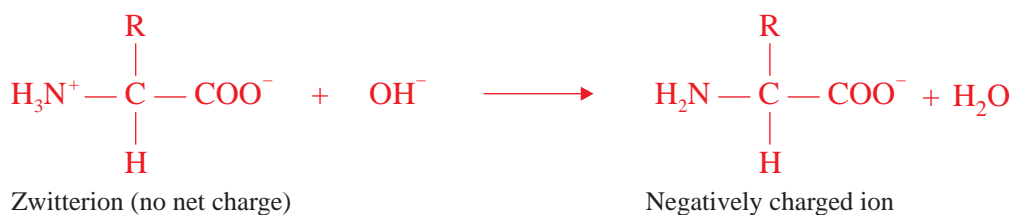
A zwitterion has no net charge.



A zwitterion structure changes when the pH of a solution containing an amino acid is changed from neutral either to acidic (low pH), by adding an acid such as HCl , or to basic (high pH), by adding a base such as NaOH . In acidic solution, the zwitterion accepts a proton (H^+) to form a positively charged ion.

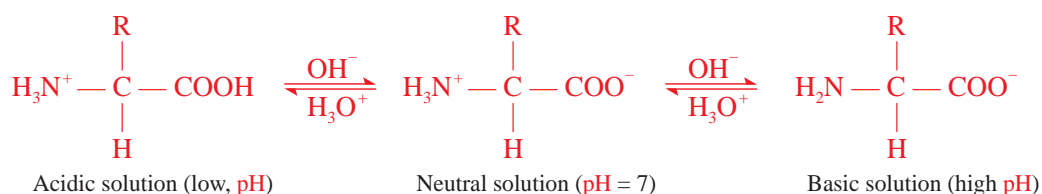


In a basic solution, the $-\text{NH}_3^+$ of zwitterion loses a proton, and a negatively charged species is formed.



Thus, in a solution, three different amino acid forms can exist (*zwitterion*, *negative ion*, and *positive ion*).

The three species are in equilibrium with each other and the equilibrium shift with **pH** change.



In acidic solution, the positively charged species on the left predominates. Nearly neutral solutions have the middle species (*the zwitterion*) as the dominant species. In basic solution, the negatively charged species on the right predominates.

Peptide Bond Formation

Activity 6.9



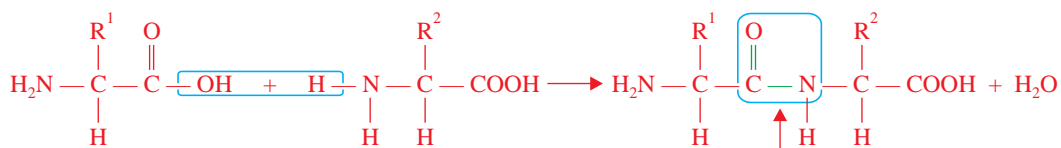
Form a group and discuss each of the following questions.

1. Why amino acids form zwitterions?
2. How many different tripeptides can be obtained by various combinations of three amino acid residues?
3. How do amino acids join together to form proteins?
4. What type of polymerization is it?
5. What are the differences between different proteins?

After the discussion, share your ideas with the rest of the class

A peptide (*amide*) is a bond formed between the carboxyl group of one amino acid and the amino group of another amino acid.

If two amino acids are allowed to react, the carboxyl group of one amino acid reacts with the amino group of the other amino acid. The products are a molecule containing the two amino acids linked by an amide bond or a peptide bond and water.



Amide or peptide bond

A compound containing two amino acids joined by a peptide bond is called a *dipeptide*. Either end of the dipeptide can undergo a condensation reaction with another amino acid to form a tripeptide, tetrapeptide and so on.

Recall that, in the preparation of nylon 66, adipic acid contains two acid functional groups and hexamethylene diamine contains two amine functional groups.

A polypeptide is a sequence of amino acids, containing up to 50 amino acid units, in which the amino acids are joined together through amide (peptide) bonds. Proteins are polypeptides that contain more than 50 amino acid units.

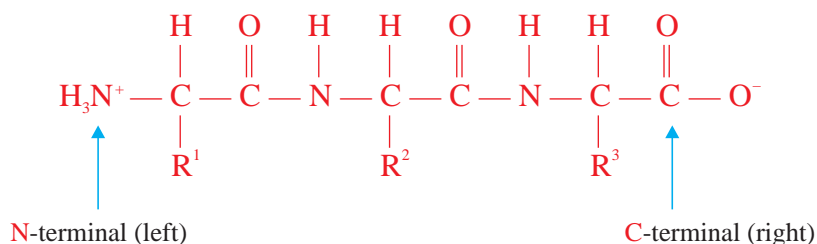
Are proteins condensation polymers or addition polymers? Which small molecule is mostly expelled in the synthesis of protein?

Proteins have many functions, as shown in [Table 6.2](#).

Table 6.2 Some Functions of Proteins.

Type of protein	Example	Function
Enzymes	amylase	Promotes the breakdown of starch to the simple sugar glucose.
Structural proteins	keratin, collagen	Promotes the formation of hair, wool, nails, horns, tendons and cartilage.
Contractile proteins	actin, myosin	Contracting fibers in muscle.
Hormones	insulin, glucagon	Regulates use of blood sugar.
Storage proteins	ferritin	Stores iron in spleen.
Transport proteins	hemoglobin	Carries oxygen in blood.
	serum albumin	Carries fatty acids in blood.
Immunological proteins	antibodies	Defends the body from foreign invaders.

By convention the sequence of amino acids in a peptide is written with the N-terminal amino acid at the left and the C-terminal amino acid at the right. The individual amino acids within a peptide chain are called amino acid residues.



Exercise 6.12

- Draw the appropriate structural form for the amino acid alanine that predominates in a solution at each of the following pH values.
 - pH = 1
 - pH = 7
 - pH = 11
- What two functional groups are involved in the formation of a peptide bond?
- How do amino acids, peptides, and protein differ?
- Write a chemical equation that indicates the formation of a dipeptide from glycine and alanine.

Unit Summary

- *Monomers are the building blocks of polymers.*
- *Homopolymers are made from identical monomers, and copolymers are synthesized from more than one kind of monomer.*
- *Based on their sources, polymers can be classified as synthetic or natural. Synthetic polymers are man-made, while natural polymers exist naturally.*
- *Polymerization is the process of combining monomer units to form large molecules called polymers.*
- *Polymerization can be effected through either addition polymerization or condensation polymerization.*
- *Each of the following polymers are made by addition polymerization.*
 - ◆ *Polyethylene*
 - ◆ *Polypropylene*

- ◆ *Polyvinyl chloride (PVC)*
- ◆ *Polymethyl methacrylate (PMMA)*
- ◆ *Teflon*
- ◆ *Polystyrene*
- ◆ *Natural rubber*
- ◆ *Neoprene*
- ◆ *Styrene-butadiene rubber and*
- ◆ *Butyl rubber*
- *Polymers that are synthesized by condensation polymerization are.*
 - ◆ *Nylons*
 - ◆ *Polyesters*
 - ◆ *Bakelite*
 - ◆ *Carbohydrates, and*
 - ◆ *Proteins.*
- *Thermoplastics soften on heating and can be molded into different shapes, and the process of heating and cooling can be repeated several times, but once thermosetting plastics are solidified they cannot be softened or remolded on heating.*
- *Synthetic polymers pollute the environment during their preparations, use and disposal.*
- *Monosaccharides are the building blocks of carbohydrates.*
- *Proteins are made from the twenty naturally occurring amino acids.*

Check list

Key terms of the unit

- | | |
|----------------------------------|------------------------|
| • <i>Addition polymerization</i> | • <i>Carbohydrates</i> |
| • <i>Adipic acid</i> | • <i>Catalyst</i> |
| • <i>Amino acids</i> | • <i>Copolymer</i> |
| • <i>Bakelite</i> | • <i>Disaccharides</i> |
| • <i>Butyl rubber</i> | • <i>Ethylene</i> |

- Ethylene glycol
- Formaldehyde
- Hexamethylene diamine
- Homopolymer
- Isoprene
- Methyl methacrylate
- Monomer
- Monosaccharides
- Natural polymer
- Natural rubber
- Nylon
- Peptides
- Phenol
- Polyester
- Polyethylene
- Polymer
- Polymerization
- Polymethyl methacrylate (PMMA)
- Polypropylene
- Polysaccharides
- Polystyrene
- Polyvinyl chloride (PVC)
- Propylene
- Protiens
- Repeating unit
- SBR
- Styrene
- Synthetic polymer
- Teflon
- Terephthaleic acid
- Tetrafluoroethylene
- Thermoplastic and thermosetting plastics
- Vinyl chloride
- Vulcanization

REVIEW EXERCISE FOR UNIT 6

Part I: Mutiple Choice Questions

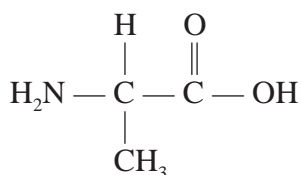
1. Which of the following statement is incorrect about polymers?
 - a they are macromolecules made from smaller units.
 - b they can be prepared by either condensation or addition polymerization.
 - c most condensation polymers are homopolymers.
 - d disposing synthetic polymers can pollute the environment.
2. The process by which monomer units combine to form polymers, is:

a condensation	c thermosetting
b thermoplastic	d evaporation

3. What is the molar mass of a polyethylene sample, $\left(\text{CH}_2\text{—CH}_2\right)_n$, when $n = 4600$? (Atomic mass, H = 1 and C = 12).
- a 1.288×10^3 g/mol c 1.196×10^3 g/mol
 b 1.288×10^5 g/mol d 1.196×10^4 g/mol
4. Which one of the following is not formed by addition polymerization?
- a polyethylene c teflon
 b polyvinyl chloride d dacron
5. Which one of the following polymer-monomer pairs is incorrectly matched?
- a Teflon-propylene c Plexiglass-methyl methacrylate
 b PVC-chloroethene d Bakelite-phenol and formaldehyde
6. Which one of the following is not a synthetic polymer?
- a nylon c teflon
 b cotton d dacron
7. Polyethylene is not used for making:
- a squeeze bottles c electrical insulation
 b trash bags d airplane windows
8. Dacron is made by the polymerization of _____ and _____.
- a terephthalic acid, ethylene c terephthalic acid, ethylene glycol
 b adipic acid, ethylene glycol d adipic acid, hexamethylene diamine
9. Which one of the following is a thermosetting plastic?
- a polyethylene c dacron
 b polypropylene d bakelite
10. Which of the following structures represents the monomer of $\left(\text{CH}_2\text{—CH}_2\text{=CH}_2\text{—CH}_2\right)_n$?
- a $\text{CH}_3\text{CH=CHCH}_3$ c $\text{CH}_2\text{=CH—CH}_2\text{—CH}_3$
 b $\text{CH}_2\text{=CH—CH=CH}_2$ d none of the above

11. The monomer of natural rubber is:
- a isoprene
 - b 2-methyl-1,3-butadiene
 - c chloroprene
 - d a and b are correct answers
12. Which one of the following statements is incorrect about synthetic and natural polymers?
- a Nucleic acids, proteins and carbohydrates are natural polymers
 - b Natural polymers are the major pollutants of the environment
 - c Synthetic polymers have wide applications
 - d None of the above
13. Which one of the following is not the characteristic of vulcanized rubber?
- a It is a sticky solid
 - b It is hard
 - c It has high tensile strength
 - d It has higher elasticity over a higher range of temperature
14. Which of the following statement is correct about natural and synthetic rubbers?
- a Natural rubber is a copolymer but synthetic rubbers are homopolymers.
 - b Natural rubber is superior to styrene-butadiene rubber with regard to mechanical strength.
 - c Butyl rubber holds air better than natural rubber and is used for inner tubes.
 - d All of the above.
15. Which of the following statement is false about carbohydrates?
- a They are prepared by green plants during photosynthesis.
 - b They are polyhydroxyl ketones or aldehydes or substances that yield such substances upon hydrolysis.
 - c All carbohydrates are polymers.
 - d None of the above.
16. Which of the following monosaccharides is a ketohexose?
- a Ribose
 - b Glucose
 - c Galactose
 - d Fructose

17. An amino acid differs from the others by:
- a the amine functional group c the side-chain
b the acid functional group d a and b are correct answers
18. Pyranose ring can be formed by:
- a galactose c ribose
b fructose d a and b are correct answers
19. A disaccharide made from two glucose units that are linked by α -1,4 glycosidic bond is:
- a cellulose b maltose
c lactose d sucrose
20. Which one of the following disaccharide is prepared from two different monosaccharide units?
- a Cellulose b Maltose
c Lactose d Fructose
21. Which one of the following statement is incorrect about polysaccharides?
- a Cellulose, starch and glycogen are homopolymers.
b Cellulose is a linear polymer in which the glucose units are linked by β -1,4 glycosidic bonds.
c Amylose and amylopectin are the two forms of glycogen.
d Glycogen is a glucose storage polysaccharide in humans and animals.
22. Which type of amino acids contain two amino groups and one carboxyl group?
- a Non-polar c Polar basic
b Polar neutral d Polar acidic
23. What is the charge on the following amino acid at pH 14?



- a +1 b +2
c -1 d -2

24. A bond that is formed between amino acids is called:
- a hydrogen bond
 - b amide bond
 - c peptide bond
 - d b and c are correct answers

Part II: Short Answer Questions

25. Define each of the following terms and give an example for each:
- a Monomer
 - b Polymer
 - c Carbohydrate
 - d Amino acid
 - e Polypeptide
 - f Protein
26. Classify each of the following polymers as natural or synthetic.
- a Polyethylene
 - b Polypropylene
 - c Cellulose
 - d Polyvinyl chloride
 - e Deoxyribonucleic acid
 - f Polytetrafluoroethylene
 - g Polystyrene
 - h Nylons
 - i Cotton
 - j Dacron
27. Classify each polymer in Question 26 as an addition polymer or a condensation polymer.
28. What functional groups are involved in the addition and condensation polymerization processes?
29. Mention major uses of each of the following synthetic polymers.
- a Polypropylene
 - b Polyvinyl chloride
 - c Teflon
 - d Polystyrene
 - e Bakelite
 - f Nylons
 - g Plexiglass
30. Draw the open chain and cyclic structures of each of the following compounds.
- a Galactose
 - b Fructose
 - c Ribose
 - d Maltose
 - e Sucrose
 - f Cellulose
 - g Phenylalanine