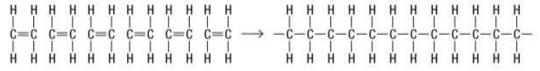
## **Grade 12 Chemistry**

Organic Chemistry
Class 4

#### **Polymers**

- Polymer large molecule built from monomers
- Monomer a simple, repeating unit
- Natural and synthetic polymers are used in textile fibres, rubber, and plastics



ethene monomers

polyethene (polyethylene) polymer

Figure 2 Polymerization of ethene molecules produces polyethene (polyethylene).

 Homopolymer – polymer formed by reactions involving a single type of monomer

- Copolymer different types of monomers combined to form the polymer chain
  - May join in an addition reaction or in a condensation reaction
  - Ex: Silk a natural polymer is formed by joining amino acids in multiple condensation reactions

$$\begin{array}{c} \text{NH}_2\\ \text{CH}_2\\ \text{CH}_2\\ \text{CH}_2\\ \text{CH}_2\\ \text{CH}_2\\ \text{CH}_2\\ \text{CH}_2\\ \text{OH} \\ \text{H}_2\text{N}-\text{C}-\text{C}_{\text{C}}\\ \text{OH} \\ \text{H} \\ \text{H} \\ \text{OH} \\ \text{H} \\ \text{H} \\ \text{OH} \\ \text{O$$

#### **Natural vs. Synthetic**

#### **Natural Synthetic** Starch Polyester Polyethene Cellulose Glycogen Polypropene • DNA/RNA Fluoropolymers – used in non-stick coating on Silk Spider silk cookware Amber Rubber tires Rubber Kevlar fibres in body Animal horns armour



1839: Vulcanized rubber was developed by American Charles Goodyear to make natural rubber stronger. Natural rubber is polymer produced from the liquid sap of rubber trees. Natural rubber tends to be brittle when cold and soft when warm. Heating natural rubber with suffur—vulcanizing—made the product harder and raised its melting point. Vulcanized rubber was used for battery boxes, pumps, dental plates, fountain pens, and, eventually, automobile tires.



1909: Bakelite, invented by Leo Hendrik Baekeland, was the first fully synthetic polymer. It was widely used to replace wood, ivory, and ebony (thereby reducing the pressure on some endangered species). A lightweight plastic, it was non-conductive, heat and moisture resistant, chemically unreactive, and could be coloured. It revolutionized the design of consumer and industrial products. Many things made of Bakelite, such as jowellery, dishes, telephones, and toys, are collectables today. ¬



1929: Vinyl (PVC), invented by Waldo Semon, came to be used worldwide in products such as flooring, shower curtains, and plumbing pipes. It was the first durable material that was used to record and play back music.



1935: Nylon, invented by Wallace Carothers to replace silk in parachutes and stockings, became widely used in many consumer

1830 1840 1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010

1868: Celluloid was invented to replace ivory in billiard balls. In the form of celluloid film, this polymer played a central role in the development of the movie industry



1910: Formica was invented for use as an electrical insulator. The polymer was modified during the 1930s to make it more durable. Formica is widely used as a laminate on household surfaces, such as kitchen or bathroom counters.



L 1933: Saran was invented by Ralph Whiley. It was originally used as a coating: sprayed onto fighter planes to protect the surfaces against corrosion from sea salt. It was eventually approved for use in food packaging.





## **Synthetic Addition Polymers**

 Addition polymer – result of the reaction between monomers with unsaturated carboncarbon bonds

 Polytetrafluoroethene (PTFE) is commonly known as Teflon on non-stick pans

Monomer		Polymer	
Name	Formula	Name	Uses
ethene	H <sub>2</sub> C=CH <sub>2</sub>	polyethene (polyethylene)	plastic bottles and pipes, insulation on electric wires, toys
propene	H <sub>2</sub> C=C C CH <sub>3</sub>	polypropene (polypropylene)	rope, packaging film, carpet fibres, toys
chloroethene (vinyl chloride)	H <sub>Z</sub> C=C CI	polyvinyl chloride (PVC)	pipes, construction materials, floor tile, clothing, reusable bags
cyanoethene (acrylonitrile)	H <sub>z</sub> C=C H	polyacrylonitrile (PAN)	carpet fibres, synthetic fabrics
tetrafluoroethene	F <sub>2</sub> C=CF <sub>2</sub>	polytetrafluoroethene (Teffon)	non-stick cookware, electrical insulation, ball bearings

vinylbenzene (styrene)	H <sub>2</sub> C=C H	polystyrene	food and beverage containers, insulation, toys
butane-1,3-diene (butadiene)	H <sub>2</sub> C=C-C=CH <sub>2</sub>	polybutadiene	tires, industrial coatings
vinylbenzene (styrene) and butane-1,3-diene (butadiene)	H <sub>2</sub> C=C H H <sub>2</sub> C=C-C=CH <sub>2</sub>	styrene-butadiene rubber (a copolymer)	synthetic rubber





Draw a structural diagram showing three repeating units of the addition polymer formed from cis-but-2-ene





Draw a structural diagram of the monomer used to make Saran wrap. Name the monomer.

#### **Plastics**

- A synthetic substance that can be moulded (often under heat and pressure) and retains its given shape
- Held together by single carbon-carbon bonds; very strong and less reactive than double bonds
- Weak intermolecular forces between carbon atoms allow the plastic to flex and stretch



- Plastics are categorized based on their density
- Low-density polyethene (LDPE)
   has more branches in its
   structure prevent it from packing
   as tightly as High-density
   polyethene (HDPE)
- LDPE is used in plastic bags, packaging materials
- HDPE is used in blow-moulded products such as milk jugs and water bottles

#### **Polymer Cross-Linking**

- Formation of chemical bonds between separate polymer strands
- The more cross-links, the more rigid and inflexible the polymer

#### **Synthetic Condensation Polymers**

- Composed of repeating groups of monomers with two reactive functional groups involved in the polymerization reaction
- Polyesters are formed by a series of esterification reactions that produce a water

- Polyamides are formed by the condensation of an amine and a carboxylic acid
- Ex: Kevlar in body armour
- Nylon 6,6 is a copolymer with two types of monomers



$$\begin{array}{c} O \\ \parallel \\ Cl-C-CH_2CH_2CH_2CH_2CC + HN-CH_2CH_2CH_2CH_2CH_2CH_2-NH \longrightarrow \\ \text{hexane-dioyl dichloride} \\ \hline \\ \begin{pmatrix} O \\ \parallel \\ -C-CH_2CH_2CH_2CH_2C - N - CH_2CH_2CH_2CH_2CH_2-N + HCl \\ \text{amide linkage} \\ \text{nylon-6,6} \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2CH_2CH_2CH_2CH_2-N - CH_2CH_2CH_2CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2CH_2CH_2CH_2-N - CH_2CH_2CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2CH_2-CH_2-N - CH_2CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N - CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N - CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N - CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N - CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N - CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N - CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N - CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N - CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N - CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ -C-CH_2-CH_2-N + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ + HCl \\ \end{pmatrix} \\ + \begin{array}{c} H \\ \parallel \\ + HCl \\$$





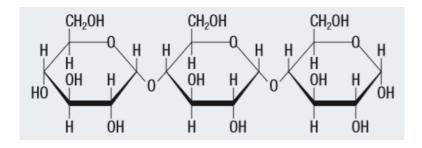
Draw a condensed structural diagram of the polymer made from repeating units of a 4-carbon diamine and a 6-carbon dicarboxylic acid



#### Checkpoint



Starch is a polymer formed in a condensation reaction in which molecules of water are eliminated from the new bonds. Draw the monomer that makes up starch.





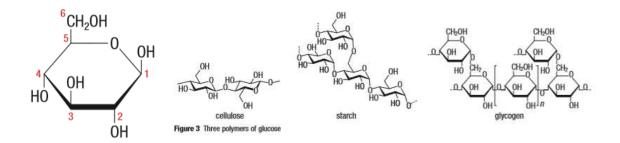


Draw a structural diagram of the polymer formed by the reaction of:

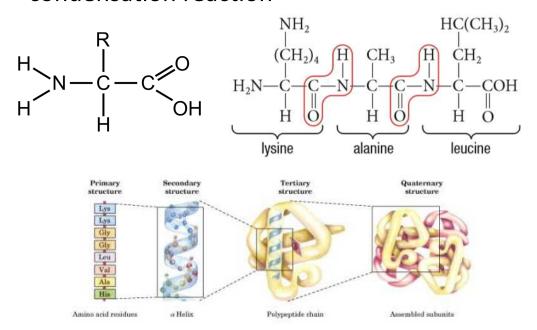
- a) Propane-1,3-diol and pentanedioic acid
- b) Butanedioic acid and a 5-carbon diamine
- c) Hexanedioic acid and a 3-carbon diamine

## **Natural Polymers**

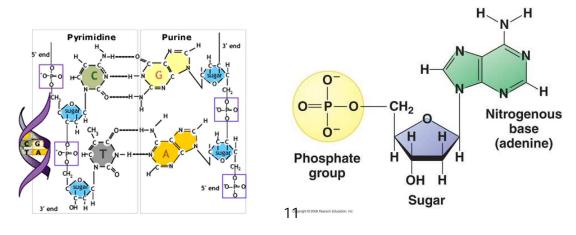
- Carbohydrates polymer of monosaccharides (simple sugars) to form a polysaccharide
  - Ex: starch, cellulose, glycogen



 Protein – polymer made of amino acids joined together by peptide bonds through a condensation reaction



- Nucleic Acids polymer made of nucleotides consisting of a 5-carbon sugar, a nitrogencontaining base and a phosphoric acid molecule
- Nucleotides link together through condensation reactions



# **Summary of Natural Polymers**

Macromolecule	Monomer	Bond/Linkage	Polymer
Carbohydrate	Monosaccharides	Glycosidic Linkage	Polysaccharides
Protein	Amino Acid	Peptide Bonds	Polypeptide
Nucleic Acids	Nucleotide	Phosphodiester Linkages	Strand