CHEMISTRY

Stage 6

Module 7: Organic Chemistry

Polymers

Teacher: Shane Sandot

Exam Equivalent Time: 49.5 minutes *(based on allocation of 1.5 minutes per mark)*

M7 Organic Chemistry

- Nomenclature
- Hydrocarbons and Associated Reactions
- Alcohols
- Reactions of Organic Acids and Bases
- Polymers

***SmarterScience analytics based on the average contribution of new syllabus content since 2019.**

HISTORICAL CONTRIBUTION

- *M7 Organic Chemistry* has contributed an average of 25.0% per HSC Chemistry exam since the new syllabus was introduced in 2019.
- This topic has been split into five sub-categories for analysis purposes which are: *1-Nomenclature (3.7%), 2-Hydrocarbons and Associated Reactions (3.4%), 3-Alcohols (9.8%), 4-Reactions of Organic Acids and Bases (6.8%) and 5-Polymers (1.3%).*
- This analysis looks at the smallest sub-topic, *Polymers*.

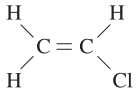
HSC ANALYSIS - What to expect and common pitfalls

- *Polymers* has only contributed 1.3% to new syllabus exams to date which is below its old-syllabus historical average and belies its importance, in our view.
- Revision attention is warranted due to the topic's potential for long response questions, examples of which are included in the database.
- *Addition Polymers* and *Condensation Polymers* have been examined via multiple choice in 5 of 6 new syllabus exams. We also note that *Addition Polymers* were examined for the first time in the longer answer section of new syllabus exams in 2024.
- A common question style involves requiring students to deduce the monomer(s) that a given polymer is made up from.
- We recommend careful attention be paid to *2022 HSC 18 MC* which assessed *Condensation Polymers* and exposed a knowledge gap (state mean mark 23%).

Questions

1. CHEMISTRY, M7 2016 HSC 1 MC

What is the name of this compound?



A. Styrene

B. Ethylene

C. Chloroethane

D. Vinyl chloride

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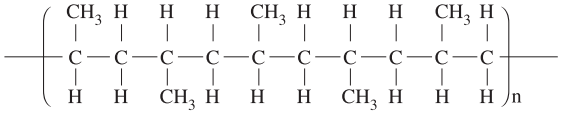
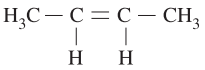
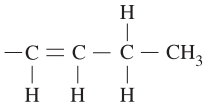
2. CHEMISTRY, M7 2016 HSC 17 MC

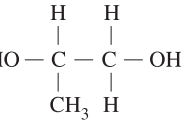
A polymer has the following structure.

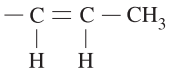


Which of the following represents the monomer from which this polymer can be produced?

(A) 

(B) 

(C) 

(D) 

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3. CHEMISTRY, M7 2018 HSC 11 MC

Which row of the table correctly matches the polymer with its structural feature and property?

	Polymer	*Structural feature*	*Property*
A.	Polyvinyl chloride	Chlorine side group	Rigid
B.	Low density polyethylene	Tightly packed molecules	Opaque
C.	High density polyethylene	Branched chains	Transparent
D.	Polystyrene	Large side chains	Flexible

4. CHEMISTRY, M7 2022 HSC 1 MC

What term is used to define the repeating unit of a polymer?

A. Dimer

B. Isomer

C. Monomer

D. Primer

5. CHEMISTRY, M7 2016 VCE 12 MC

A condensation reaction involving 200 glucose molecules, $C_6H_{12}O_6$, results in a polysaccharide. The molar mass, in g mol^{-1}, of the polysaccharide is

A. 36 000

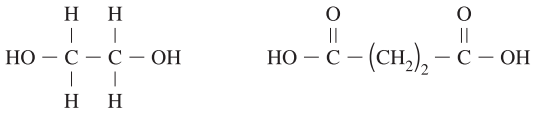
B. 35 982

C. 32 418

D. 32 400

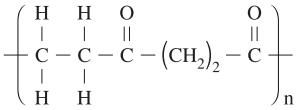
6. CHEMISTRY, M7 2015 HSC 11 MC

Two monomers are shown.

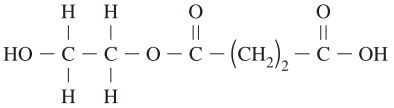


Which of the following shows a condensation polymer that could be formed from the monomers?

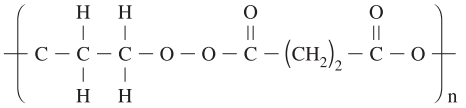
(A)



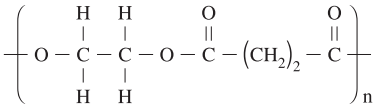
(B)



(C)



(D)



7. CHEMISTRY, M7 2016 HSC 4 MC

Which row of the table correctly identifies an application of polystyrene and the reason for its suitability for that application?

	Application	*Reason for suitability*
A.	Shopping bags	Rigidity
B.	Shopping bags	Flexibility
C.	Screwdriver handles	Rigidity
D.	Screwdriver handles	Flexibility

8. CHEMISTRY, M7 2018 HSC 5 MC

Cellulose extracted from biomass is able to be used as a raw material in the manufacture of polymers because it

A. is a condensation polymer.

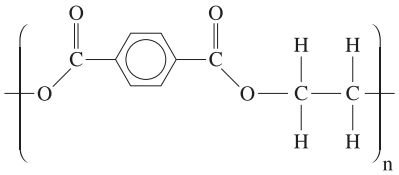
B. is a strong flexible molecule.

C. produces carbon dioxide when burnt.

D. contains a basic carbon-chain structure.

9. CHEMISTRY, M7 2020 HSC 12 MC

The structure of part of a polymer chain is shown.



Which statement best explains why plastics made from this polymer require a temperature of approximately 250°C before they begin to soften?

A. The carbon–carbon bonds in the polymer chains are strong.

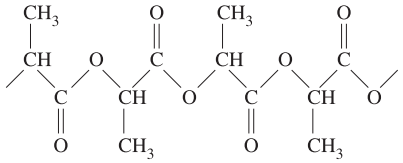
B. The carbon–hydrogen bonds in the polymer chains are strong.

C. Extensive dipole–dipole and dispersion forces exist between the polymer chains.

D. Extensive hydrogen bonds and dispersion forces exist between the polymer chains.

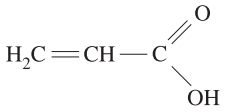
10. CHEMISTRY, M7 2021 HSC 10 MC

The structure of part of a polymer chain is shown.

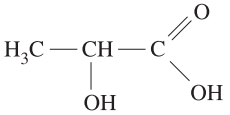


Which is the monomer of this polymer?

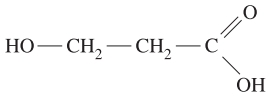
A.



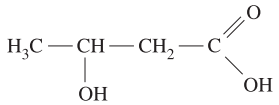
B.



C.



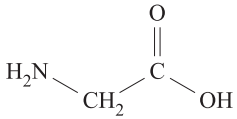
D.



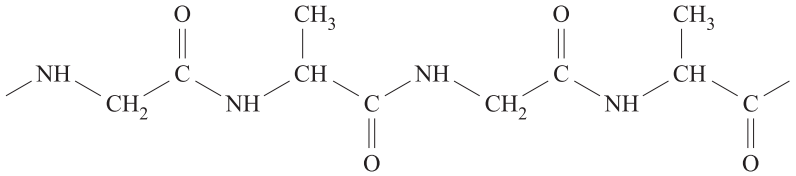
11. CHEMISTRY, M7 2024 HSC 14 MC

Glycine, an amino acid, can react with itself or other amino acid monomers to form silk, a natural polymer.

Glycine has the structure:

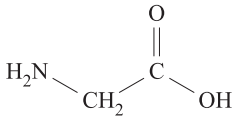


A section of silk polymer is shown.

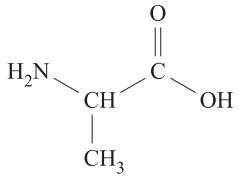


Which monomer could react with glycine to form this section of silk polymer?

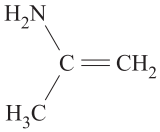
A.



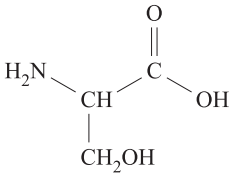
B.



C.



D.



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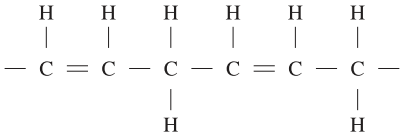
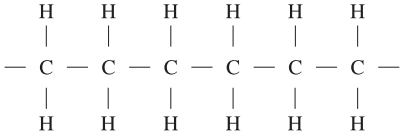
12. CHEMISTRY, M7 2017 HSC 12 MC

What is the product when propene undergoes addition polymerisation?

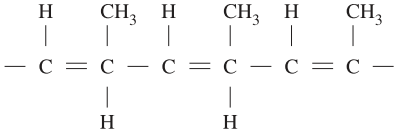
A.



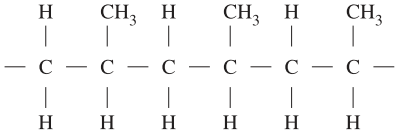
B.



C.



D.



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13. CHEMISTRY, M7 2019 HSC 13 MC

A sample of polydifluoroethylene is determined to have an average molar mass of 4.8×10^4 g mol $^{-1}$.

Approximately how many carbon atoms are there in an average molecule?

A. 750

B. 1500

C. 2500

D. 4000

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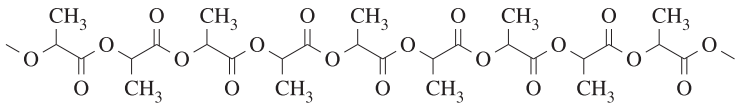
14. CHEMISTRY, M7 2022 HSC 18 MC

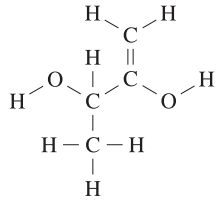
A low molecular weight biopolymer is being investigated for its suitability for medical use. In one trial a molecular weight of $2900 \pm 100 \text{ g mol}^{-1}$ proved to be optimum.

A section of this biopolymer is shown.



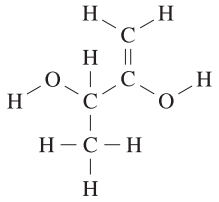
Which will produce the suitable biopolymer?

A.



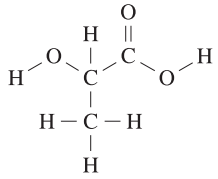
Molar mass: 88.01 g mol^{-1}
Number of units: 42

B.



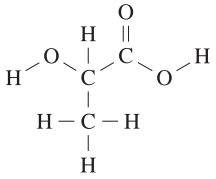
Molar mass: 88.01 g mol^{-1}
Number of units: 33

C.



Molar mass: 90.078 g mol^{-1}
Number of units: 32

D.



Molar mass: 90.078 g mol^{-1}
Number of units: 40

15. CHEMISTRY, M7 2018 HSC 21

Ethylene can be readily transformed into many useful products.

a. What is the name of the industrial process by which ethylene is obtained from long chain alkanes? ***(1 mark)***

b. Ethylene can be converted into vinyl chloride.

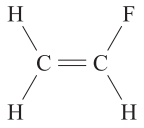
Draw structural formulae for vinyl chloride and its polymer, polyvinyl chloride. ***(2 marks)***

16. CHEMISTRY, M7 2015 HSC 25b

Explain the uses of polyethylene and polystyrene in terms of their structures and properties. ***(4 marks)***

17. CHEMISTRY, M7 2024 HSC 22

Vinyl fluoride can be polymerised.



vinyl fluoride

In the box provided, draw the structural formula for a six-carbon section of the polymer formed from the polymerisation of vinyl fluoride. ***(2 marks)***

18. CHEMISTRY, M7 EQ-Bank 27

Contrast ONE addition polymer and ONE condensation polymer in terms of their structures, properties and uses. Include structural formulae in your answers. ***(7 marks)***

19. CHEMISTRY, M7 2015 HSC 25a

Describe the steps involved in the process of addition polymerisation. ***(3 marks)***

Worked Solutions

1. CHEMISTRY, M7 2016 HSC 1 MC

→ The compound is known as chloroethene or vinyl chloride.

$\Rightarrow D$

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2. CHEMISTRY, M7 2016 HSC 17 MC

→ Break the polymer at every second $\mathrm{C}-\mathrm{C}$ bond (yields identical sections)

→ Adjust single carbon bond to $\mathrm{C}=\mathrm{C}$ bond in monomer

$\Rightarrow D$

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3. CHEMISTRY, M7 2018 HSC 11 MC

→ A chlorine side group is responsible for the property of rigidity in polymers.

$\Rightarrow A$

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4. CHEMISTRY, M7 2022 HSC 1 MC

Polymers are made of repeating units called monomers.

$\Rightarrow C$

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5. CHEMISTRY, M7 2016 VCE 12 MC

→ 200 $\mathrm{C_6H_{12}O_6}$ molecules react to form a polysaccharide

→ 199 $\mathrm{H_2O}$ molecules are released in this condensation polymerisation

$$\mathrm{MM(C_6H_{12}O_6)} = 180.0 \text{ g mol}^{-1}$$

$$\mathrm{MM(H_2O)} = 18.0 \text{ g mol}^{-1}$$

$$\begin{aligned}\mathrm{MM(polysaccharide)} &= 200 \times 180.0 - 199 \times 18.0 \\ &= 32\,418 \text{ g mol}^{-1}\end{aligned}$$

$\Rightarrow C$

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6. CHEMISTRY, M7 2015 HSC 11 MC

→ Condensation polymer will eliminate molecule ($\mathrm{H_2O}$ in this case)

$\Rightarrow D$

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7. CHEMISTRY, M7 2016 HSC 4 MC

Polystyrene is used to make stiff and durable plastics vs polyethylene that produces flexible and transparent plastic products.

$\Rightarrow C$

Worked Solutions

8. CHEMISTRY, M7 2018 HSC 5 MC

→ The cellulose molecule can be used in polymer manufacture as it contains a basic carbon chain structure.

$\Rightarrow D$

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9. CHEMISTRY, M7 2020 HSC 12 MC

→ The polymer diagram shows the following intermolecular forces: dipole-dipole forces and dispersion forces.

→ High temperatures break some of the intermolecular forces, causing the plastic to soften (polyesters can't form H-bonds).

$\Rightarrow C$

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10. CHEMISTRY, M7 2021 HSC 10 MC

→ The polymer formed is a condensation polymer, where the by-product is water ($\mathrm{H_2O}$).

→ From the polymer shown, the alcohol functional group must ie on the second carbon atom, and the carboxylic functional group must lie on the first carbon atom.

→ Thus, could only be formed from monomer B.

$\Rightarrow B$

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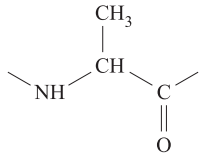
11. CHEMISTRY, M7 2024 HSC 14 MC

→ The silk polymer shown is a condensation polymer and also a polyamide formed from monomers containing the amine and carboxylic functional groups.

→ During the formation of the polymer, the $\mathrm{NH_2}$ amine group will lose a hydrogen and that hydrogen will form a water molecule with the hydroxyl group.

→ The part of glycine that remains in the polymer is $\mathrm{NHCH_2CO}$.

→ The second repeating unit in the polymer is $\mathrm{NHCHCH_3CO}$.



$\Rightarrow B$

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12. CHEMISTRY, M7 2017 HSC 12 MC

Polymerisation of propene:

→ No double bonds (eliminate A and C)

♦ Mean mark 43%.

→ Methyl functional group appear on every second carbon atom

$\Rightarrow D$

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13. CHEMISTRY, M7 2019 HSC 13 MC

→ Polydifluoroethylene: $C_2F_2H_2$

→ $MM(C_2F_2H_2) = 64.036$ g

♦ Mean mark 50%.

$$\begin{aligned} \text{N (repeating units)} &= \frac{\text{MM (total sample)}}{\text{MM (repeating sample)}} \\ &= \frac{4.8 \times 10^4}{64.036} \\ &= 750 \text{ carbons per repeating unit} \\ &= 1500 \text{ carbons (2 per repeating unit)} \end{aligned}$$

$\Rightarrow B$

14. CHEMISTRY, M7 2022 HSC 18 MC

This polymer is a condensation polymer, meaning that it is formed through the reaction between monomers that consist of a carboxylic acid and/or an alcohol functional group, with the elimination of water.

♦♦ Mean mark 23%.

Thus, if n monomers react to form this polyester, $(\mathrm{n}-1)$ molecules of water would be eliminated.

Calculating their molar masses:

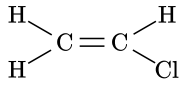
$$\begin{aligned} \mathrm{n} \times \text{monomers} &= \text{polymer} + (\mathrm{n}-1) \times H_2O \\ \mathrm{n} \times (90.078) &= 2900 + (\mathrm{n}-1) \times (18.016) \\ \mathrm{n}(90.078 - 18.016) &= 2900 - 18.016 \\ \therefore\ \mathrm{n} &= \frac{2881.984}{72.062} \\ &= 39.99\ldots \end{aligned}$$

$\Rightarrow D$

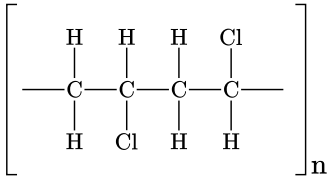
15. CHEMISTRY, M7 2018 HSC 21

a. Cracking

b. Vinyl chloride:



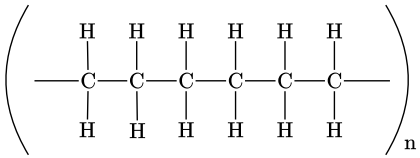
Polyvinyl chloride:



16. CHEMISTRY, M7 2015 HSC 25b

Polyethylene:

→ Polyethylene consists of long carbon chains with numerous branches but with no side groups.

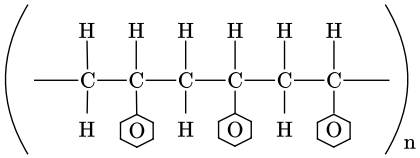


→ The branches do not allow the long chains to pack closely together and the weak dispersion forces between chains make it flexible, transparent and soft.

→ These characteristics make polyethylene a great material for making cling-wrap and milk bottles.

Polystyrene:

→ Polystyrene consists of long carbon chains with benzene rings attached to alternative carbon atoms along the chain.



→ The benzene rings create a much stiffer and hardier material with excellent heat insulation and water resistant properties.

→ Polystyrene can be used for screwdriver handles and car battery cases, as well as packaging white goods and other electrical products that can be ruined by water damage.

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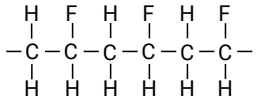

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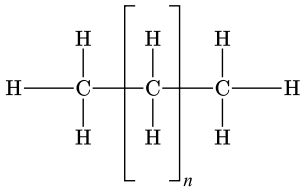
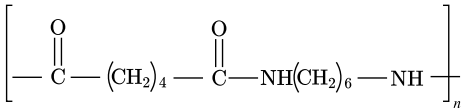
Addition polymer – polyethylene. Condensation polymer – nylon.

Structures

→ Polyethylene is made by the addition of ethylene monomers with the following structural formula:



→ Nylon is a condensation polymer made from 1,6-diaminohexane and adipic acid, producing a by-product of water molecules. It has the following structural formula.



Properties

→ Polyethylene is inexpensive, weatherproof and relatively resistant to chemicals.

→ There are two main types of polyethylene which have different properties. Low-density polyethylene (LDPE) is semi-rigid while high density polyethylene (HDPE) is fluid.

→ Nylon is strong and relatively resistant to moisture absorptivity. It is longer lasting than polyethylene, resistant to chemicals and is used to make nylon fibre.

Applications

→ LDPE is used to produce products such as plastic soft drink bottles, flexible water pipes and cling wrap. HDPE's fluidity make it an appropriate material for producing shopping bags, plastic crates and drums for storage.

→ Nylon is very versatile in its manufacturing uses. It is a common input for clothing, can be used for injection-moulded parts for vehicles and also as reinforcement for rubber tyres.

→ Nylon is also used as the main material input for nylon thread which has a myriad of uses, including stitching for clothes and the production of rope.

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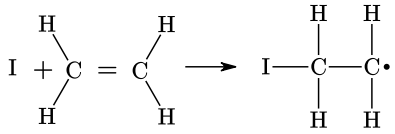
♦ Mean mark 50%.

Step 1:

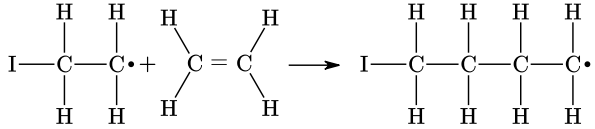
→ An organic peroxide (initiator – I) attacks the ethylene molecule, breaking its double bond and forming a free radical.

→ An unpaired reactive electron can be seen on the end of the growing chain (initiation).



Step 2:

→ The free radical will then attack another ethylene molecule, increasing the length of the growing polymer chain (propagation).



Step 3:

→ Chain length increases in this fashion until two growing chains combine (termination).