FSc / ICS Part-II Chemistry — Punjab Board

CHAPTER 14
Macromolecules

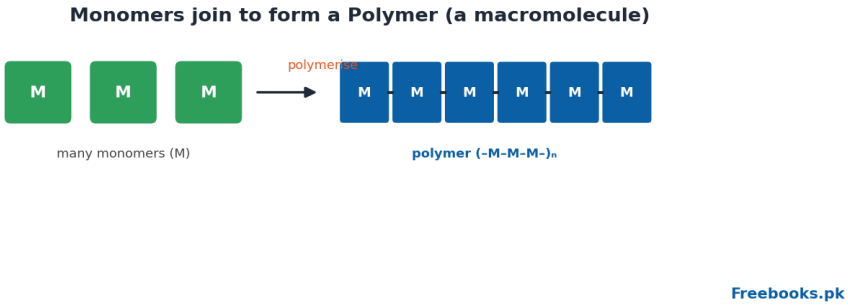

Figure 14.1 — Many small monomers join to form a giant polymer molecule.

1. Chapter Overview

Macromolecules are very large molecules built by joining together many small repeating units. The most important macromolecules are polymers, formed when hundreds or thousands of small molecules called monomers link together. Polymers are all around us: natural polymers such as starch, cellulose, proteins and natural rubber, and synthetic polymers such as polythene, PVC, nylon and polyester. This chapter explains how polymers form, the two main types of polymerisation, the difference between thermoplastics and thermosetting plastics, and the uses and environmental effects of these materials.

2. Learning Objectives

- Define macromolecule, polymer and monomer.
- Distinguish addition and condensation polymerisation.
- Give examples of natural and synthetic polymers.
- Distinguish thermoplastic and thermosetting plastics.
- Describe important polymers such as polythene, PVC, nylon and Bakelite.
- Discuss the uses and environmental impact of plastics.

3. Key Concepts

3.1 Polymers and Monomers

A polymer is a large molecule made of many repeating units joined together; the small molecules that join up are called monomers, and the process is called polymerisation. For example, thousands of ethene molecules (the monomer) join to form polythene (the polymer). Because polymers are so large, they are also called macromolecules or 'giant molecules'.

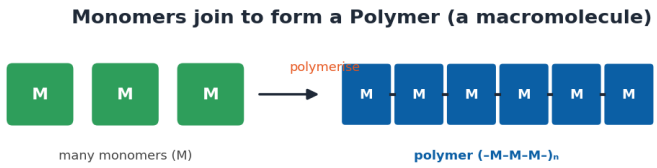

Figure 14.2 — Polymerisation: monomers → polymer.

> **Memory Trick**
>
> **Remember:** 'Poly' = many, 'mono' = one, 'mer' = part. A polymer is 'many parts'; a monomer is 'one part'.

3.2 Two Types of Polymerisation

There are two main ways in which monomers join together:

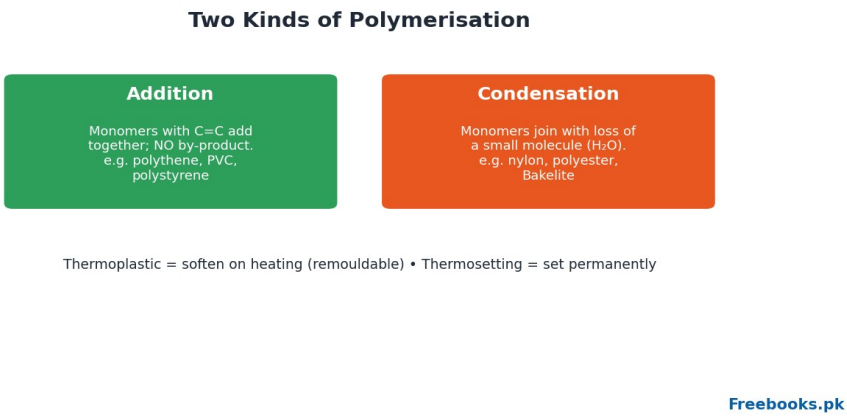

Figure 14.3 — Addition versus condensation polymerisation.

Addition polymerisation. Monomers that contain a carbon–carbon double bond simply add to one another, with no other product formed. Examples are polythene (from ethene), PVC (from vinyl chloride) and polystyrene (from styrene).

Condensation polymerisation. Monomers join with the loss of a small molecule (usually water) at each link. Examples are nylon and polyester (both from two different monomers) and Bakelite.

3.3 Natural and Synthetic Polymers

Natural polymers are made by living things: examples are starch and cellulose (polymers of glucose), proteins (polymers of amino acids), natural rubber and DNA. Synthetic polymers are made in industry from petroleum products: examples are polythene, PVC, nylon, polyester, Bakelite and synthetic rubber. Synthetic polymers can be designed to have almost any property — flexible or rigid, transparent or opaque, insulating or tough.

3.4 Thermoplastic and Thermosetting Plastics

Plastics are synthetic polymers that can be moulded into shape. They are of two kinds. Thermoplastics (such as polythene and PVC) soften on heating and can be melted and remoulded again and again, because their chains are only weakly held together. Thermosetting plastics (such as Bakelite) set permanently on first heating and cannot be softened again, because their chains become joined by strong cross-links into a rigid network.

Feature	Thermoplastic	Thermosetting
On heating	Softens, can be remoulded	Sets permanently, chars
Structure	Long chains, weak forces	Cross-linked network
Reusable	Yes (can be recycled)	No
Examples	Polythene, PVC, polystyrene	Bakelite, melamine, epoxy

Teacher's Note

A neat memory hook: 'thermoPLASTIC stays plastic (can be reshaped); thermoSET is set

Feature	Thermoplastic	Thermosetting
forever.'		

3.5 Some Important Polymers

Polymer	Monomer / type	Main uses
Polythene	ethene (addition)	Bags, bottles, sheets, insulation
PVC	vinyl chloride (addition)	Pipes, cable covering, floor tiles
Polystyrene	styrene (addition)	Packaging, disposable cups
Nylon	condensation (2 monomers)	Fibres, ropes, fabrics
Polyester	condensation (2 monomers)	Clothing fibres, bottles (PET)
Bakelite	phenol + methanal (condensation)	Electrical fittings, handles

3.6 Uses and Environmental Impact

Polymers are cheap, light, strong, and resistant to water and corrosion, which is why they have replaced many traditional materials in packaging, clothing, building and electronics. However, most synthetic plastics are non-biodegradable, so they persist in the environment and cause pollution. Careful use, recycling of thermoplastics and the development of biodegradable plastics are important ways to reduce this problem.

4. Important Definitions

Term	Definition
Macromolecule	A very large molecule built from many repeating units.
Polymer	A large molecule made of many repeating monomer units.
Monomer	The small molecule that joins to form a polymer.
Addition polymerisation	Joining of unsaturated monomers with no by-product.
Condensation polymerisation	Joining of monomers with loss of a small molecule (e.g. water).
Thermoplastic	A plastic that softens on heating and can be remoulded.

5. Formulas / Rules

Must-Know Facts

Polymer = many monomers; polymerisation is the joining process.
Addition: unsaturated monomers, no by-product (polythene, PVC, polystyrene).
Condensation: loss of a small molecule (nylon, polyester, Bakelite).
Thermoplastic = remouldable; thermosetting = set permanently.
Natural: starch, cellulose, protein, rubber, DNA; Synthetic: plastics/fibres.

6. Diagrams / Illustrations

Key diagrams for revision:

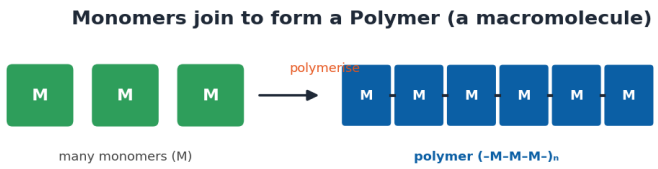

Diagram 1 — Monomer to polymer.

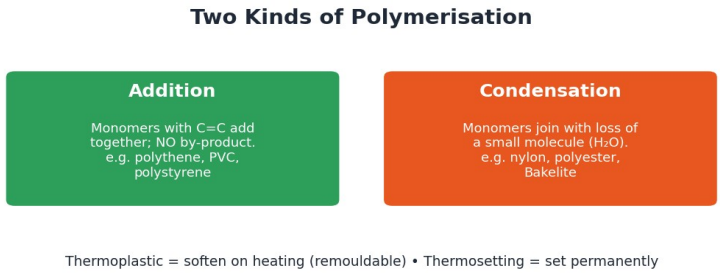

Diagram 2 — Addition vs condensation.

7. Solved Examples

Example 1 — Type of polymerisation

Q: Is the formation of polythene addition or condensation polymerisation?

Solution: It is addition polymerisation. Ethene molecules (which contain C=C) simply add to one another with no small molecule being lost.

Example 2 — Classifying a plastic

Q: Why can polythene be recycled but Bakelite cannot?

Solution: Polythene is a thermoplastic; its chains are weakly held, so it softens on heating and can be remoulded. Bakelite is thermosetting; its chains are cross-linked into a rigid network that does not soften, so it cannot be reshaped.

Example 3 — Natural polymer

Q: Name the monomer of starch and of protein.

Solution: Starch is a polymer of glucose; proteins are polymers of amino acids.

8. Short Questions

Q1. Define a polymer.
Ans. A large molecule made of many repeating monomer units.

Q2. What is a monomer?
Ans. The small molecule that joins with others to form a polymer.

Q3. Differentiate addition and condensation polymerisation.
Ans. In addition, unsaturated monomers join with no by-product; in condensation, monomers join with loss of a small molecule such as water.

Q4. Give two natural polymers.
Ans. Starch and protein (also cellulose, rubber, DNA).

Q5. Give two synthetic polymers.
Ans. Polythene and nylon (also PVC, polyester, Bakelite).

Q6. Differentiate thermoplastic and thermosetting plastics.
Ans. Thermoplastics soften on heating and can be remoulded; thermosetting plastics set permanently and cannot.

Q7. Name the monomer of PVC.
Ans. Vinyl chloride.

Q8. Why are plastics an environmental problem?
Ans. Most are non-biodegradable, so they persist and cause pollution.

9. Long Questions

Q1. Distinguish between addition and condensation polymerisation with examples.

Polymers are formed by joining many monomers, and this can happen in two different ways. In addition polymerisation the monomers contain a carbon–carbon double bond, and they simply add to one another when the double bond opens; no other molecule is produced, so the polymer has exactly the same empirical formula as the monomer. Common examples are polythene (from ethene), PVC (from vinyl chloride) and polystyrene (from styrene). In condensation polymerisation the monomers usually contain two reactive groups, and they join with the elimination of a small molecule — most often water — at every link. Because a small molecule is lost, the polymer does not have the same formula as the monomers. Common examples are nylon and polyester, each made from two different monomers, and Bakelite, made from phenol and methanal. Thus the key difference is whether or not a small molecule is given off during polymerisation.

Q2. Compare thermoplastic and thermosetting plastics.

Plastics are moulded synthetic polymers, and they fall into two classes that behave very differently on heating. Thermoplastics are made of long polymer chains held together only by weak forces; when heated they soften and can be melted and remoulded into a new shape, and this can be repeated many times, which also makes them easy to recycle. Familiar thermoplastics are polythene, PVC and polystyrene. Thermosetting plastics, by contrast, form strong chemical cross-links between their chains during their first heating and moulding, so they set into a hard, rigid, three-dimensional network; once set they cannot be softened or remoulded, and on strong heating

they simply char. Familiar thermosetting plastics are Bakelite, melamine and epoxy resins. Because of these differences, thermoplastics are used where reshaping and recycling are useful, while thermosetting plastics are used where permanent hardness and heat resistance are needed, such as in electrical fittings.

Q3. Discuss the importance and environmental impact of polymers.

Polymers have become some of the most important materials in modern life because they are cheap to make, light in weight, strong, easily shaped, and resistant to water and corrosion. They are used in packaging (polythene bags and bottles), building (PVC pipes and fittings), clothing (nylon and polyester fibres), electrical insulation, medical equipment and countless everyday objects, often replacing heavier or more expensive materials such as metal, wood and glass. However, this usefulness comes with a serious drawback: most synthetic polymers are non-biodegradable, meaning that micro-organisms cannot break them down, so discarded plastics remain in the environment for a very long time, litter the land and oceans, and harm wildlife. Burning them can release toxic gases. The impact can be reduced by using plastics responsibly, by recycling thermoplastics, and by developing biodegradable and plant-based plastics. Balancing the great benefits of polymers against their environmental cost is one of the important challenges of chemistry today.

10. Multiple Choice Questions (MCQs)

1. A polymer is made of many:
(A) atoms (B) monomers (C) ions (D) isotopes

2. Polythene is formed by ___ polymerisation:
(A) condensation (B) addition (C) substitution (D) elimination

3. Which is a condensation polymer?
(A) polythene (B) PVC (C) nylon (D) polystyrene

4. The monomer of PVC is:
(A) ethene (B) vinyl chloride (C) styrene (D) glucose

5. Which is a natural polymer?
(A) nylon (B) starch (C) PVC (D) Bakelite

6. A plastic that can be remoulded on heating is:
(A) thermosetting (B) thermoplastic (C) cross-linked (D) elastomer

7. Bakelite is a ___ plastic:
(A) thermoplastic (B) thermosetting (C) natural (D) biodegradable

8. Proteins are polymers of:
(A) glucose (B) amino acids (C) nucleotides (D) fatty acids

9. In condensation polymerisation, the small molecule usually lost is:
(A) CO_2 (B) H_2O (C) O_2 (D) NH_3

10. Most synthetic plastics harm the environment because they are:
(A) biodegradable (B) non-biodegradable (C) soluble (D) volatile

MCQ Answer Key

1-B 2-B 3-C 4-B 5-B 6-B 7-B 8-B 9-B 10-B

11. Quick Revision / Summary

- Polymer = many monomers joined; macromolecule = giant molecule.
- Addition polymerisation: unsaturated monomers, no by-product (polythene, PVC).
- Condensation polymerisation: loses a small molecule (nylon, polyester, Bakelite).
- Natural polymers: starch, cellulose, protein, rubber; synthetic: plastics/fibres.
- Thermoplastic = remouldable; thermosetting = set permanently.
- Plastics are useful but mostly non-biodegradable → pollution.

12. Exam Tips

Teacher's Note

Define monomer and polymer precisely, with one example each.
Contrast addition vs condensation by whether a small molecule is lost.
Learn the thermoplastic vs thermosetting table — a common question.
Know monomers of polythene (ethene) and PVC (vinyl chloride).
Mention 'non-biodegradable' when discussing environmental impact.