CHEMISTRY
O - LEVEL

CAMBRIDGE UNIVERSITY EXAMINATIONS

General Certificate of Education Ordinary Level
O – LEVEL 5070. Notes, P1, P2 and P4

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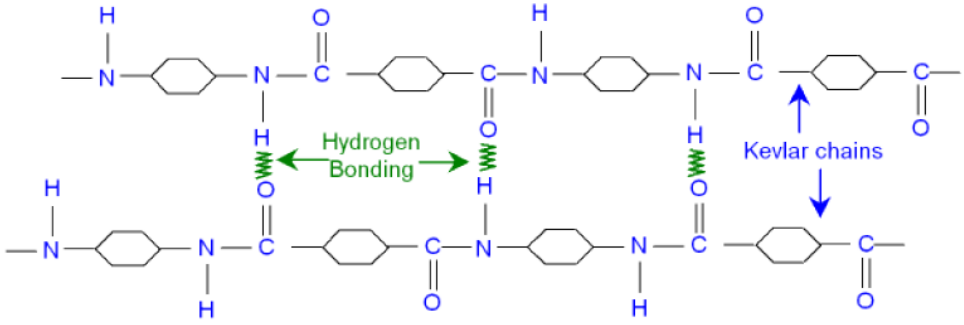
Chapter

Polymerization



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POLYMERS

Polymer is a large molecule made by joining together many small molecules. Large molecule is called polymer and the small molecules are known as monomers

Polymerisation

is the process of making polymers from monomers.

Types of polymerisation

There are two types of polymerization.

- Addition polymerization
- Condensation polymerisation

ADDITION POLYMERISATION

In addition polymerization, small molecules (monomers) join together to form one large molecule(polymer) as the only product.

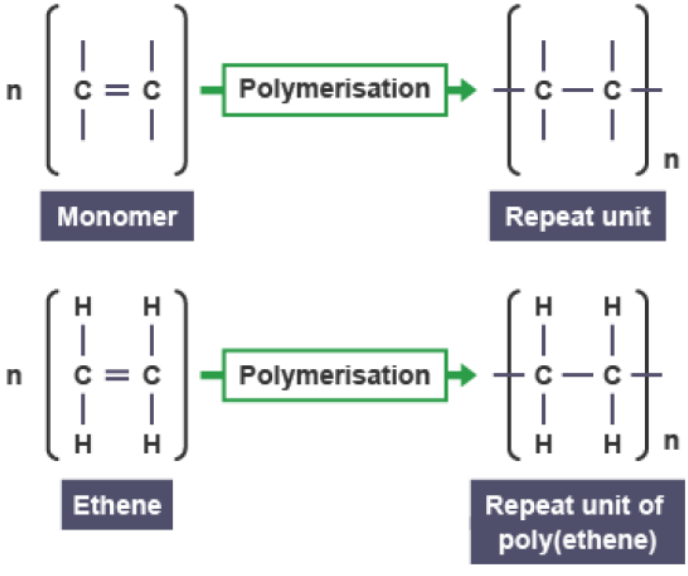
It is a chemical reaction in which simple molecules (monomers, which are mostly unsaturated) are added to each other to form long-chain molecules (polymers) without by-products.

Repeat Unit:- *A **repeat unit** or **repeating unit** is a part of a polymer whose repetition would produce the complete polymer chain. It* is the simplest part of the polymer which is repeated many times to form the polymer

When drawing repeat unit, you need to:

- change the double bond in the monomer to a single bond in the repeat unit
- add a bond to each end of the repeat unit

e.g.



Example: Formation of poly(ethene) from ethene

Each Ethene has double bond. So these unsaturated monomers add up with each by addition

polymerisation to form bigger polymer(polyethene).

Since the many monomers join together to form a single polymer. The molecular weight of the polymer so formed is thus the total of the molecular weights of all monomer units combined.

Finding Polymer from Repeat unit. From repeat unit, to find the monomer formula, we add double bond between C – C and remove the bonds on each of their sides.

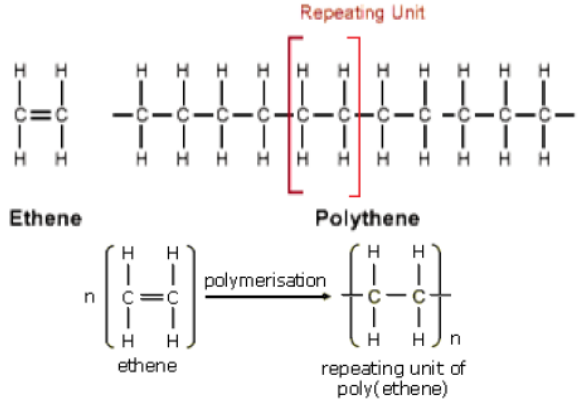


Table. Addition polymers

Polymer name	Monomer(s)	Polymer	Use
Polyethylene	$CH_2=CH_2$ (ethene)	$-CH_2-CH_2-$	Most common polymer. Used in bags, wire insulation, and squeeze bottles
Polypropylene	$CH_2=CH$ with CH_3 (1-propene)	$-CH_2-CH-$ with CH_3	Fibers, indoor-outdoor carpets, bottles
Polystyrene	$CH_2=CH$ with benzene (styrene)	$-CH_2-CH-$ with benzene	Styrofoam, molded objects such as tableware (forks, knives and spoons), trays, videocassette cases.
Poly(vinyl chloride) (PVC)	$CH_2=CH$ with Cl (vinyl chloride)	$-CH_2-CH-$ with Cl	Clear food wrap, bottles, floor covering, synthetic leather, water and drain pipe
Polytetrafluoroethylene (Teflon)	$CF_2=CF_2$ (tetraflouroethene)	$-CF_2-CF_2-$	Nonstick surfaces, plumbing tape, chemical resistant containers and films

CONDENSATION POLYMERISATION

In condensation polymer, monomers are combined together, to form polymer, losing small molecules as by products such as H_2O which escapes as a gas.

Generally in condensation polymerization,

- the monomers have functional groups (like alcohol, amine, or carboxylic acid groups)Instead of

double bonds

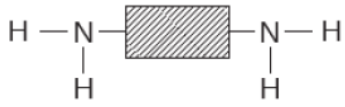
- Each monomer has at least functional groups.

A familiar example of a condensation polymer is *nylon*, which is obtained from the reaction of two monomers

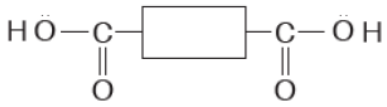
Nylon

- The monomers used are Dicarboxylic acids (acid with 2 –COOH groups) and Diamines (with 2 $–NH_2$ groups)
- The monomers are joined together by amide linkages to form a polyamide. A molecule of water is eliminated.

So Dicarboxylic acid and diamine undergo condensation polymerisation to form nylon.

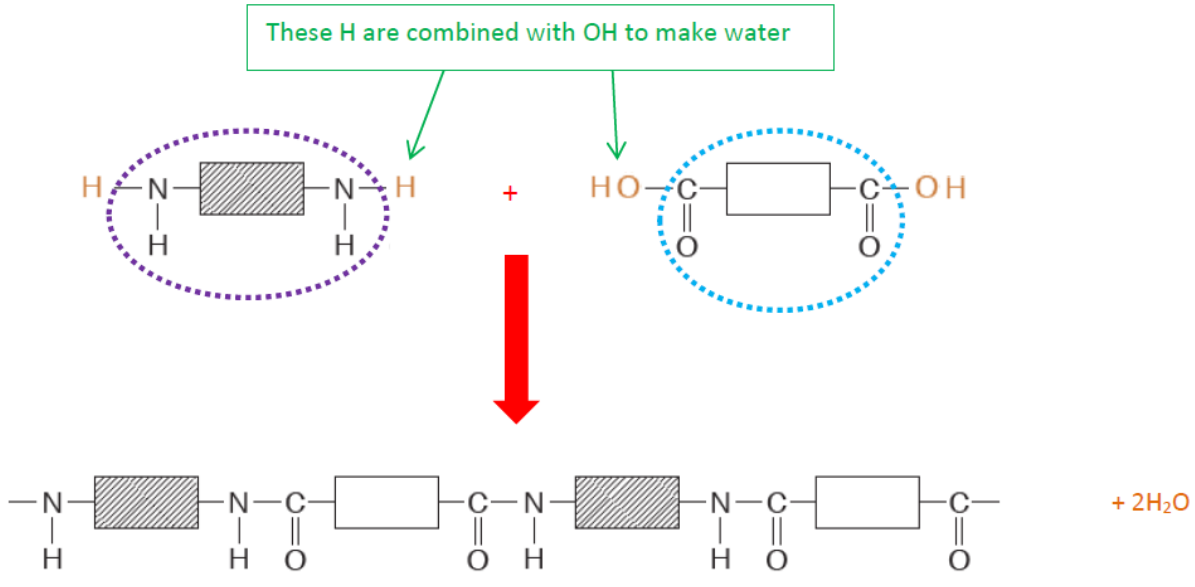


Diamine



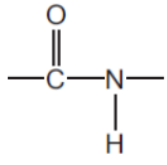
Dicarboxylic acid

When dicarboxylic acid is treated with diamine for polymerization, OH from acid and H from diamine are removed to make water whereas remaining parts of molecules combine together to form nylon and this process continue as long as we want.



Nylon makes extremely strong threads and fibers because its long-chain molecules have stronger intermolecular forces

The linkage between monomers in nylon is called **amide linkage**.

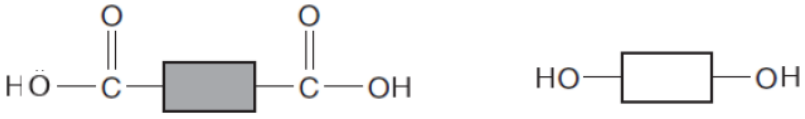


Therefore we can also call nylon as **polyamide**. The diacid and diamine units alternate in the polymer chain.
Today, we use nylon as:

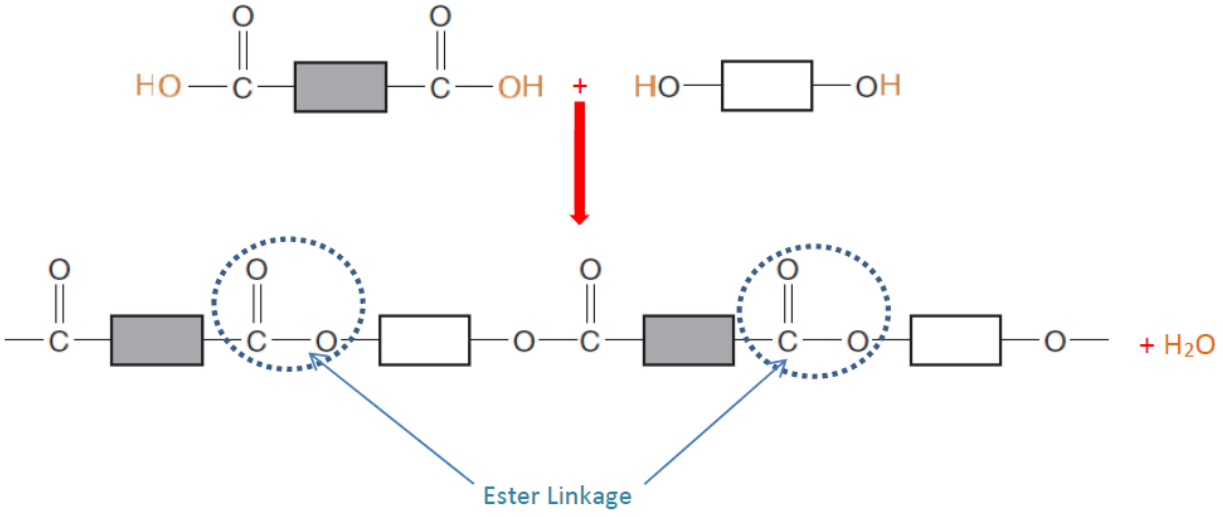
- Used in carpets, clothing, luggage, car parts, tights.
- Bedspreads, curtains, upholstery
- Hoses, Tire cord, seat belts, parachutes, ropes, camping equipment..

Terylene

A polyester is made by a reaction involving an acid with two -COOH groups, and an alcohol with two -OH groups. Dicarboxylic acid (acid with 2 –COOH groups) and diol (alcohol with 2 –OH groups) undergo condensation polymerisation to form terylene.



When we polymerize di-acid and di-alcohol to form terylene, every acid molecule releases OH group and every alcohol molecule releases H thus water is removed as shown in fig.



The linkage between the monomers in terylene is called **ester linkage**. Therefore we can call this polymer as **polyester**.
Today, we use terylene in fabrics as it's strong, resists stretching and sinking and doesn't crumple when washed.

PLASTICS

- Plastics are non-biodegradable – they cannot be decomposed by bacteria. Therefore, many plastics waste will pollute the Earth
- Plastics produce toxic gases (such as hydrogen chloride) when burnt and this contribute to acid rain.
- Plastics produce carbon dioxide when burnt – increases global warming.
- Plastics that require CFC during production may contribute to global warming when the CFC is allowed to escape.

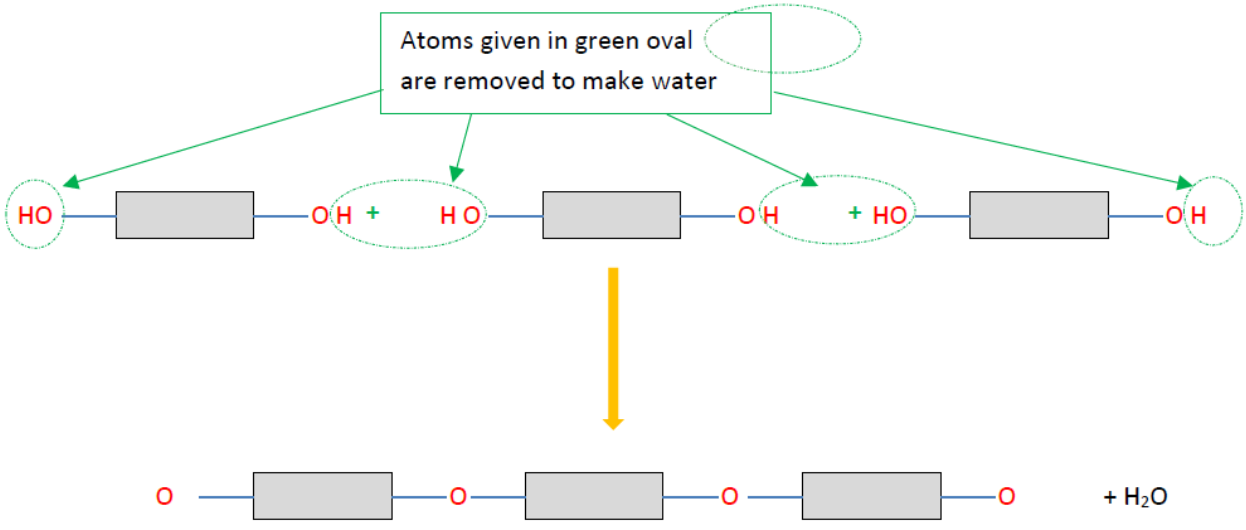
Natural Macromolecules

CARBOHYDRATES

Carbohydrates contain **carbon**, **hydrogen** & **oxygen**. General formula is $C_n(H_2O)_n$.

The simplest carbohydrate is $C_6H_{12}O_6$ (glucose).

Glucose polymerise each other to form **starch**.

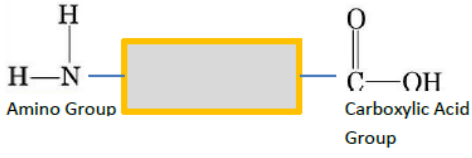


Starch can also be broken down into glucose by heating with **sulfuric acid**. This is **HYDROLYSIS**.

PROTEINS

Proteins have similar linkage to that of a nylon. Only difference is that their monomers are **amino acids**. These monomers are joined together by condensation polymerisation. Proteins can be called as **polyamide (** or polypeptide) as it has **amide linkage(** or peptide linkage).

Proteins can also be broken down into amino acids by **boiling protein with sulfuric acid**. This adds water molecule into the polymer.

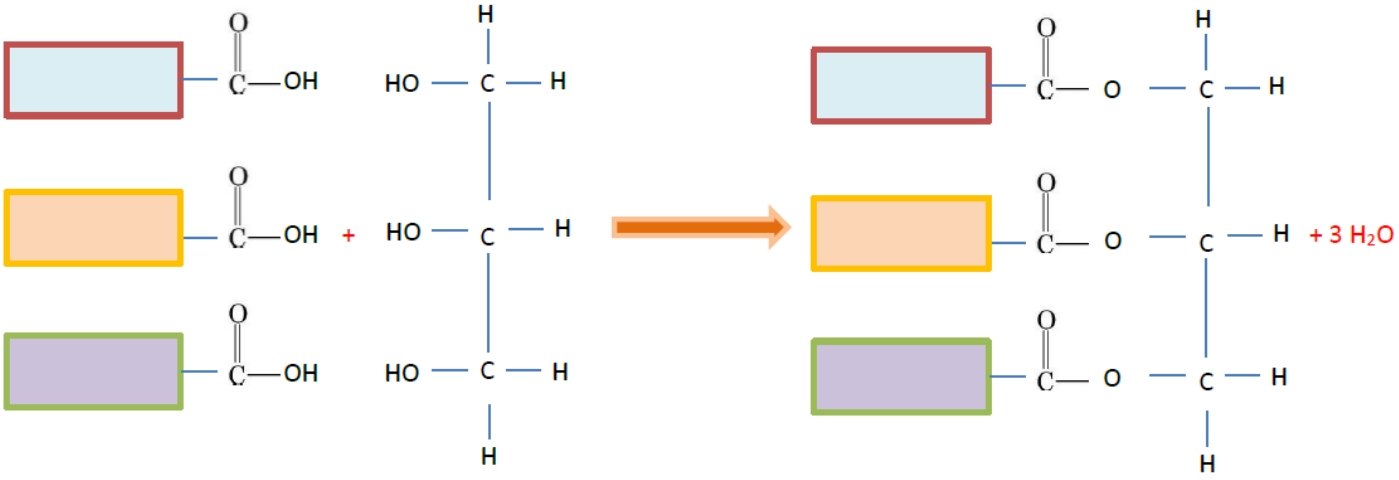


Amino acids (one molecule is shown above) contain amino group and carboxylic acid group. Amino releases H whereas carboxylic acid releases OH to make water, remaining parts combine together to form protein.

The structure of a section of a protein can be represented as:

FATS

Fats have similar linkage to that of a terylene (**ester linkage**). Only difference is that their monomers consist of glycerol and fatty acids. In terylene, monomers are dicarboxylic acids and dialcohols.



HYDROLYSIS of fat

Fat can also be broken down into (sodium salts of)fatty acids and glycerol by **boiling it with an acid (or alkali)**. This is **HYDROLYSIS** of fat.