POLYMERISATION

General A process in which small molecules called monomers join together into large molecules consisting of repeating units.

There are two basic types **ADDITION** & **CONDENSATION**

ADDITION POLYMERS

- all the atoms in the monomer are used to form the polymer
- occurs with alkenes
- mechanism can be **free radical** or **ionic**

Examples

	Formula of monomer	*Formula of polymer*	*Use(s)*
poly(ethene)	**n CH_2=CH_2** ——>	**— (CH_2 — CH_2)$_n$ —**	
poly(phenylethene)			
poly(chloroethene)			
poly(tetrafluoroethene)			
poly(ethenyl ethanoate)			

Preparation Many are prepared by a free radical process involving high pressure, high temperature and a catalyst. The catalyst is usually a substance (eg an organic peroxide) which readily breaks up to form radicals which, in turn, initiate a chain reaction.

Another famous type of catalyst is a Ziegler-Natta catalyst (named after the scientists who developed it). Such catalysts are based on the compound $TiCl_4$.

Properties

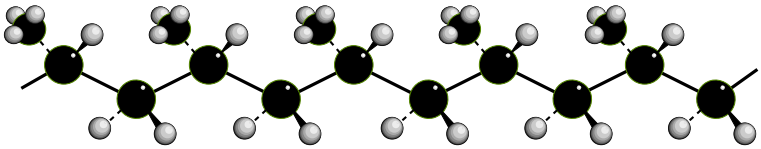
Physical These can be varied by changing the reaction conditions (pressure, temperature etc).

Chemical Are based on the functional groups within their structure.

e.g. *poly(ethene) is typical; it is fairly inert as it is basically a very large alkane. This means it is resistant to chemical attack and non-biodegradable.*

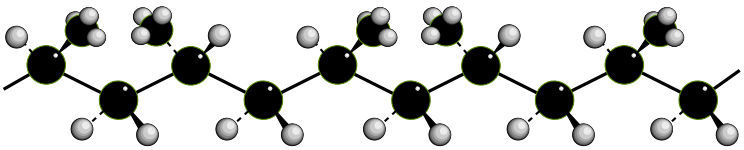
Structures Polymers based on substituted alkenes (propene and phenylethene) can exist in a variety of forms.

POLY(PROPENE)

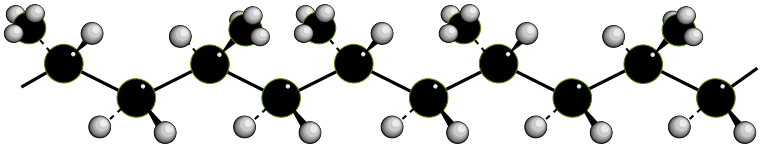


ISOTACTIC
substituents on same side
most desirable properties

Has the highest melting point because chains can get closer together giving greater intermolecular attraction



SYNDIOTACTIC
substituents on alternate sides



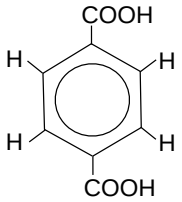
ATACTIC
random arrangement
most likely outcome

CONDENSATION POLYMERS

- monomers join up the with expulsion of small molecules
- not all the original atoms are present in the polymer
- examples include **polyamides (nylon)**
  polyesters (terylene)
  peptides
  starch
- reactions occur between **diprotic carboxylic acids** and **diols**
  diprotic carboxylic acids and **diamines**
  amino acids

POLYESTERS

Terylene



Reagents — *terephthalic acid* **$HOOC\text{-}C_6H_4\text{-}COOH$**
ethane-1,2-diol **$HOCH_2CH_2OH$**

Reaction — *Esterification*

Eliminated — *water*

Product — *poly(ethylene terephthalate)* *'Terylene', 'Dacron'*

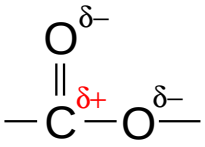
Repeat unit — $— [\text{-}OCH_2CH_2OOC(C_6H_4)CO\text{-}]_n —$

Structure

Equation **$HOCH_2CH_2OH + HOOC\text{-}C_6H_4\text{-}COOH \longrightarrow \text{-}[\text{-}OCH_2CH_2OOC(C_6H_4)CO\text{-}]_n\text{-} + n\ H_2O$**

Properties

- contain an **ester link**
- can be broken down by hydrolysis
- the C-O bond breaks
- behaves as an ester
- biodegradable



Uses

-
-

POLYAMIDES

Nylon-6,6

Reagents — *hexanedioic acid* **$HOOC(CH_2)_4COOH$**; *hexane-1,6-diamine* **$H_2N(CH_2)_6NH_2$**

Mechanism — *Addition-elimination*

Eliminated — *water*

Product — *Nylon-6,6* — *two repeating units, each with 6 carbon atoms*

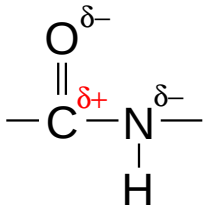
Repeat unit — $—[-NH(CH_2)_6NHOC(CH_2)_4CO-]_n—$

Structure

Equation — $\mathbf{HOOC(CH_2)_4COOH + H_2N(CH_2)_6NH_2 \longrightarrow -[-NH(CH_2)_6NHOC(CH_2)_4CO-]_n- + \mathit{n}\ H_2O}$

Properties

- contain a **peptide (or amide) link**
- can be broken down by hydrolysis
- the C-N bond breaks
- behave as amides
- biodegradable
- can be spun into fibres for strength



Uses

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-

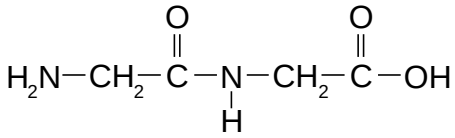
Q.1 *Find out details of the synthesis of Nylon-6 .*

Peptides

- formed by joining amino acids together
- are examples of **polyamides**
- amino acids have two main functional groups **-COOH** carboxylic acid; **-NH_2** amine
- amino acids can join together using a **peptide link**
- **dipeptide** two amino acids joined together; **tripeptide** three amino acids joined; **polypeptide** many amino acids joined together
- a **protein** is a polypeptide with a **large relative molecular mass** (>10000)
- **peptides/proteins can be broken down** into the original amino acids **by hydrolysis**

Q.2 *Look up the structures of alanine and glycine. Draw the structure of the **dipeptide** formed when they react together.*

Q.3 *Look at the structure of the following dipeptide.*



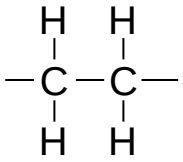
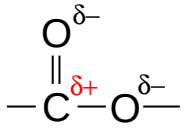
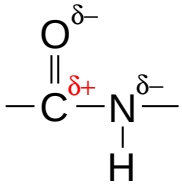
How many different amino acids formed the dipeptide? Draw any structures.

*Give the **formulae** of the organic products formed when the dipeptide is hydrolysed using...*

a) NaOH(aq)

b) HCl(aq)

POLYMER FORMATION - A SUMMARY

	ADDITION	CONDENSATION
Monomers	**ALKENES** C=C bond	**ALCOHOLS** + **ACIDS** **AMINES** + **ACIDS** **AMINO ACIDS** **AMINES** + **ACYL CHLORIDES**
Process	All the atoms in the original monomers end up in the polymer	Monomers join up with the expulsion of a small molecule (e.g. water)
Bonding	ALKANE LINK 	ESTER LINK  AMIDE (PEPTIDE) LINK 
Reactivity	**UNREACTIVE** - NON-POLAR Resistant to hydrolysis	**REACTIVE** - POLAR BONDS Hydrolysed by acids and alkalis reflux with acid RCOOH + ROH reflux with alkali $RCOO^-Na^+$ + ROH
Uses	Packaging Insulation	Clothing Ropes
Examples	poly(ethene) poly(propene) poly(phenylethene) poly(chloroethene)	nylon 6,6 Terylene peptides