



Polymer structures

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Polymer structures are very complex and many of the structures are difficult to ascertain with a high degree of confidence. If we have made any mistakes then we would be glad to hear from readers with corrections and/or suggestions for additional structures to include.

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**TANGRAM
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Specialist Consulting Engineers for Plastics Processing.

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Company Profile

Tangram Technology Ltd. is a technology based consultancy dealing with the needs of the plastics processing industry.

Tangram provides high quality energy and environmental management, change management, technical writing, training, product design consultancy and field services for these diverse industries.

Our client base consists of some of the largest plastics processing companies in the world, PVC-U window systems designers, window fabricators and computer services companies. We carry out extensive work for the UK Government (DEFRA and BIS), the EC and the World Bank in a variety of fields.

Tangram is technology based consultancy, not a management consultancy. We supply specialist technical knowledge needed by our client base.

Products and Services

Energy and Environmental Management

We survey and assess plastics processing factories for energy efficiency and provide detailed programmes for energy efficiency improvements. We manage the energy reduction process inside the factory. We develop, install and externally monitor Environmental Management Systems

Energy Management Surveys, Development and installation of Energy Management Systems, Development and installation of Environmental Management Systems, Training for Energy Managers.

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We develop and implement energy management systems and strategies, manufacturing strategies, quality systems and Health and Safety management systems to meet the requirements of the latest legislation. We can also provide project management services for similar large projects.

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Introduction

Polymers

Polymers are long chain molecules, i.e., they are made up of many 'monomers', where the 'monomer' is the repeating element of the long chain. Understanding the structure of the monomer is the key to understanding the structure and, more importantly, the properties of the resulting polymer.

This publication aims to outline most of the monomers for the common polymers lastics common e structure of most monomers is easy to

Polymers versus plastics

We take a very simple view on the terminology of 'polymers' and 'plastics' and do not regard these words as interchangeable (although some do).

- A polymer is a long chain molecule in the pure state, i.e., a collection of long chain molecules. Very few polymers are processed in this pure state. Most are compounded with additives, processing aids and, at a minimum, colouring agents.
- A plastic is a polymer when it has been compounded with these additives and is ready for processing.

Drawing the structures

The conventions for drawing and naming chemicals are well laid down by International organisations and these are very suitable for the chemists who are familiar with them.

However, many people in the plastics industry do not have a chemistry background and find the standard diagrams hard to read and understand.

As an example, the structure of PA 6 (Nylon 6) should be written as:

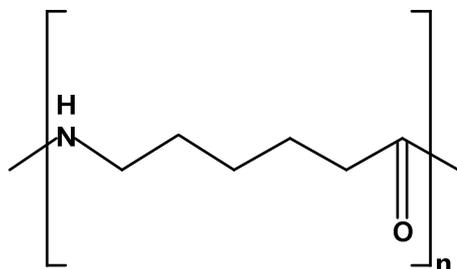


Figure 1: PA 6

This does not show the carbon and hydrogen atoms as they are assumed to be present at the intersections of the lines. An alternative representation of the structure to show the location of the carbon and hydrogen atoms would be:

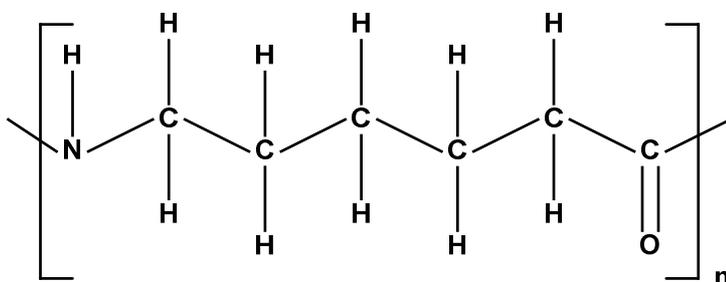


Figure 2: PA 6 – alternative representation 1

This shows the angular nature of the carbon-carbon bonds as well as all the individual atoms.

It is also possible to draw this same structure as:

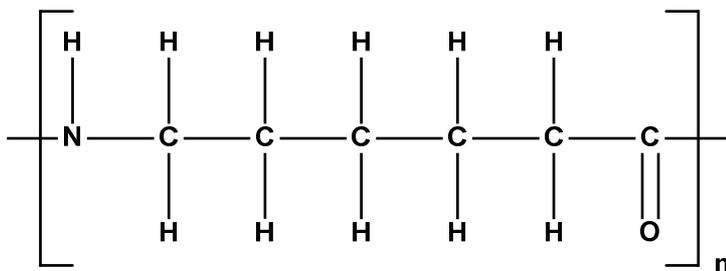


Figure 3: PA 6 – alternative representation 2

This does not show the angular nature of the carbon-carbon bonds but does show all the individual atoms.

For some structures, such as PA 6, the repeated CH_2 features can be shortened to give the representation:

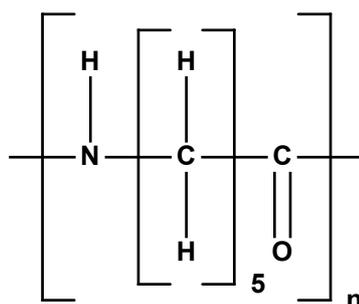


Figure 4: PA 6 – alternative representation 2

In this document, as a general rule, we will use the simple form shown in Figure 3 as this is easy to understand and visualise for non-chemists. We will sometimes use the form shown in Figure 4 when the number of repeating units is large and the structure becomes unnecessarily complex.

The benzene ring

The benzene ring appears in many polymer structures and the full representation of the benzene ring is as shown in Figure 5

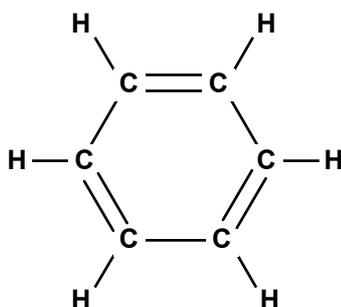


Figure 5: The 'classic' structure of the benzene ring

This shows the 'ring' of 6 carbon atoms with the associated double bonds and hydrogen atoms. The 'shorthand' form of this is much easier to draw and this is shown in Figure 6:

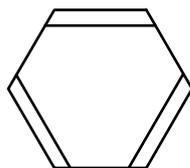


Figure 6: Short form of the classic structure

This representation is now regarded as largely incorrect because the double bonds and the hydrogen atoms are as not clearly delineated as this drawing would imply. In fact the hydrogen atoms exist more as a cloud and the current preferred representation is shown in Figure 7:

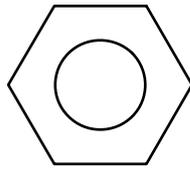


Figure 7: Closer to reality

This is the representation that will be used in all polymers containing a benzene ring structure.

Where do we start?

The repeating nature of the monomer and the length of some of the monomers means that it is possible for monomers to look very different but to be exactly the same. Simply 'starting' the monomer at a different position can make the representations look very different (although they are exactly the same when continuously repeated). Two representations of PC (polycarbonate) are shown below:

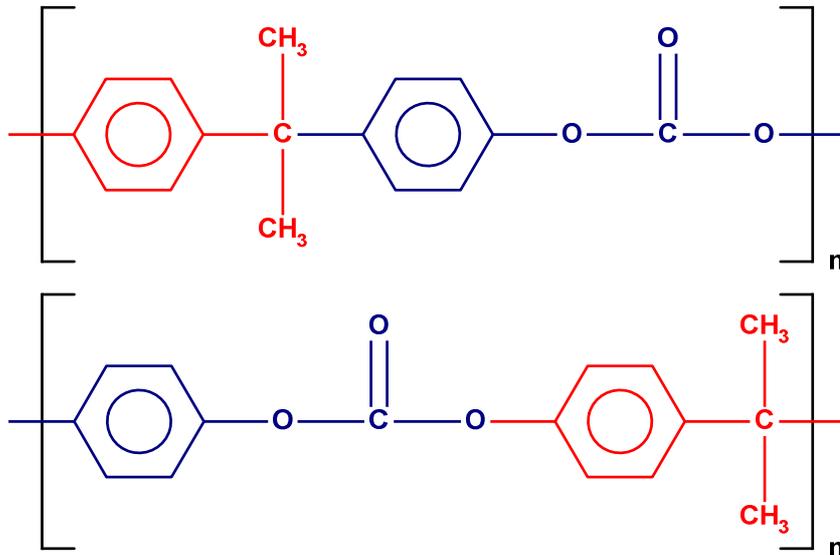


Figure 8: Two views of Polycarbonate

These monomers look very different but are identical when repeated in the polymer chain. Readers are advised to be wary of where the monomer starts when looking at the structure drawings.

Homopolymers and copolymers

Homopolymers consist of a single monomer (A) that is repeatedly joined together to form the long chain of the polymer molecule:

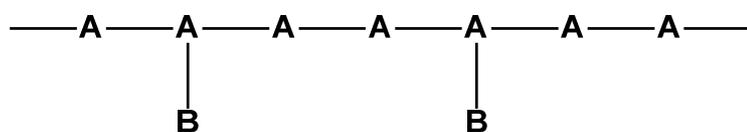


Copolymers consist of two different monomers (A and B) that are alternated when joined together to form the long chain of the polymer molecule:



In some copolymers the ratio of A to B is not 1:1, i.e. the B molecule is repeated less often than the A molecule and we will indicate this where this is the case.

Graft copolymers are copolymers with a branched structure in the long chain of the polymer molecule:



Terpolymers consist of three different monomers (A, B and C) that are alternated when joined together to form the long chain of the polymer molecule:



It is also possible that terpolymers will not have a ratio 1:1:1 and we will indicate where this is the case.

Isotactic, atactic and syndiotactic

The structure is not only important in terms of the atoms that make it up but the actual layout of the atoms around the main backbone carbon chain can be also be significant. The repeating structure of PS is shown below in two forms, the atactic and the syndiotactic

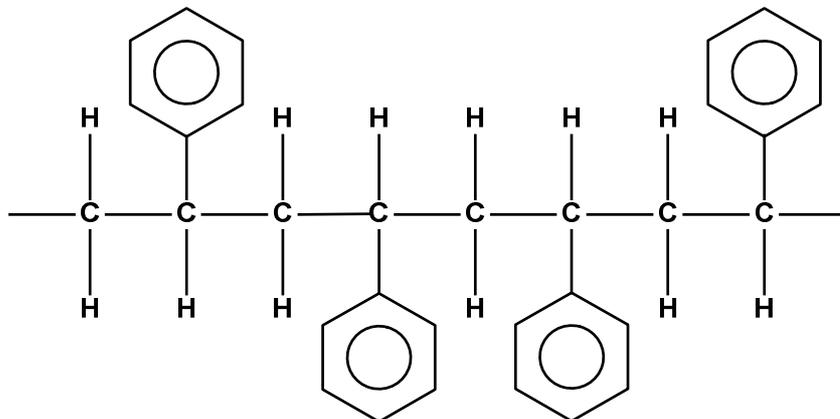


Figure 9: Atactic PS - irregular structure and cannot pack to form crystals

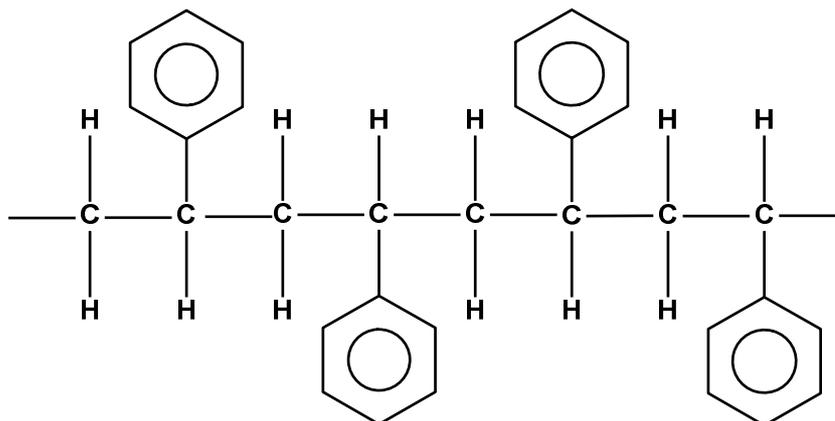


Figure 10: Syndiotactic PS - regular structure and can pack to form crystals
Where the forms vary significantly then this will be indicated.

The Periodic Table of Thermoplastics

The general layout of this document will follow the Periodic Table of Thermoplastics (see right for a simplified version). A full version is available for free download from www.tangram.co.uk.

This was developed by Tangram Technology Ltd. to provide a framework for looking at and classifying the main families of thermoplastics. This will also be used as a framework for the polymer structures. As a general rule, we will move along the rows and then down to the columns but polymers from a single family will all be treated together. As with the Periodic Table of Thermoplastics, polymers will be colour coded to indicate the broad family to which they belong.

Polymer structures are very complex and many of the structures are difficult to ascertain with a high degree of confidence. If we have made any mistakes then we would be glad to hear from readers with corrections and/or suggestions for additional structures to include.

Tangram Technology Consulting Engineers

Periodic Table of Thermoplastics

TANGRAM TECHNOLOGY Consulting Engineers

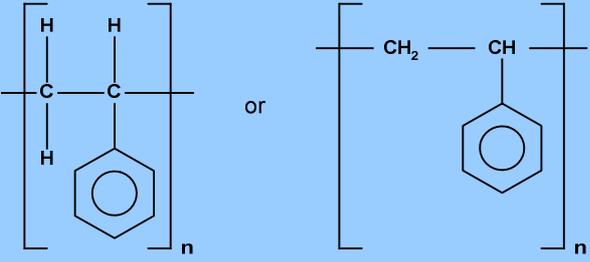
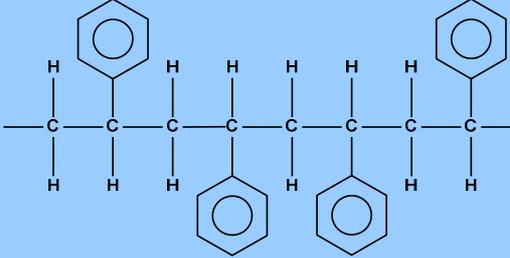
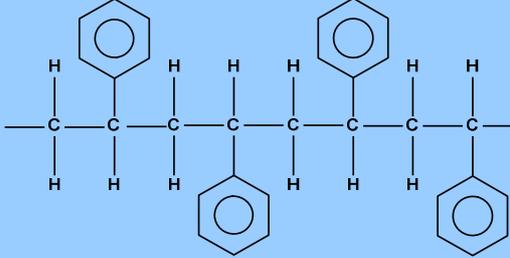
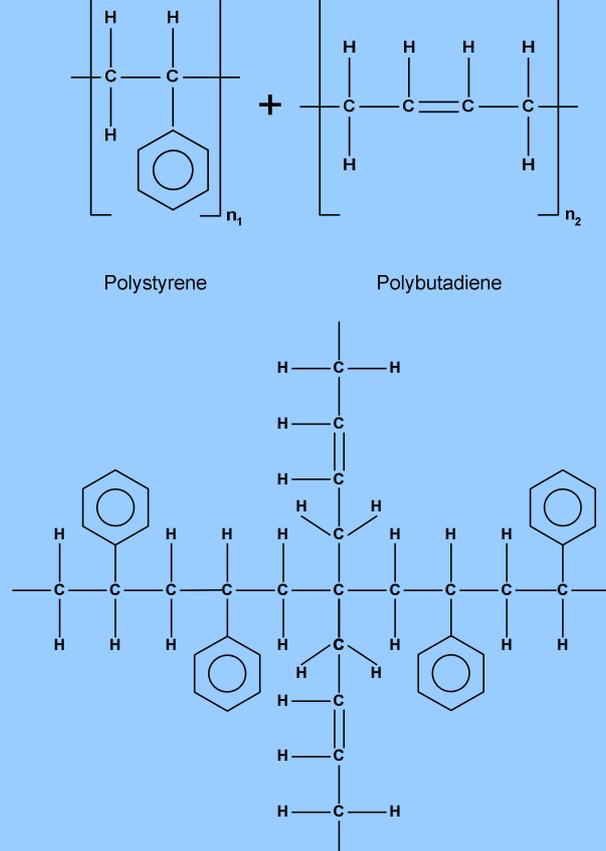


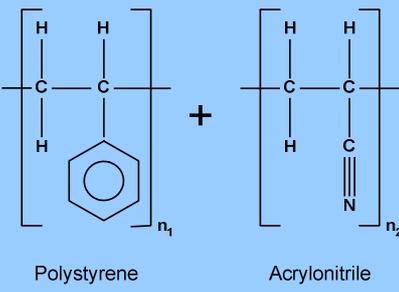
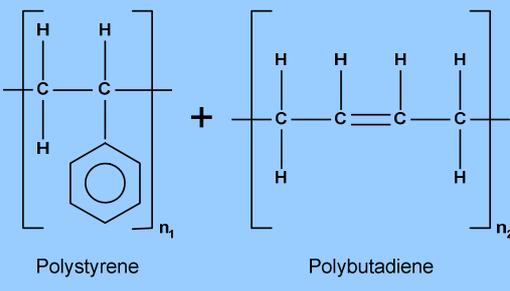
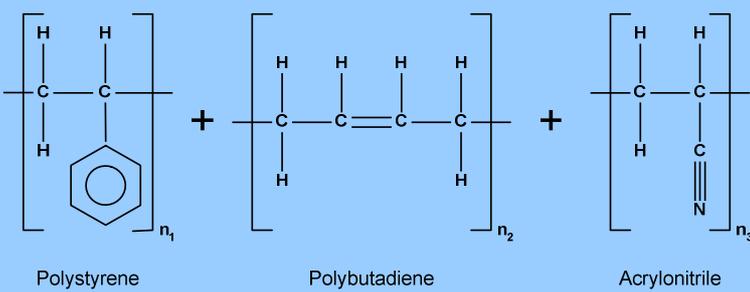
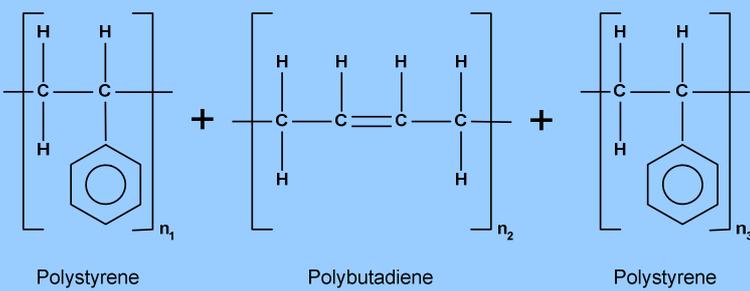
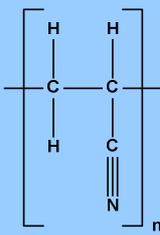
		Commodity				Engineering				Performance			
Amorphous	Increasing crystallinity	PS-HI High Impact Polystyrene	PS-GP General Purpose Polystyrene	ABS Acrylonitrile Butadiene Styrene (Copolymer)	SAN Styrene Acrylonitrile (Copolymer)	PMMA Polymethyl methacrylate (Acrylic)	PPO (Modified) Polyphenylene Oxide	PC Polycarbonate	PAR Polyarylate	PSU Polysulphone	PES Polyethersulphone	PPSU Polyethersulphone (Block copolymer)	
		PVC-P Plasticised Polyvinylchloride	SBS Styrene-Butadiene (Copolymer)	SMA Styrene-Maleic Anhydride (Copolymer)	ASA Acrylonitrile Styrene Acrylate (Copolymer)	SB Styrene-Butadiene (Copolymer)	PET-G Glycolised Polyethylene terephthalate	PVC-UJ Crosslinked Unplasticised PVC	PVC-C Chlorinated PVC	PEI Polyetherimide	PAI Polyamideimide	PI Polyimide	PBI Polybenzimidazole
Semicrystalline	Increasing crystallinity	PVC-U Unplasticised Polyvinylchloride	CA Cellulose Acetate	CAB Cellulose Acetate Butyrate	CAP Cellulose Acetate Propionate				PPA Polyphthalimide (Amorphous)	PA 6/3/T Amorphous polyamide	PPA Polyphthalimide (Amorphous)	PEEK Polyetherether ketone	
		PE-LD Low Density Polyethylene	PE-LLD Linear Low Density Polyethylene	PE-MD Medium Density Polyethylene	PMP Polymethyl pentene	EVA Ethylene-vinyl Acetate (12% VA)	PE-X Crosslinked Polyethylene	PB Polybutene-1 (Polybutylene)	PE-UHMW Ultra-high Molecular Weight PE	PA 12 Polyamide 12 (Nylon 12)	PA 11 Polyamide 11 (Nylon 11)	PA 46 Polyamide 46 (Nylon 46)	PEK Polyetherketone
		PE-HD High Density Polyethylene	PP Polypropylene (Homopolymer)	PE-C Chlorinated Polyethylene	PE-VLD Very Low Density Polyethylene	PBT Polybutylene-terephthalate	PA 6 Polyamide 6 (Nylon 6)	PA 6/6 Polyamide 66 (Nylon 66)	LCP Liquid Crystal Polymer (Aromatic copolyester)	PFA Perfluoroalkoxy	ECTFE Ethylene-chlorotrifluoroethylene	PCTFE Polychlorotrifluoroethylene	PVDF Polyvinylidene fluoride
			PP Polypropylene (Copolymer)	PP	PET Crystalline Polyethylene-terephthalate	PA 6/10 Polyamide 6/10 (Nylon 6/10)	PA 6/12 Polyamide 6/12 (Nylon 6/12)	PA 6/12 Polyamide 6/12 (Nylon 6/12)	EVOH Ethylene-vinyl Alcohol	PPS Polyphenylene Sulphide	FEP Fluorinated ethylene-propylene	ETFE Ethylene-tetrafluoroethylene	
						POM Polymethyl oxymethylene (Acetal Copolymer)	POM Polymethyl oxymethylene (Acetal Homopolymer)						

KEY TO MAJOR POLYMER FAMILIES:

- Styrenes
- Polyolefins
- Vinyls
- Cellulosics
- Polyesters
- Polyamides
- Acrylics
- Polycarbonates
- Acetals
- Polysulphones
- Imides
- Fluoropolymers

Styrenes - Amorphous/commodity

<p>PS - Polystyrene</p>	 <p>The diagram shows two equivalent representations of the polystyrene repeating unit. On the left, a carbon-carbon backbone is shown with two hydrogen atoms on each carbon, and one carbon is substituted with a benzene ring. On the right, the same unit is shown as a $-\text{CH}_2-\text{CH}(\text{C}_6\text{H}_5)-$ unit.</p>
<p>Atactic PS Random distribution of the benzene rings, irregular structure and cannot pack to form crystals.</p>	 <p>The diagram illustrates the atactic form of polystyrene, where the benzene rings are randomly distributed along the carbon backbone, resulting in an irregular structure.</p>
<p>Syndiotactic PS Regular distribution of the benzene rings and can pack to form crystals. Therefore, not an amorphous but a crystalline polymer.</p>	 <p>The diagram illustrates the syndiotactic form of polystyrene, where the benzene rings are arranged in a regular, alternating pattern along the carbon backbone.</p>
<p>High impact PS PS- HI is a graft copolymer where the butadiene is generally at right angles to the main PS backbone chain. This adds considerable extra impact resistance to the normally brittle PS.</p>	 <p>The diagram shows the components and the resulting graft copolymer for High Impact Polystyrene (HI-PS). It includes the repeating unit of polystyrene (labeled n_1) and the repeating unit of polybutadiene (labeled n_2). Below these, a detailed structure of the graft copolymer is shown, where the polybutadiene chain is grafted onto the polystyrene backbone at right angles.</p>

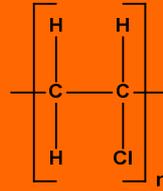
<p>SAN - Styrene acrylonitrile copolymer</p>	 <p>The diagram shows the chemical structures of Polystyrene and Acrylonitrile. Polystyrene is represented as a repeating unit with two carbon atoms in the backbone, each bonded to two hydrogen atoms and one phenyl ring. Acrylonitrile is represented as a repeating unit with two carbon atoms in the backbone, one bonded to two hydrogen atoms and the other bonded to a hydrogen atom and a cyano group (C≡N).</p>
<p>SB - Styrene butadiene copolymer</p>	 <p>The diagram shows the chemical structures of Polystyrene and Polybutadiene. Polystyrene is represented as a repeating unit with two carbon atoms in the backbone, each bonded to two hydrogen atoms and one phenyl ring. Polybutadiene is represented as a repeating unit with four carbon atoms in the backbone, with a double bond between the second and third carbons, and two hydrogen atoms on each carbon.</p>
<p>ABS - Acrylonitrile butadiene styrene copolymer</p>	 <p>The diagram shows the chemical structures of Polystyrene, Polybutadiene, and Acrylonitrile. Polystyrene is represented as a repeating unit with two carbon atoms in the backbone, each bonded to two hydrogen atoms and one phenyl ring. Polybutadiene is represented as a repeating unit with four carbon atoms in the backbone, with a double bond between the second and third carbons, and two hydrogen atoms on each carbon. Acrylonitrile is represented as a repeating unit with two carbon atoms in the backbone, one bonded to two hydrogen atoms and the other bonded to a hydrogen atom and a cyano group (C≡N).</p>
<p>SBS - Styrene butadiene styrene copolymer</p>	 <p>The diagram shows the chemical structures of Polystyrene, Polybutadiene, and Polystyrene. Polystyrene is represented as a repeating unit with two carbon atoms in the backbone, each bonded to two hydrogen atoms and one phenyl ring. Polybutadiene is represented as a repeating unit with four carbon atoms in the backbone, with a double bond between the second and third carbons, and two hydrogen atoms on each carbon. Polystyrene is represented as a repeating unit with two carbon atoms in the backbone, each bonded to two hydrogen atoms and one phenyl ring.</p>
<p>Acrylonitrile Mainly used as copolymers (with methyl acrylate or methyl methacrylate) or as part of styrene copolymers such as SAN or ABS.</p>	 <p>The diagram shows the chemical structure of Acrylonitrile, represented as a repeating unit with two carbon atoms in the backbone, one bonded to two hydrogen atoms and the other bonded to a hydrogen atom and a cyano group (C≡N).</p>

Vinyls - Amorphous/commodity

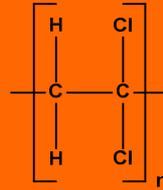
PVC - Polyvinyl chloride

Available in plasticized and unplasticized formats when compounded.

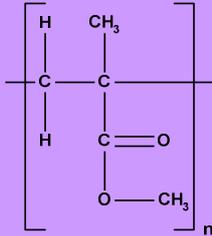
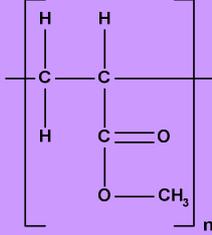
Also available as cross-linked (PVC-UX) to form a more rigid matrix.



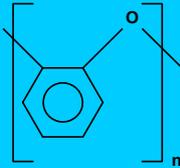
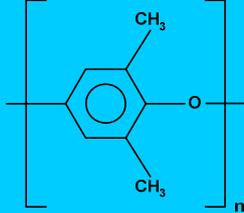
PVDC - Polyvinylidene chloride



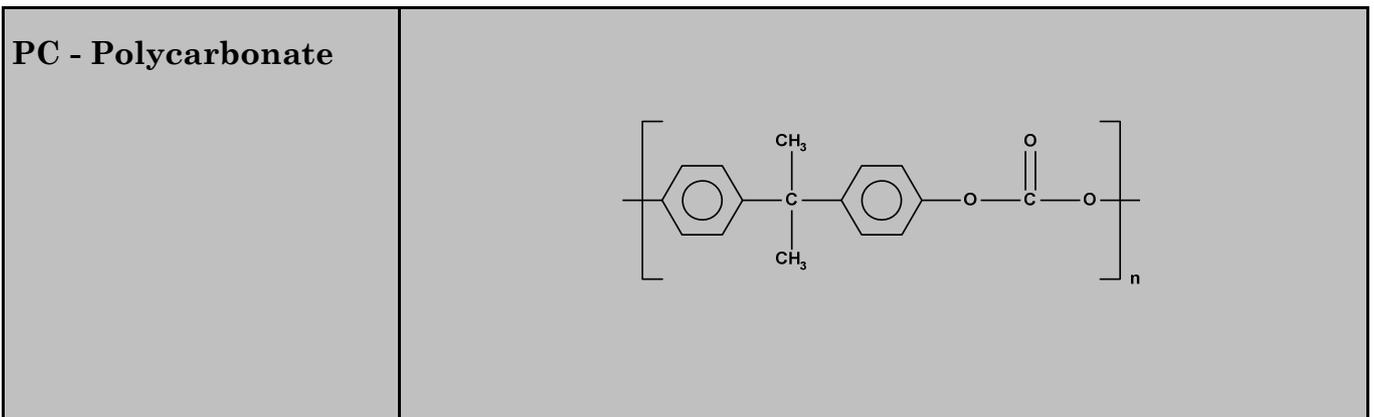
Acrylics - Amorphous/engineering

<p>PMMA - Poly (methyl methacrylate) Hard and brittle</p>	 <p>The diagram shows the repeating unit of PMMA enclosed in large square brackets with a subscript 'n'. The backbone consists of two carbon atoms connected by a single bond. The left carbon is bonded to two hydrogen atoms (H). The right carbon is bonded to a methyl group (CH₃) and a methacrylate group. The methacrylate group consists of a carbon atom double-bonded to an oxygen atom (C=O) and single-bonded to another oxygen atom, which is in turn single-bonded to a methyl group (O-CH₃).</p>
<p>Poly (methyl acrylate) - Soft and rubbery</p>	 <p>The diagram shows the repeating unit of Poly (methyl acrylate) enclosed in large square brackets with a subscript 'n'. The backbone consists of two carbon atoms connected by a single bond. The left carbon is bonded to two hydrogen atoms (H). The right carbon is bonded to a hydrogen atom (H) and an acrylate group. The acrylate group consists of a carbon atom double-bonded to an oxygen atom (C=O) and single-bonded to another oxygen atom, which is in turn single-bonded to a methyl group (O-CH₃).</p>

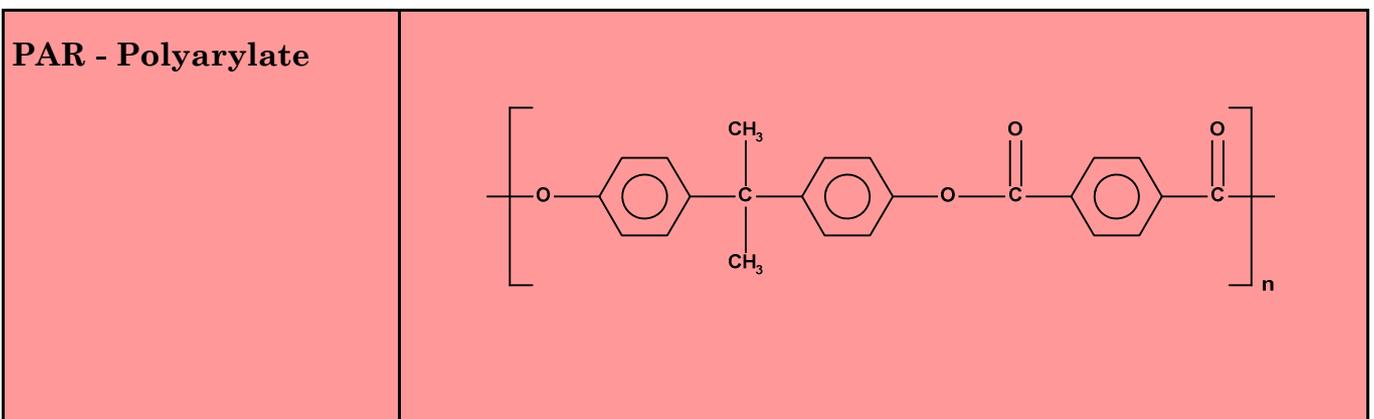
Polyphenylenes - Amorphous/engineering

<p>PPE - Polyphenyl ether.</p>	 <p>The diagram shows the repeating unit of PPE enclosed in large square brackets with a subscript 'n'. It features a central benzene ring. Two oxygen atoms are attached to the ring at the 1 and 4 positions, forming ether linkages that connect to the next repeating unit. The other four positions on the benzene ring are occupied by phenyl groups, represented by hexagons with a circle inside.</p>
<p>PPO: Polyphenylene oxide Not strictly an oxide but actually an ether.</p>	 <p>The diagram shows the repeating unit of PPO enclosed in large square brackets with a subscript 'n'. It features a central benzene ring. Two oxygen atoms are attached to the ring at the 1 and 4 positions, forming ether linkages that connect to the next repeating unit. The other four positions on the benzene ring are occupied by methyl groups (CH₃).</p>

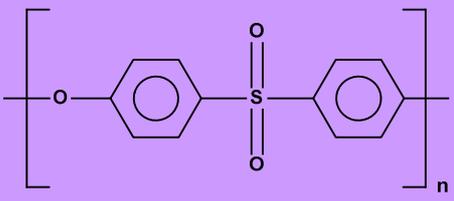
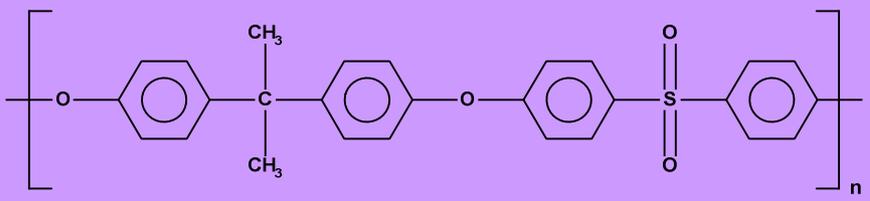
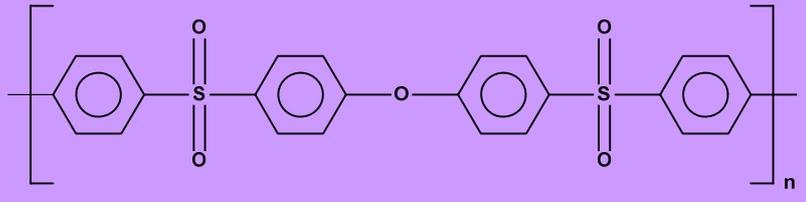
Polycarbonates - Amorphous/engineering



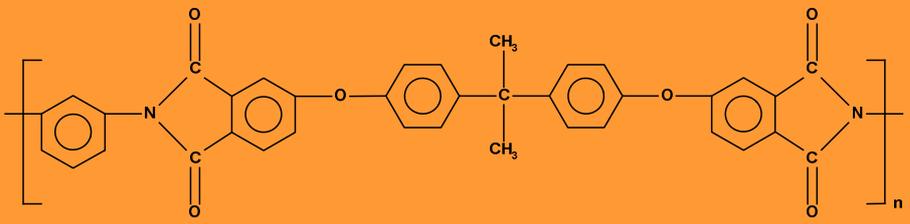
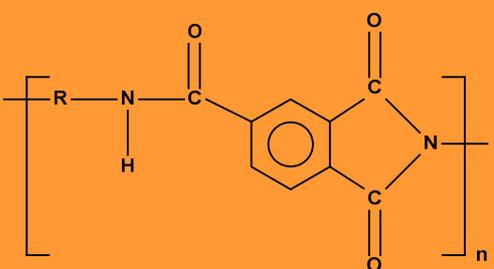
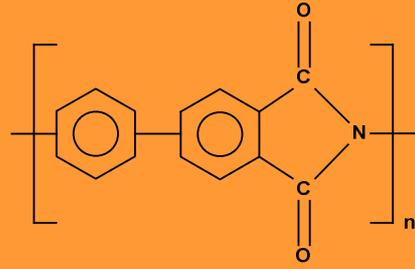
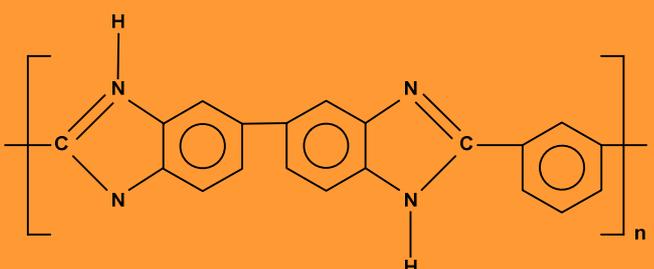
Polyarylates - Amorphous/engineering



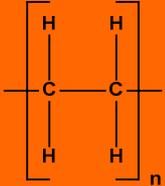
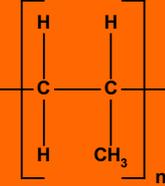
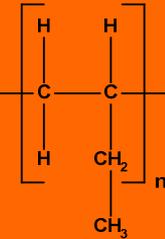
Polysulphones - Amorphous/performance

<p>PES: Polyethersulphone: The general structure of the polysulphones</p>	 <p>The diagram shows the repeating unit of Polyethersulphone (PES) enclosed in large square brackets with a subscript 'n'. The structure consists of two benzene rings connected by an oxygen atom (-O-) on the left and a sulfonyl group (-SO₂-) on the right. The oxygen atom is bonded to the para position of the first benzene ring, and the sulfonyl group is bonded to the para position of the second benzene ring. The bonds extending from the brackets are at the 1 and 4 positions of the respective rings.</p>
<p>PSU: Polysulphone</p>	 <p>The diagram shows the repeating unit of Polysulfone (PSU) enclosed in large square brackets with a subscript 'n'. The structure consists of four benzene rings. From left to right: the first benzene ring is connected to the second by an oxygen atom (-O-); the second benzene ring is connected to the third by a central carbon atom (-C-) which has two methyl groups (-CH₃) attached to it; the third benzene ring is connected to the fourth by an oxygen atom (-O-); and the fourth benzene ring is connected to the next unit by a sulfonyl group (-SO₂-). The bonds extending from the brackets are at the 1 and 4 positions of the respective rings.</p>
<p>PPSU: Polyphenylsulphone</p>	 <p>The diagram shows the repeating unit of Polyphenylsulfone (PPSU) enclosed in large square brackets with a subscript 'n'. The structure consists of four benzene rings. From left to right: the first benzene ring is connected to the second by a sulfonyl group (-SO₂-); the second benzene ring is connected to the third by an oxygen atom (-O-); the third benzene ring is connected to the fourth by a sulfonyl group (-SO₂-). The bonds extending from the brackets are at the 1 and 4 positions of the respective rings.</p>

Polyimides - Amorphous/performance

<p>PEI: Polyetherimide</p>	
<p>PAI: Polyamideimide</p>	
<p>PI: Polyimide</p>	
<p>PBI: Polybenzimidazole</p>	

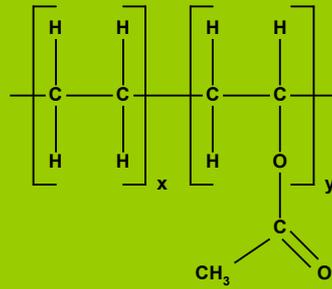
Polyolefins - Crystalline/commodity

PE: Polyethylene	 <p>The diagram shows the repeating unit of polyethylene, consisting of two carbon atoms bonded together. Each carbon atom is also bonded to two hydrogen atoms. The entire unit is enclosed in brackets with a subscript 'n'.</p>
PP: Polypropylene	 <p>The diagram shows the repeating unit of polypropylene, consisting of two carbon atoms bonded together. The first carbon atom is bonded to two hydrogen atoms. The second carbon atom is bonded to one hydrogen atom and one methyl group (CH3). The entire unit is enclosed in brackets with a subscript 'n'.</p>
PB: Polybutylene This is more accurately a crystalline engineering polymer but belongs to the polyolefin family and is presented here for completeness.	 <p>The diagram shows the repeating unit of polybutylene, consisting of four carbon atoms bonded in a chain. The first and third carbon atoms are each bonded to two hydrogen atoms. The second carbon atom is bonded to two hydrogen atoms. The fourth carbon atom is bonded to two hydrogen atoms. The entire unit is enclosed in brackets with a subscript 'n'.</p>

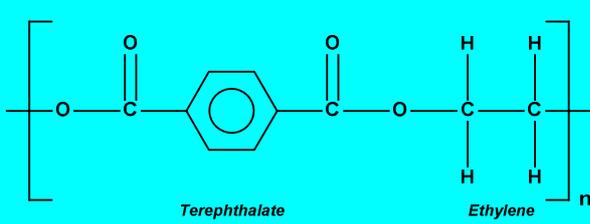
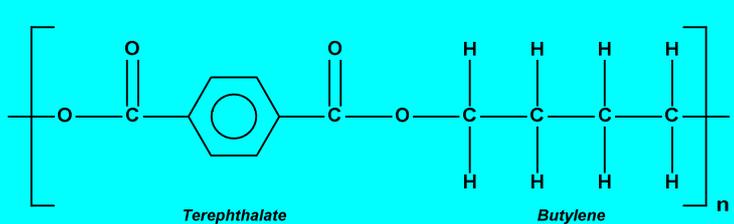
Vinyl acetate - Crystalline/commodity

EVA: Ethylene vinyl
acetate.

Random copolymer.



Polyesters - Crystalline/engineering

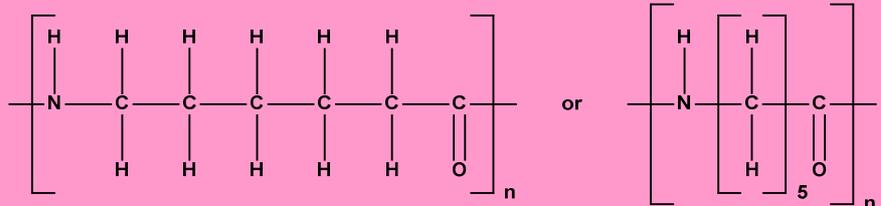
PET: Polyethylene terephthalate	 <p>The diagram shows the repeating unit of Polyethylene terephthalate (PET). It consists of a terephthalate group (a benzene ring with two carbonyl groups at the para positions) linked to an ethylene group (two carbon atoms with four hydrogen atoms). The repeating unit is enclosed in brackets with a subscript 'n'.</p>
PBT: Polybutylene terephthalate	 <p>The diagram shows the repeating unit of Polybutylene terephthalate (PBT). It consists of a terephthalate group (a benzene ring with two carbonyl groups at the para positions) linked to a butylene group (four carbon atoms with eight hydrogen atoms). The repeating unit is enclosed in brackets with a subscript 'n'.</p>

Polyamides - Crystalline/engineering

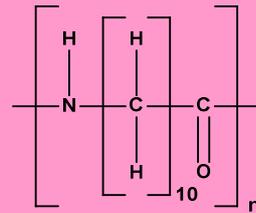
Homopolymers

PA 6: Polyamide 6 (Nylon 6)

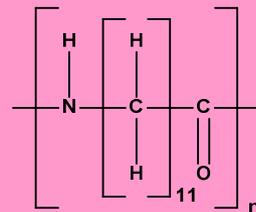
There are 5 repeating CH₂ elements but there are a total of 6 carbon atoms in the monomer.



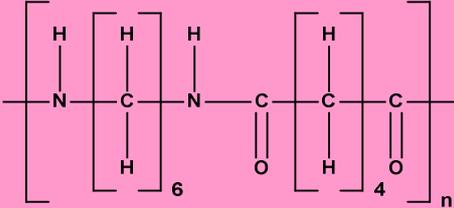
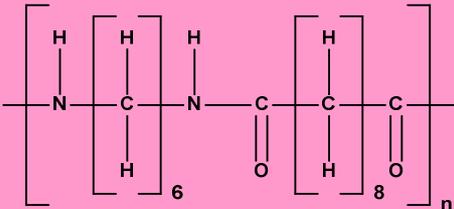
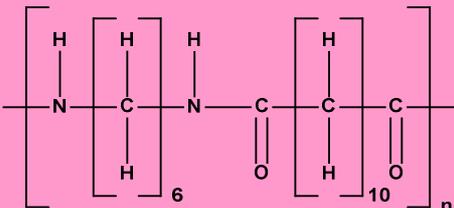
PA 11: Polyamide 11 (Nylon 11)



PA 12: Polyamide 12 (Nylon 12)

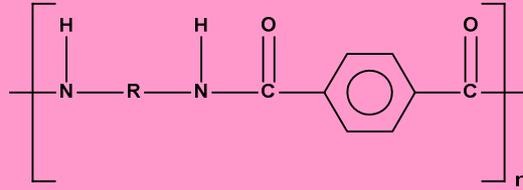


Polyamides - Crystalline/engineering

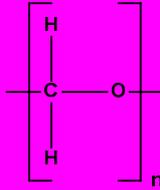
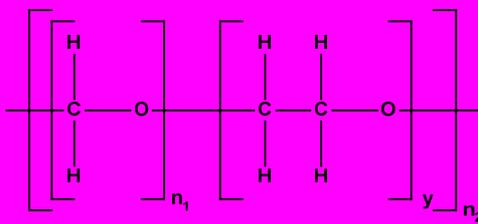
Copolymers	
<p>PA 6/6: Polyamide 6/6 (Nylon 6/6) 6 carbons in copolymer chain.</p>	 <p>The diagram shows the repeating unit of PA 6/6. It consists of a diamine group (left) and a diacid group (right) linked by an amide bond. The diamine group is enclosed in a bracket with a subscript '6' and contains a nitrogen atom bonded to two hydrogen atoms and a methylene group (CH₂)₆. The diacid group is enclosed in a bracket with a subscript '4' and contains a carbonyl group (C=O) bonded to a methylene group (CH₂)₄ and another carbonyl group (C=O). The entire unit is enclosed in large square brackets with a subscript 'n'.</p>
<p>PA 6/10: Polyamide 6/10 (Nylon 6/10) 10 carbons in copolymer chain.</p>	 <p>The diagram shows the repeating unit of PA 6/10. It consists of a diamine group (left) and a diacid group (right) linked by an amide bond. The diamine group is enclosed in a bracket with a subscript '6' and contains a nitrogen atom bonded to two hydrogen atoms and a methylene group (CH₂)₆. The diacid group is enclosed in a bracket with a subscript '8' and contains a carbonyl group (C=O) bonded to a methylene group (CH₂)₈ and another carbonyl group (C=O). The entire unit is enclosed in large square brackets with a subscript 'n'.</p>
<p>PA 6/12: Polyamide 6/12 (Nylon 6/12) 12 carbons in copolymer chain.</p>	 <p>The diagram shows the repeating unit of PA 6/12. It consists of a diamine group (left) and a diacid group (right) linked by an amide bond. The diamine group is enclosed in a bracket with a subscript '6' and contains a nitrogen atom bonded to two hydrogen atoms and a methylene group (CH₂)₆. The diacid group is enclosed in a bracket with a subscript '10' and contains a carbonyl group (C=O) bonded to a methylene group (CH₂)₁₀ and another carbonyl group (C=O). The entire unit is enclosed in large square brackets with a subscript 'n'.</p>

Polyamides - Crystalline/performance

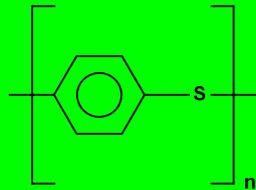
PPA: Polyphthalamide
(PA 6/3/T)



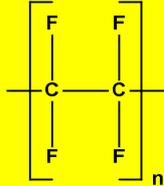
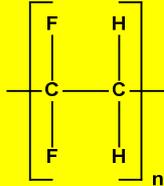
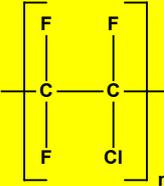
Polyoxymethylenes - Crystalline/performance

<p>POM: Polyoxymethylene Acetal copolymer</p>	 <p>The diagram shows the repeating unit of Polyoxymethylene (POM) as an acetal copolymer. It consists of a central carbon atom (C) bonded to two hydrogen atoms (H) above and below it, and an oxygen atom (O) to its right. The carbon and oxygen atoms are enclosed in square brackets with a subscript 'n' at the bottom right. Horizontal lines extend from the carbon and oxygen atoms through the brackets, indicating the polymer chain continuation.</p>
<p>POM: Polyoxymethylene Acetal homopolymer. Where n_1 and n_2 are statistically distributed in the copolymer.</p>	 <p>The diagram shows the repeating unit of Polyoxymethylene (POM) as an acetal homopolymer. It consists of two different repeating units. The first unit is a carbon atom (C) bonded to two hydrogen atoms (H) above and below it, and an oxygen atom (O) to its right, enclosed in square brackets with a subscript n_1 at the bottom right. The second unit is a carbon atom (C) bonded to two hydrogen atoms (H) above and below it, and another carbon atom (C) to its right, which is then bonded to an oxygen atom (O) to its right. This second unit is enclosed in square brackets with a subscript y at the bottom right and a subscript n_2 at the bottom right. Horizontal lines extend from the carbon and oxygen atoms through the brackets, indicating the polymer chain continuation.</p>

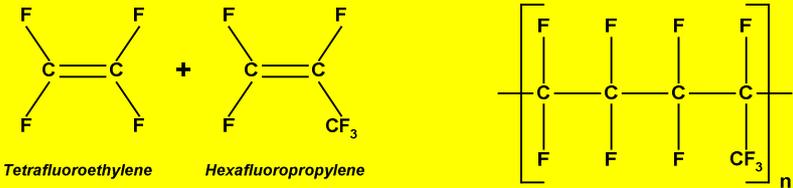
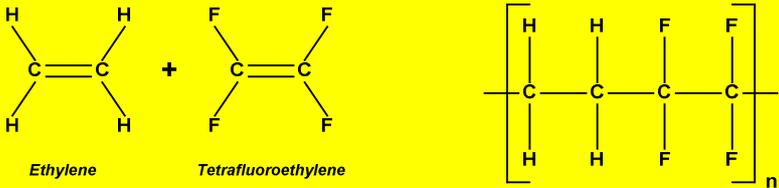
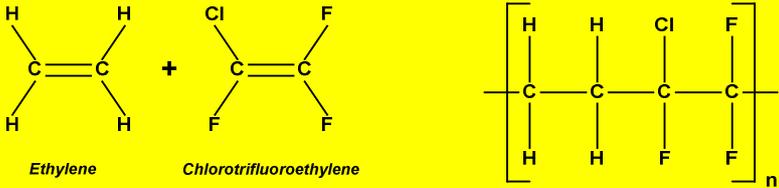
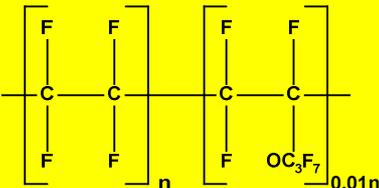
Polysulphides - Crystalline/performance

<p>PPS - Polyphenylene sulphide</p>	 <p>The diagram shows the repeating unit of Polyphenylene sulphide (PPS). It consists of a benzene ring (a hexagon with a circle inside) bonded to a sulfur atom (S) to its right. The benzene ring and sulfur atom are enclosed in square brackets with a subscript 'n' at the bottom right. Horizontal lines extend from the benzene ring and sulfur atom through the brackets, indicating the polymer chain continuation.</p>
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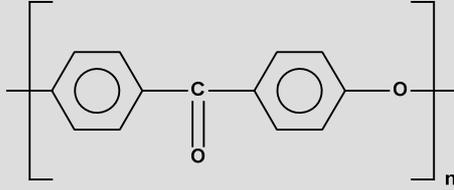
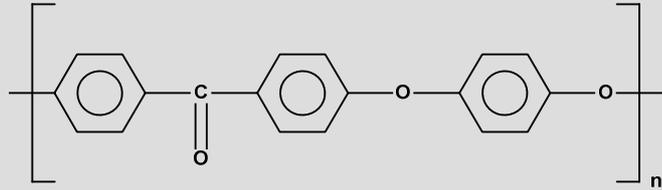
Fluoropolymers - Crystalline/performance

Homopolymers	
PTFE: Polytetrafluoroethylene	
PVDF: Polyvinylidene fluoride	
PCTFE: Polychlorotrifluoroethylene	

Fluoropolymers - Crystalline/performance

Copolymers	
<p>FEP: Fluorinated ethylene propylene</p> <p>Copolymer of tetrafluoroethylene and hexafluoropropylene</p>	 <p style="text-align: center;"> <i>Tetrafluoroethylene</i> <i>Hexafluoropropylene</i> </p>
<p>ETFE: Ethylene-Tetrafluoroethylene copolymer</p> <p>Copolymer of ethylene and tetrafluoroethylene</p>	 <p style="text-align: center;"> <i>Ethylene</i> <i>Tetrafluoroethylene</i> </p>
<p>ECTFE: Polyethylenechlorotrifluoroethylene</p> <p>(Ethylene-Chlorotrifluoroethylene copolymer)</p>	 <p style="text-align: center;"> <i>Ethylene</i> <i>Chlorotrifluoroethylene</i> </p>
<p>PFA: Perfluoroalkoxy</p>	

Polyether ketones - Crystalline/performance

<p>PEK: Polyetherketone The general structure of the polyether ketones</p>	 <p>The diagram shows the repeating unit of a polyetherketone (PEK) polymer. It consists of a central carbon atom double-bonded to an oxygen atom (C=O), which is connected to a benzene ring. This benzene ring is further connected to another carbon atom, which is double-bonded to another oxygen atom (C=O), which is then connected to a second benzene ring. This second benzene ring is connected to an oxygen atom, which is then connected to the next repeating unit. The entire structure is enclosed in large square brackets with a subscript 'n' at the bottom right, indicating a polymer chain of length n.</p>
<p>PEEK: Polyether ether ketone B</p>	 <p>The diagram shows the repeating unit of a polyether ether ketone B (PEEK) polymer. It consists of a central carbon atom double-bonded to an oxygen atom (C=O), which is connected to a benzene ring. This benzene ring is further connected to another carbon atom, which is double-bonded to another oxygen atom (C=O), which is then connected to a second benzene ring. This second benzene ring is connected to an oxygen atom, which is then connected to a third benzene ring. This third benzene ring is connected to another oxygen atom, which is then connected to the next repeating unit. The entire structure is enclosed in large square brackets with a subscript 'n' at the bottom right, indicating a polymer chain of length n.</p>

