Q1 In today's world, many traditional materials have been replaced by different sorts of polymers.
This includes rigid polymers such as those used in car bodies to replace steel and flexible polymers like those used in textiles to replace cotton or wool.
(a) (i) To form a polymer, what is the **minimum** number of functional groups that the monomer must possess?

.....
(ii) Illustrate your answer to **(i)** with the structure of a possible monomer.

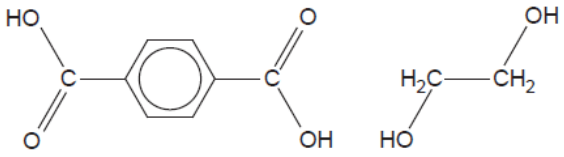
(b) State **two** differences between addition and condensation polymerisation.

(i) .....

.....

(ii) .....

.....
(c) The polymer formed from the co-polymerisation of the two monomers shown is known as *Terylene.*



benzene-1, 4-dicarboxylic acid **ethane-1-2-diol**

(i) The two monomers react by condensation polymerisation. What other molecule is formed in this reaction?

.....
(ii) Draw the structure of **one** repeat unit of *Terylene.*

(iii) What is the name given to polymers containing the same functional group as *Terylene*?

.....
(d) The monomers ethene and but-1-ene can also co-polymerise to form a polyalkene, but this does not produce a regular alternating structure like *Terylene.* Explain why this is the case, drawing diagrams if you wish.

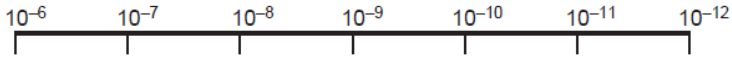
.....

.....

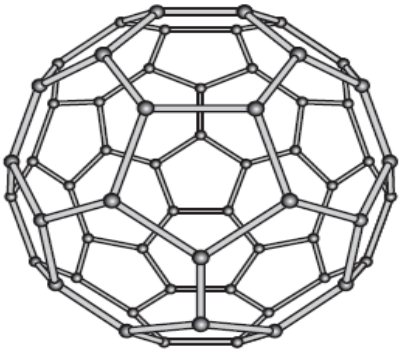
.....
(June 2011 P41 Q9)

Q2 Nanotechnology is a fast-developing area of science based on the ability to manipulate materials of very small dimensions.

(a) On the scale shown in metres, mark the upper and lower limits of the range of sizes for nanoparticles.



(b) One of the most commonly recognised nanoparticles is the 'buckyball', a spherical form of carbon containing 60 carbon atoms. It has been referred to as the third allotrope of carbon.



Diamond and graphite are two other allotropes of carbon. Suggest what is meant by the term *allotrope*.

.....

.....

..... [2]

(c) Nanoparticles are used to deliver drugs within cells. Suggest what property of nanoparticles enables them to be used in this way. Explain your answer.

.....

.....

..... [2]

(d) Copper is an important metal that has been used for thousands of years. The problem today is that most of the ores rich in copper compounds have been used up. A century ago ores containing >2% of copper by mass would have been worked; today's mines have to operate at much lower percentages, down to 0.5% of copper by mass.

(i) By what *type of reaction* is the copper present in the ore converted to copper metal?

.....

One of the main ores of copper contains the mineral *chalcopyrite*, $CuFeS_2$.

(ii) Calculate the percentage of copper by mass in *chalcopyrite*.

(iii) If the ore contains 2% of *chalcopyrite* by mass, calculate the mass of copper which can be produced from each tonne of ore.

(iv) Certain bacteria are able to extract copper from the 'spoil' heaps of previously mined copper ore. These bacteria are sprayed onto the spoil heaps in an aqueous solution and the resulting solution containing iron(II) sulfate and copper(II) sulfate is collected in tanks. Suggest how the copper could be recovered as metal.

.....

.....

.....

(June 2011 P42 Q8)

Q3 In today's world we make use of a wide range of different polymers. These polymers are often substitutes for traditional materials, but may have more useful properties.
(a) Complete the table identifying one traditional material that has been replaced by each polymer.

traditional material	modern polymer and its use
	PVC in packaging
	Terylene in fabrics
	polycarbonate bottle

(b) Throwing away articles made from polymers after use is a major environmental concern for **two** main reasons. Identify **each** of these reasons and suggest a strategy that has been adopted to try to overcome each of these.

reasons : .....

.....

.....

strategy 1 : .....

.....

strategy 2 : .....

.....

(c) One suggestion for the disposal of polymers is to use them as a fuel to provide energy for small-scale power stations or district heating schemes.
Identify one polymer which would be **unsuitable** for this use, explaining the reason behind this.
polymer .....

reason .....

.....

.....

(d) Polymers can be either thermoplastic or thermosetting.

Name a thermoplastic polymer. .....
State which type of polymerisation produces thermoplastic polymers, explaining your answer in terms of the structure of the polymer.

.....

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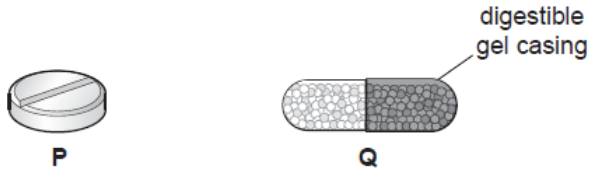
(Nov 2011 P41 Q8)

Q4 Drugs can be delivered in a number of ways. The method chosen depends both on the nature of the drug, and the problem it is being used to treat.
(a) Many common drugs are taken by mouth in forms similar to those shown.



(i) Some drugs are available in solution. How would the speed of action of this form compare with **P** and **Q**? Explain your answer.

.....

.....

(ii) Explain which of the two forms, **P** or **Q**, would act the most rapidly when taken by mouth.

.....

.....

(iii) Some drugs are broken down before they can be absorbed by the intestine. Suggest how the design of **Q** prevents this.

.....

.....

(b) After an abdominal operation drugs are often delivered by means of a 'drip' inserted into a blood vessel in the patient's arm. Explain why this is more effective than taking painkillers by mouth.

.....

.....

.....

(c) One of the molecules that has found a variety of uses in drug delivery is poly(ethylene glycol) or PEG. It is formed from dihydroxyethane, $HOCH_2CH_2OH$.

$$2n\ HOCH_2CH_2OH \longrightarrow H{-}(OCH_2CH_2OCH_2CH_2)_n{-}OH + (2n{-}1)\ H_2O$$

(i) What type of reaction is this?

.....

Attaching a PEG molecule to a drug increases the time that it takes for the drug to be broken down and flushed from the body. There are thought to be two major reasons for this: firstly the PEG can form bonds to slow the passage of the drug around the body; secondly it may reduce the efficiency of breakdown of the drug by enzymes.

(ii) What type of bonds would the PEG part of the molecule form with molecules in the body?

.....

(iii) Suggest why attaching a PEG molecule to a drug molecule would reduce the rate of the drug's decomposition by enzymes.

.....

.....

.....

(iv) Drugs are often protein or polypeptide molecules. What type of reaction might occur in the breakdown of such a drug?

.....

(Nov 2011 P43 Q8)

Q5 Some of the most commonly used polymers are formed by the polymerisation of ethene, C_2H_4. The presence of side-chains affects the bulk properties of an addition polymer. Unbranched polymers pack closer together than polymers with several side-chains. Poly(ethene) exists in two different forms LDPE (low density poly(ethene)) which has lots of side-chains, and HDPE (high density poly(ethene)) in which there are fewer and shorter side-chains.

(a) Explain with the aid of sketches why the presence of side-chains causes a difference in density in poly(ethene).

.....

.....

.....

(b) By reference to the type of bonding between the poly(ethene) chains, explain why LDPE has a lower melting point that HDPE.

.....

.....

.....

(c) Polymerisation can take place by two different methods depending on the monomers involved. The two methods are addition and condensation.

Give **two** differences between the methods.

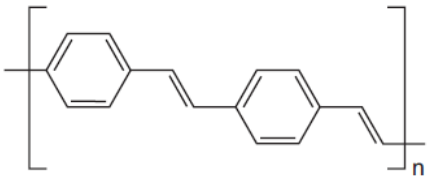
1. .....

.....

2. .....

.....

(d) There has been a great deal of commercial interest in the development of polymers that can conduct electricity and/or emit light. A length of one such polymer is shown.



(i) Suggest how this polymer conducts electricity.

.....

(ii) Suggest the molecular geometry required for this molecule to conduct. Explain your answer.

.....

.....

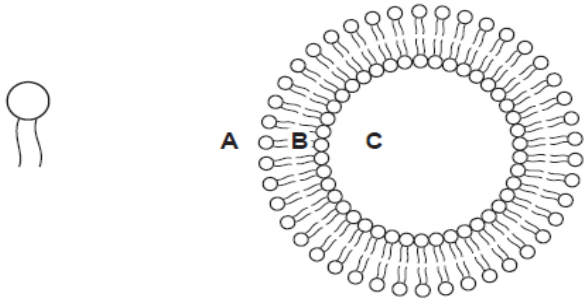
(iii) What is the empirical formula of this polymer?

.....

(June 2012 P41 Q8)

Q6 The developments in nanotechnology and drug delivery over the past 20 years have been wide-ranging.

(a) One of the most widespread developments for delivering a range of pharmaceutical products has been the use of liposomes. These are artifi cially created spheres made from phospholipids which have an ionic phosphate 'head' and two hydrocarbon 'tails'.



phospholipid liposome

Liposomes have also been used to carry pharmaceuticals such as vitamins and moisturisers used in cosmetic anti-ageing creams. Otherwise these pharmaceuticals may be oxidised or dehydrated if exposed to air.

(i) State in which area of the liposome, **A**, **B** or **C**, each of the following types of molecule would be carried.

a hydrophilic moisturiser .....

a fat-soluble vitamin .....

(ii) For one of the areas, **A**, **B** or **C**, suggest why this would **not** be an appropriate place to carry either molecule.

.....

.....

.....

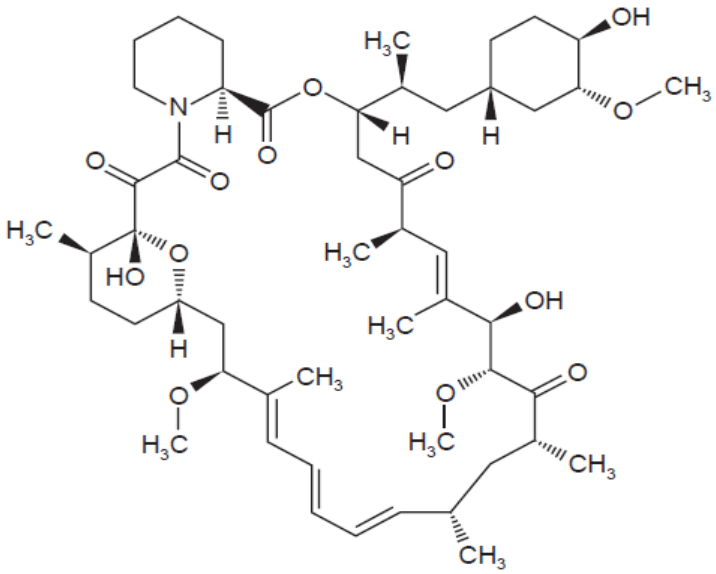
(b) When liposomes are used to carry drugs, their main purpose is to prevent the drug molecules from being broken down on passage through the digestive system.
(i) Name a functional group present in drug molecules that might be broken down by acid in the stomach.

.....

(ii) Name the *type of reaction* that would cause such a breakdown.

.....

(iii) The drug *Sirolimus* is used to suppress possible rejection by the body after kidney transplants.



Sirolimus

Circle **two bonds**, each in a **different** functional group that could be broken down in the digestive system.

(c) *Sirolimus* is not very soluble in water, greatly reducing its effectiveness when given by mouth or by injection. To increase its effectiveness when taken by mouth nano-sized crystals of the drug combined with poly(ethylene glycol) or PEG (shown below) are produced.

$$HO—(CH_2—CH_2—O)_n—H$$

(i) Suggest what is meant by the term *nano-sized*.

.....

(ii) Suggest where on the molecule of PEG the drug would be attached.

.....

(iii) Why would bonding the drug to a PEG molecule improve its solubility in water?

.....

(June 2012 P42 Q8)

Q7 The increasing awareness of the diminishing supply of crude oil has resulted in a number of initiatives to replace oil-based polymers with those derived from natural products. One such polymer, 'polylactide' or PLA, is produced from corn starch and has a range of applications.

(a) The raw material for the polymer, lactic acid (2-hydroxypropanoic acid), is formed by the fermentation of corn starch using enzymes from bacteria.

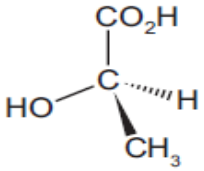
(i) Calcium hydroxide is added to the fermentation tanks to prevent the production of lactic acid from slowing down.

Why might high acidity reduce the effectiveness of the enzymes?

.....

.....

(ii) The structure of lactic acid is shown.



What type of reaction takes place in this polymerisation?

.....

(b) Lactic acid exists in two stereoisomeric forms. Draw the other form in the box.

(c) One of the reasons PLA has attracted so much attention is that it is biodegradeable. This does, however, restrict some potential uses. The simple polymer has a melting point of around 175 ° C, but softens between 60-80 ° C. However, its thermoplastic properties enable it to have a range of uses in fi bres and in food packaging.

(i) Explain why PLA would **not** be a suitable packaging material for foods pickled in vinegar.

.....

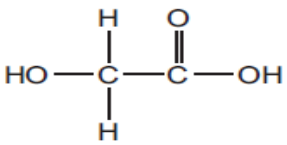
.....

(ii) PLA containers are not used for hot drinks. Suggest why.

.....

.....

(d) Lactic acid can also be co-polymerised with glycolic acid.



glycolic acid

(i) Draw a section of the co-polymer showing one repeat unit.

(ii) Suggest what type(s) of bonding will occur between chains of this co-polymer, indicating the groups involved.

.....

.....

.....

(iii) Suggest one property in which the co-polymer differs from PLA.

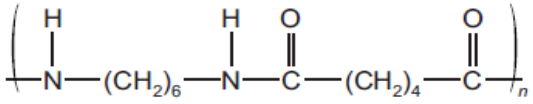
.....

.....

(Nov 2012 P41 Q8)

Q8 The physical properties of polymers depend on the average relative molecular mass of the polymer chains and on the functional groups present in the monomers.
The presence of side-chains in addition polymers can increase the spacing between polymer chains in the bulk substance and hence reduce the overall density.
In condensation polymers it is the *nature* of the side-chain that is often more important since this can lead to cross-linking of the polymer chains forming a three-dimensional structure.
(a) For each of the following polymers, give the structure of the monomer(s) and state the *type of reaction* used to produce the polymer.

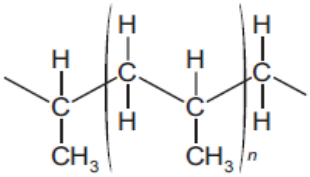
polymer **A**



monomer(s)

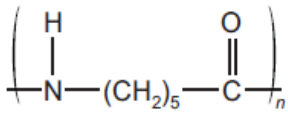
type of reaction .....

polymer **B**



monomer(s)

type of reaction .....

polymer **C** 

monomer(s)

type of reaction .....

(b) Look at the structures of the three polymers and answer the following questions.
(i) Suggest why the density of **B** is lower than that of **A**.

.....

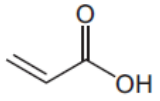
.....
(ii) Which polymer will have the weakest forces between chains, and what is the nature of these forces?

.....

.....

(Nov 2012 P43 Q8)

Q9 In recent years there has been a lot of interest in polymers in the form of gels that absorb aqueous materials. One of the largest uses of these polymers is in disposable nappies (diapers). The gel which is used in this case is a polymer of propenoic acid.



propenoic acid

(a) (i) Draw a section of the polymer of propenoic acid showing **two** repeat units.

(ii) By what type of chemical reaction is this polymer formed?

.....
(iii) By what type of bonding is water held on the polymer?

.....
(b) For some disposable nappies (diapers), the monomer is a mixture of propenoic acid and sodium propenoate. The properties of the polymer are infl uenced by the proportion of sodium salt in the monomer mixture.
(i) Suggest and explain how the difference in the structure of this polymer compared to one formed only from propenoic acid might affect the water absorbing properties of the polymer.

.....

.....

(ii) Suggest a property the polymer should have in order to be used in disposable products.

.....

(c) A variation on the gel used for disposable nappies (diapers) containing more sodium propenoate has been used to treat soils contaminated by heavy metals such as lead (Pb^{2+}) and cadmium (Cd^{2+}). Suggest why the gel is effective.

.....

.....

.....

(d) Another variation on this type of polymer is used in hair gels. In these, the polymer hains are cross-linked by a compound known as pentaerythritol.

pentaerythritol

(i) By what type of chemical reaction are the cross-links in this polymer formed?

.....

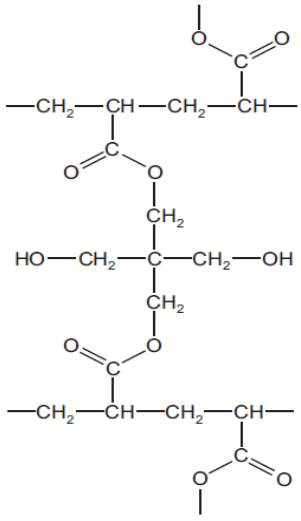
(ii) It is important that the gel should be easily washed out of hair. What is it about the structure of the polymer that allows this to happen?

.....

(June 2013 P41 Q8)

Q10 In recent years there has been considerable interest in a range of polymers known as 'hydrogels'. These polymers are hydrophilic and can absorb large quantities of water.

(a) The diagram shows part of the structure of a hydrogel.



The hydrogel is formed from chains of one polymer which are cross-linked using another molecule.

(i) Draw the structure of the monomer used in the polymer chains.

(ii) State the type of polymerisation used to form these chains.

.....

.....

(iii) Draw the structure of the molecule used to cross-link the polymer chains.

(iv) During the cross-linking, a small molecule is formed as a by-product. Identify this molecule.

.....

(b) Once a hydrogel has absorbed water, it can be dried and re-used many times. Explain why this is possible, referring to the structure on the opposite page.

.....

.....

.....

(c) Not every available side chain in the polymer is cross-linked, and the amount of cross-linking affects the properties of the hydrogel.

(i) The amount of cross-linking has little effect on the ability of the gel to absorb water. Suggest why this is the case.

.....

.....

(ii) Suggest **one** property of the hydrogel that will change if more cross-linking takes place. Explain how the increased cross-linking brings about this change.

.....

.....

(June 2013 P42 Q8)

Q11 In a world with a rapidly increasing population, access to clean drinking water is critical. For many countries, groundwater sources, rather than stored rainwater or river-water, are vital. *Groundwater* is water that exists in the pore spaces and fractures in rock and sediment beneath the Earth's surface. The World Health Organisation (WHO) provides maximum recommended concentrations for different ions present in drinking water.

(a) The geological nature of the soil determines the chemical composition of the groundwater. The table shows some ions which may contaminate groundwater.

ion present	WHO maximum permitted concentration / mg dm^{-3}
Ba^{2+}	0.30
Cl^-	250.00
NO_3^-	50.00
Pb^{2+}	0.01
Na^+	20.00
SO_4^{2-}	500.00

(i) Nitrate, NO_3^-, ions are difficult to remove from groundwater.
What is the reason for this?

.....

(ii) State which ions in the table above are likely to be removed from the water by treatment with powdered limestone, $CaCO_3$, giving reasons for each of your answers.

.....

.....

.....

(b) Nitrates and phosphates can enter water courses such as rivers or streams as a result of human activity. Both of these ions are nutrients for algae.
(i) What is the origin of these nitrates?

.....

(ii) Suggest an origin for the phosphates found in water courses.

.....

(iii) What effect do nitrates and phosphates have on water courses?

.....

.....

(c) Acid rain can have a major impact on natural waters, particularly lakes. In recent years there has been a worldwide effort to reduce the amount of acid rain produced.
(i) Write equations to show the production of acid rain from sulfur dioxide, SO_2.

.....

.....

(ii) The use of fossil fuels is one major source of sulfur dioxide.
Name another major industrial source.

.....

(Nov 2013 P42 Q8)

Q12 Until 1985, carbon was thought to exist in only two structural forms or *allotropes*. In 1985 another form, buckminsterfullerene, was discovered, in which the carbon exists as spherical molecules.
(a) The other two forms of carbon have very different structures.
(i) Name these two forms.

..... and .....

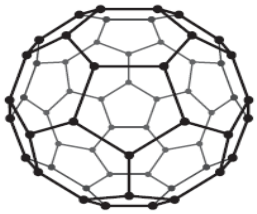
(ii) Give **three** differences in physical properties between these two forms.

.....

.....

.....

(b) The diagram shows the structure of buckminsterfullerene.



buckminsterfullerene

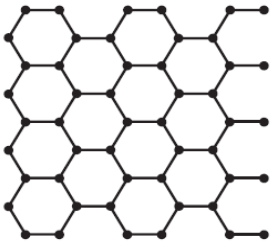
The molecule of buckminsterfullerene contains 60 carbon atoms. Suggest a reason why buckminsterfullerene reacts with hydrogen under suitable conditions and give a formula for the product.

.....

.....

.....

(c) In 2010, two scientists from the University of Manchester were awarded the Nobel Prize for Physics for their work on graphene, a new structural form of carbon. Graphene is one of the new 'nano-materials' being developed for commercial uses in the next 10 years.



graphene

(i) Graphene is in the form of sheets of carbon one atom thick. Calculate the number of carbon atoms present in a sheet of graphene with a mass of one thousandth of a gram (0.001 g).

The number of hexagons in a large sheet of graphene can be assumed to be one half of the number of carbon atoms. Each hexagon has an area of 690 nm^2.
(ii) Calculate the area of the sheet of graphene in **(i)**.

area of sheet = ... nm^2
(iii) Would you expect samples of graphene and buckminsterfullerene to be electrical conductors? Explain your answers.

graphene .....

.....

buckminsterfullerene .....

.....

(Nov 2013 P43 Q9)