Q1.

10 (a) A number of drugs, such as insulin for diabetics, are delivered by injection rather than by mouth (oral delivery). Suggest **two** reasons why this might be necessary.

(i) .....

.....

(ii) .....

.....

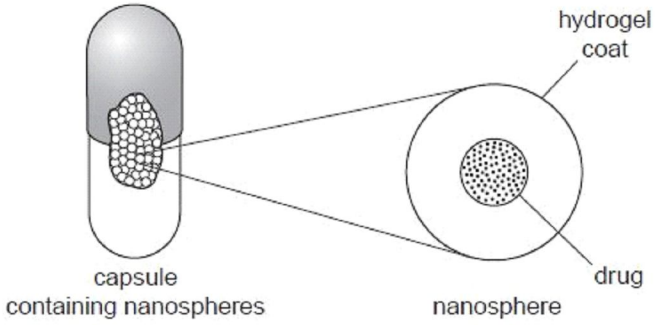
[2]

(b) Many patients prefer oral delivery to injection, and a number of methods for overcoming the problems of oral delivery are being investigated. Several of these use nanotechnology.

Study the passage and diagram and then answer the questions that follow.

At a 2004 meeting, engineers from the University of Texas described their research into nanospheres for oral drug delivery. Nanospheres can transport a drug safely through the hostile environment of the stomach.

The nanospheres are created from hydrogels which are stable, organic materials formed from a network of polymer chains. Hydrogels have a variety of uses including disposable nappies, soft contact lenses, dressings for burns and, more recently, drug delivery. The drug is contained in the hydrogel nanosphere as shown in the diagram below. Hydrogels absorb water and swell at a rate dependent on the pH of their environment. As the hydrogel swells, the drug is released.



(i) What is a *nanosphere*?

.....

(ii) Suggest why the stomach might be a particularly hostile environment for drugs.

.....

.....

(iii) Suggest **two** ways in which the nanosphere shown in the diagram can be modified to change the rate of drug release.

.....

.....

.....

[4]

Use

(c) Hydrogels may be formed as homopolymers (using a single monomer), or heteropolymers (using two or more different monomers).

By using the monomers below, you are to draw sections of **both** a homopolymer and a heteropolymer. Each of your drawings should show a three-monomer section of the polymer.

$HOCH_2CH_2OH$ $HO_2CCHRNH_2$ $HO_2CCH(OH)CH_2CO_2H$

homopolymer

heteropolymer

[3]

[Total: 9]

Q2.

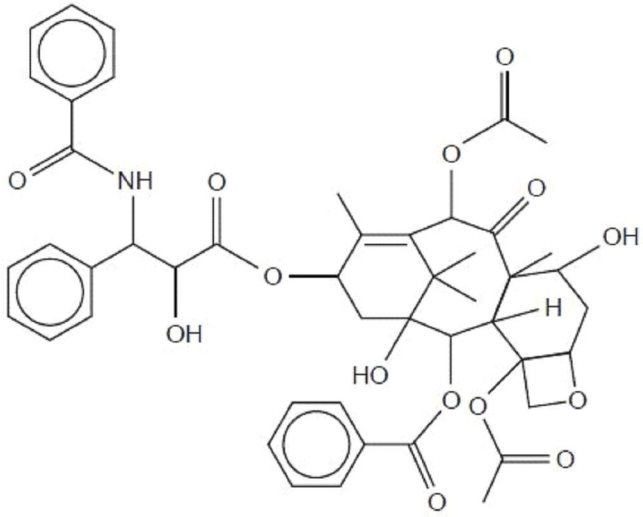
10 The nature and variety of drugs that are available to treat diseases or life-threatening conditions has never been greater. At the same time, we are much better able to deliver drugs to their targets in the body.

For Examiner's Use

(a) Some drugs have to be given by injection, rather than by mouth.
Name a functional group in a drug molecule that might be broken down by the acid in the stomach.

.....[1]

(b) The anti-cancer drug *Taxol* could be broken down if taken by mouth.

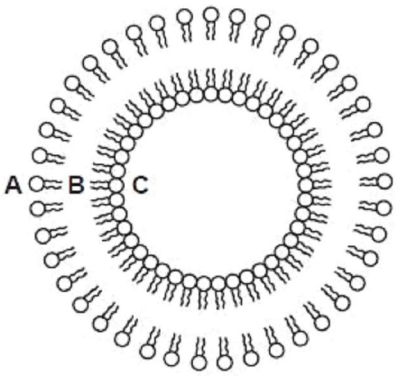


Taxol

Circle **two** bonds, each in a **different** functional group, that could be hydrolysed in the digestive system. [2]

(c) One way of protecting drug molecules that are taken by mouth is to enclose them in liposomes. These are artificially created spheres made from phospholipids which have an ionic phosphate 'head' and two hydrocarbon 'tails'.

For Examiner's Use



phospholipid

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

a hydrophilic drug .....

a hydrophobic drug .....

(ii) For the remaining position, **A**, **B** or **C**, explain why this would **not** be a suitable area for carrying a drug.

.....

.....

[3]

(d) One way of carrying drugs in the bloodstream is to attach them by a chemical bond to a polymer. One such polymer is polyethylene glycol or PEG.

$$HO - (CH_2 - CH_2 - O)_n - H$$

(i) Where would a drug be attached to a molecule of PEG?

.....

(ii) Suggest why a liposome can carry more drug molecules than a molecule of PEG.

.....

.....

[2]

(e) Better-targeted delivery of drugs allows smaller amounts to be used, which brings significant advantages.
Suggest **two** advantages of using smaller drug doses.

For Examiner's Use

.....

.....

.....

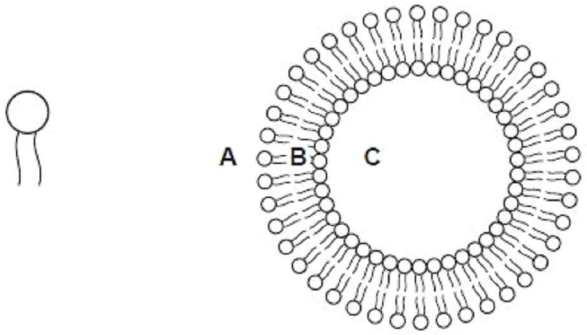
.....[2]

[Total: 10]

Q3.

8 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 artificially 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.

.....

.....

.....

[3]

(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.

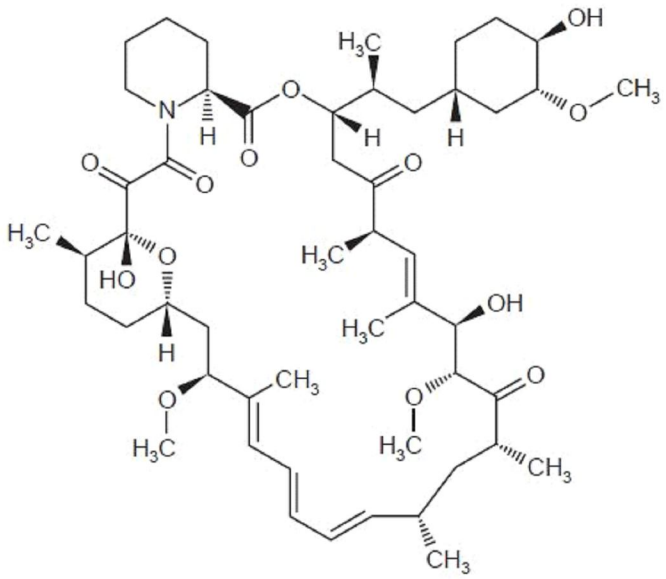
.....

For Examiner's Use

(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.

[4]

(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?

.....

[3]

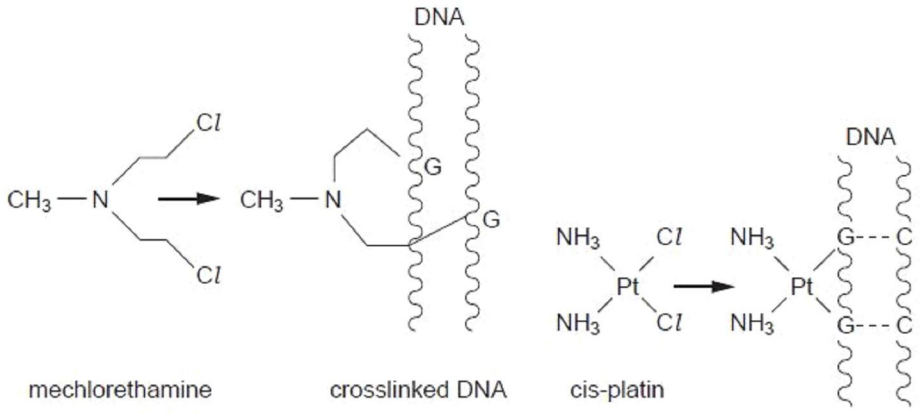
[Total: 10]

Q4.

9 In recent years a great deal of research has been carried out into finding different anti-cancer drugs. Tumours, which are often symptoms of cancer, are produced when cells replicate uncontrollably. This in turn is brought about by the replication of DNA in these cells.

For Examiner's Use

Two anti-cancer agents are mechlorethamine and *cis*-platin. They work by binding to the DNA and preventing replication.



mechlorethamine crosslinked DNA cis-platin

(a) (i) What type of bonding attaches both anti-cancer agents to the DNA?

.....

(ii) Suggest how **each** of the anti-cancer agents prevents replication of the DNA.

.....

.....

.....

.....

.....

[5]

[Total: 5]

Q5.

For Examiner's Use

11 One of the greatest challenges facing scientists today is the development of effective drugs to treat different forms of cancer.

(a) Drugs can be introduced into the body by injection or by mouth. Taking drugs by injection avoids the drug being broken down in the digestive system.
State **two** other advantages of giving drugs by injection.

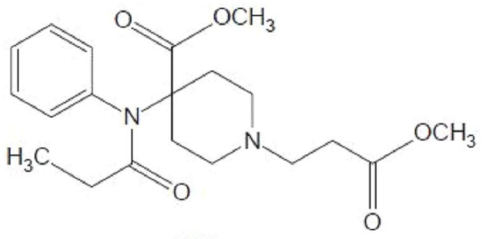
.....

.....

.....

.....[2]

(b) The drug *Ultiva* has been developed to treat ovarian cancer, and is usually given by injection.



Ultiva

Study the structure of *Ultiva* and draw a **circle** around **two different** functional groups that could be broken down in the digestive system. [2]

(c) One way of avoiding the breakdown of drugs in the body is to use a specially designed nanoparticle which encloses the drug. If the nanoparticles are made of a particular sort of polymer, they absorb water at the slightly acidic pH inside some cells, increasing their diameter from around 100 nm to around 1000 nm. This spreads out the polymer chains allowing release of the drug.

(i) Other than absorbing water, suggest a property this polymer would need to possess for its use in drug delivery.

.....

.....

(ii) Why would this method of release **not** work if the nanoparticles were taken by mouth?

.....

[2]

(d) Polymers may be formed by two different types of chemical reaction.
Name the two types of reaction and write an equation to illustrate each reaction type.

For Examiner's Use

name .....

equation .....

name .....

equation .....

[3]

(e) The breakdown of polymers, such as carbohydrates and proteins in the body is important for digestion. What type of reaction is generally involved?

.....[1]

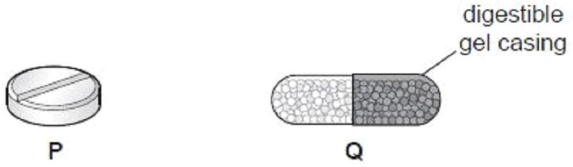
[Total: 10]

Q6.

8 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.

For Examiner's Use

(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.

.....

.....

[3]

(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.

.....

.....

.....

[2]

(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, $HOCH_2CH_2OH$.

For Examiner's Use

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

(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?

.....

[5]

[Total: 10]